The Sizewell C Project

6.3 Volume 2 Main Development Site

Chapter 21 Marine Water Quality and Sediments

Appendices 21A - 21F

Revision:	1.0
Applicable Regulation:	Regulation 5(2)(a)
PINS Reference Number:	EN010012

May 2020

Planning Act 2008
Infrastructure Planning (Applications: Prescribed
Forms and Procedure) Regulations 2009

VOLUME 2 APPENDIX 21A

SIZEWELL WATER QUALITY LITERATURE REPORT EDITION 2. 2016.

BEEMS TECHNICAL REPORT TR131.

TR131 Sizewell Water Quality Literature Report Edition 2

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Please note that the red line boundary used in the figures within this document was amended after this document was finalised, and therefore does not reflect the boundaries in respect of which development consent has been sought in this application. However, the amendment to the red line boundary does not have any impact on the findings set out in this document and all other information remains correct.

Executive summary

This Edition 2 report includes updated values for Environmental Quality Standards for lead, mercury, nickel, benzo a pyrene, copper and zinc and a corrected value for iron. In addition more detailed assessment of the temperature data and inclusion of nutrient concentrations and a discussion of their assessment as supporting elements in determining status is provided for the Suffolk coastal waterbody.

Both water quality data from monitoring surveys and data from the scientific literature collected in the vicinity of Sizewell nuclear power station and in the Suffolk waterbody or associated waterbodies were evaluated to provide a baseline against which to assess the potential for any impact of future development and operation at this site.

The data from successive Environment Agency surveys focuses on metals in seawater (1989 – 2006) and mostly the concentrations of these are low. During this period only in the case of cadmium was the Environmental Quality Standard exceeded for one location and for two locations for zinc with other locations very close to their respective EQS for zinc and copper. In the case of the latter two metals their use in antifouling of boats may have contributed. However with the exception of copper and zinc for which there are a number of diffuse input sources Nationally From 1990 - 2007 there is evidence of an overall decline in the concentration of a number of metals in riverine and direct discharges to the marine environment.

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 not exceeding current or indicative standards beyond 1-2 kilometres 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^{o}C) to not result in major areas failing to meet the temperature boundary for Good/Moderate status (20 – 23 ^{o}C). The boundary value for the Thames SPA for the Habitats Directive criteria (28^{o}C as a 98 percentile) is also likely to be met with only small areas of exceedance likely within the immediate mixing zone.

The East Suffolk region and the coast in particular is relatively sparsely populated and there are few major industries (although these include ports on the Orwell and Stour and at Lowestoft). The few industrial input sources has led to few major contaminant issues for the Suffolk waterbody and its current chemical status is considered to be Good.

During construction and operation the potential wastewater inputs from the workforce and from permanent staffing of the site will need to be assessed in terms of nutrient inputs but the current background levels have a limited impact because of the presence of relatively high suspended particulate matter (SPM) concentration in the waterbody. The impact of any additional nutrient inputs will need to be assessed against the SPM background and this may limit the extent of any effects.

The Suffolk coast waterbody is designated as heavily modified due to coastal protection and its current overall status is moderate. The waterbody is required to meet good ecological potential by 2027 so future changes that may result from power station construction and operation will need to be assessed against this target.

1 Introduction and Objectives

To provide a baseline against which to assess the potential for any impact of future development and operation of a new nuclear power station at Sizewell this report provides an evaluation of the literature on marine water quality in the adjacent Suffolk waterbody. Data from specific studies as well as from Environment Agency monitoring programmes is reported and discussed in the context of further development at Sizewell.

1.1 Background to the site

Any development at Sizewell that may affect freshwater and/or estuarine and coastal water quality must be considered in relation to the Water Framework Directive designations associated with the site which is located in East Suffolk Zone (ESZ) of the Anglian River Basin District (RBD). In this RBD, only 5% of rivers (by length) meet the requirements for good ecological status (GES) or good ecological potential (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. Lowestoft north and south of Claremont pier and Southwold the Denes and Southwold the Pier are designated as bathing waters.

The European Water Framework Directive (WFD) sets a target of achieving good ecological and chemical status by 2015, unless a waterbody is designated as heavily modified in which case its target is to achieve good ecological potential with a target date of 2027. Therefore significant improvements in water quality in the Anglian RBD are required (Appendix L Water Framework Directive Assessment, 2010).

Sizewell is situated on an area of Suffolk coast covered by the shoreline management plan 2 (SMP2) area which includes ten transitional and coastal waterbodies (Table 1).

Table 1 – WFD waterbodies within the SMP2 area (taken from Appendix L Water Framework Directive Assessment, 2010)

Name of waterbody	Type of waterbody	Reason for designation as Heavily modified waterbody	Current overall status*	Proposed status
Suffolk Coast	Coastal	Coastal Protection, Flood Protection	Moderate	GEP by 2027
Benacre Broad	Coastal	Not designated	Moderate	GES by 2027
Covehithe Broad	Coastal	Not designated	Moderate	GES by 2027
Walberswick Marshes	Coastal	Flood Protection	Good	Remain at GEP
Essex Coast	Coastal	Coastal Protection, Flood Protection	Moderate	GEP by 2027
Harwich Approaches	Coastal	Coastal Protection, Navigation, Dredge Disposal	Good	Remain at GEP
Bure and Waveney	Transitional	Flood Protection, Navigation, Structure	Moderate	GEP by 2027
Blyth	Transitional	Coastal Protection, Flood Protection	Moderate	GEP by 2027
Alde and Ore	Transitional	Flood Protection	Moderate	GEP by 2027
Deben	Transitional	Flood Protection	Moderate	GEP by 2027

1.2 Water Quality parameters of importance to the site

The Water Framework Directive classifies waterbodies on the basis of a number of biological, morphological, physicochemical and chemical quality elements; these are listed below for transitional and coastal waters (Table 2). Five ‘‘General chemical and physiochemical elements supporting the biological elements’’ are included and these are transparency, thermal conditions, oxygenation conditions, salinity and nutrient conditions. The presence of priority and other substances in waterbodies or discharges to them must be managed so that they remain at levels that prevent any deterioration. The monitoring and assessment of the physical and physicochemical quality elements will support the interpretation, assessment and classification of the results arising from the monitoring of the biological quality elements (Best et al., 2007).

Table 2 - Quality elements for transitional and coastal waterbodies

Quality element
Phytoplankton
Macro-algae
Angiosperms
Benthic Invertebrate fauna
Fish Fauna (not included for coastal)
Morphological conditions
Tidal regime
Oxygenation conditions
Transparency
Thermal conditions
Salinity
Acidification status
Nutrient Conditions
Pollution by priority substances
Pollution by other substances

For the Water Framework Directive, certain substances that are regarded as the most polluting were identified in 2001 as Priority and 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) (EQSD), also known as the Priority Substances Directive and this was further updated in 2013, DIRECTIVE 2013/39/EU. For these substances (a selected list of those that are potentially of most relevance to Sizewell are shown in Table 3), Environmental Quality Standards are determined at the European level, and these will 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”.

EQSs are concentrations below which a substance is not believed to be detrimental to aquatic life. These were originally developed for the EC Dangerous Substances Directive (76/464/EEC). The concept is now well established and is incorporated into the Environmental Quality Standards Directive(2008/105/EC) which is a daughter directive of the Water Framework Directive (60/2000/EC). EQSs are derived using acute toxicity tests on organisms at different trophic levels. To provide a safety factor, the EQS is set substantially below the concentration observed to have a toxic effect on the test organisms. EQSs vary for each substance and can be different for fresh, estuarine or coastal waters they may also be adjusted for individual waterbodies dependent upon the level of other local factors such as dissolved organic carbon concentration.

In the case of the metals, cadmium, lead, mercury and nickel, the water EQS refer to the dissolved concentration, i.e. the dissolved phase of a water sample obtained by filtration through a 0,45 μm filter or any equivalent pre-treatment, or, where specifically indicated, to the bioavailable concentration.

Table 3 - Environmental Quality Standards (EQS) for other surface waters (TraC Waters) for priority hazardous substances and other pollutants (Directive 2013/39/EU)

Substance	**Annual average (AA) EQS other surface waters(μg l^{-1})**	**Maximum allowable concentration (MAC)* EQS other surface waters (μg l^{-1})**
Cadmium and its compounds	0.2	1.5
Total DDT (sum of four isomers)	0.025	Not applicable
Para, para-DDT	0.01	Not applicable
Lead and its compounds	1.3	14
Mercury and its compounds	-	0.07**
Nickel and its compounds	8.6	34
Naphthalene	2	130
Benzo(a)pyrene	1.7×10^{-4}	0.027
Tributyltin compounds	0.0002	0.0015

*** The MAC is defined as an annual 95 percentile, (UKTAG 2013) **A biota EQS of 20 μg kg^{-1} of tissue wet weight is also available and relates specifically to fish**

UK Technical Advisory Group (UKTAG) identified a list of substances for consideration as specific pollutants based on their appearance on lists of discharge consents. Substances and their proposed EQS values relevant to subsequent discussion are listed in Table 4.

Table 4 - Environmental Quality Standards (EQSs) for specific pollutants and other substances (reference version UKTAG, 2013, Defra 2014)

Substance	**Other Surface Waters (TraC Waters) Annual average (AA) EQS (µg l^{-1})**	**Other Surface Waters (TraC Waters) MAC-EQS (µg l^{-1})**
Ammonia un-ionised	21	Not applicable
Chromium VI (dissolved)	0.6	32
Chromium III	Not applicable	Not applicable
Arsenic (dissolved)	25	Not applicable
Copper (dissolved)	3.76*	Not applicable
Chlorine	Not applicable	10 (total residual oxidants)
Iron (dissolved)	1000	Not applicable
Zinc	6.8 plus ambient background**	Not applicable

***+ (2.677 x ((DOC/2) - 0.5)) µg l^{-1} dissolved, where DOC > 1 mg l^{-1} **Ambient Background Concentration (ABC) is an estimate of background levels of zinc based on a low percentile of monitoring data. For saltwater, an ABC of 1.1 ug l^{-1} is recommended.**

As well as hazardous substances Natural England and Environment Agency also considers physical changes and other disturbance factors that represent hazards for habitats, species and birds (i.e. Table 2).

Nutrient inputs from agricultural areas and sewage discharges can have significant effects upon estuarine and coastal waters. The major concern for increased inputs of nutrients mainly nitrogen (nitrate) and phosphorus (phosphate) is the enhanced growth of attached and planktonic plants which if it reaches excessive levels can lead to oxygen depletion.

Dissolved oxygen standards are also set for coastal waters under the Water Framework Directive as are temperature standards which consider both maximum temperatures as well as the temperature uplift that is considered acceptable over the natural background temperature regimes. These criteria are summarised in Table 5.

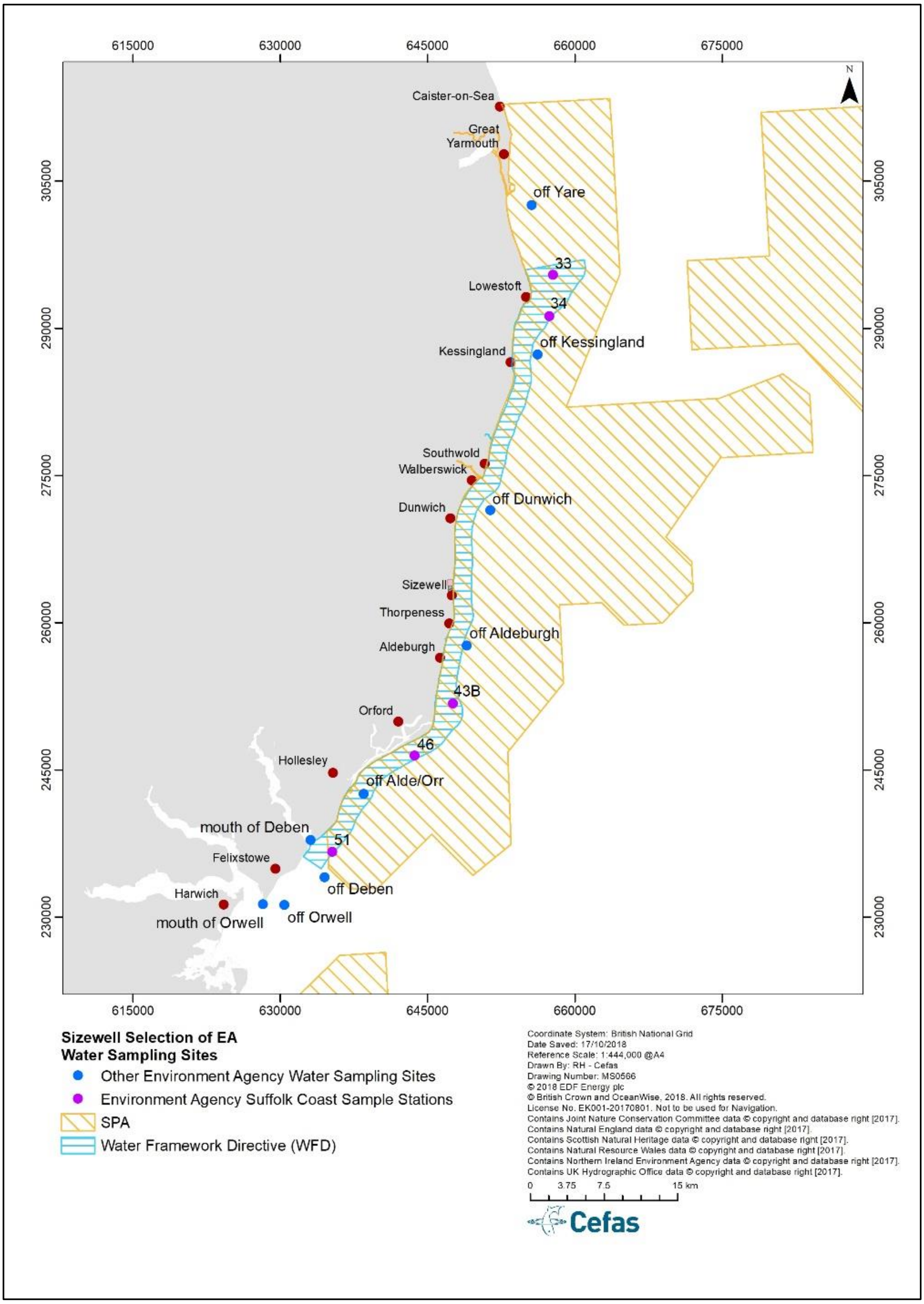
Table 5 - Summary of legislation primarily triggered by the direct and indirect impacts of thermal plumes (prolonged elevated temperatures) adapted from the Bella Earth Project Report, 2008)

POTENTIAL ACTION BY POWER PLANT : Thermal Discharge				
Activity	**Measurement**	**Threshold**	**Consequence**	**Directive**
Thermal plume, increase in temperature	Temperature of surface water	Set against WFD status thresholds exceedance, e.g. not >(defined value) for more than 2% of time	Temperature and DO part of the ecological classification. Potential to directly impact on the health of biological elements. Classification integrated into overall ecology. Failure of temperature or DO results in failure of water body	WFD assessment from 2009. Will continue to 2030
Decrease in Dissolved Oxygen (DO)	DO monitoring (high frequency)	DO value no less than 4 mg l^{-1} for more than 5% of time		WFD assessment from 2009. Will continue to 2030
Fish behaviour, fish mortality	Sub-metrics under the fish classification scheme in WFD	Failure of ecological quality ratios (EQR) in the overall sub-metrics	Changes in fish behaviour relating to migration patterns and spawning are identified in the fish classification scheme. Change in fish species composition must relate to a pressure	WFD assessment from 2009. Will continue to 2030
Benthic invertebrates	Limited data on the effect of temperature on benthic invertebrates		More information needed	
Change in phytoplankton community	Sub-metrics under the marine plant classification scheme	Exceedance threshold based on 30% deviation of natural population (community indicators)	Significant deviation in community composition is part of the normative definitions and will be identified in the phytoplankton classification tools	WFD assessment from 2009. Will continue to 2030
Impact on SPA/SAC biological element	Listed under the Habitats Directive	Measurable change in a protected species or conservation area	Modification of pressure as to eliminate the impact on the high conservation species or area	Habitats Directive

2 Approach

2.1 Data handling

The contaminants of importance to the marine environment are described in this section and in each case an attempt has been made to provide data from studies that consider each of the relevant contaminant groups. Because the East Suffolk coast is relatively sparsely populated and there are few major industries the area has been chosen as a reference site for several studies when comparisons to the more industrialised estuaries e.g. on the North East coast of the UK are the subject of study. Literature data “Contains Environment Agency information © Environment Agency and database right” for contaminants measured. The main locations from which data were available are shown in Figure 1.



Sizewell Selection of EA Water Sampling Sites

- ● Other Environment Agency Water Sampling Sites
- ● Environment Agency Suffolk Coast Sample Stations
- ▨ SPA
- ▤ Water Framework Directive (WFD)

Coordinate System: British National Grid
Date Saved: 17/10/2018
Reference Scale: 1:444,000 @A4
Drawn By: RH - Cefas
Drawing Number: MS0566
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Figure 1 - The Environment Agency (EA) sampling stations for which water quality data were available are shown in relation to Sizewell Power Station and major towns on the Suffolk coast. The numbered sample locations are the Suffolk Waterbody sampling points and the Suffolk Waterbody is delimited by the green hatched area near to shore. The brown hatched area extending further offshore shows the upper part of the Outer Thames Estuary SPA. Additional Environment Agency sampling points are shown as blue circles.

3 Results

3.1 General Literature data

Dissolved and sediment associated metals

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 more or less available for accumulation by marine organisms.

Cadmium

Cadmium has been used in the manufacture of wide range of products such as batteries, paints, plated metal etc, which may have entered waste streams for disposal to landfill in the past. A number of diffuse sources of cadmium release to controlled waters exist: numerous contributory discharges to STWs; deposition from air directly and indirectly via land; from agricultural land subject to fertiliser and biosolids applications; and from cadmium containing wastes that have been recycled or disposed to landfill. Based on monitoring data in 2006 none of the 39 waterbodies sampled in the Anglian region failed the Cadmium EQS (Pollution reduction plan for Cadmium, 2008).

Although cadmium does not break down in the environment physical and chemical processes that modify its mobility, bioavailability, and residence time in different environmental media may affect it. In both fresh and saltwaters, particulate matter and dissolved organic material may bind a substantial portion of the cadmium, and under these conditions cadmium may not be bioavailable due to this binding (Callahan et. al., 1979, Kramer et. al., 1997).

Studies conducted on the Orwell in 1999 showed elevated cadmium concentrations in sediments associated with salt marshes near the mouth of the estuary with values around 0.8 – 2.0 ug g^{-1} dry weight. Sampling of diffent estuarine organisms from the Orwell showed mussels, *mytilus edulis* to have the highest tissue concentrations of cadmium, 1.43-2.85 ug g^{-1} dry weight (Wright and Mason, 1999).

Chromium

Although chromium occurs naturally it also enters the environment through emissions from the metallurgy and metal-finishing industries, e.g. chromium compounds are used in ferrochrome production, electroplating, pigment production, and tanning and from its use as a chemical intermediate. These industries, the burning of fossil fuels and waste incineration are sources of chromium in air and water. In surface waters, chromium exists in two oxidation states, chromium (III) and chromium(VI) or hexavalent chromium, but the more thermodynamically stable state is Cr(VI). Almost all the hexavalent chromium in the environment arises from human activities. In the hexavalent oxidation state Cr (VI), chromium is relatively stable in air and pure water, but is reduced to the trivalent state CR (III) when it comes into contact with organic matter in biota, soil, and water. Chromium(III) is less toxic than Cr(VI) and its low solubility in water limits its bioavailability.

The UK EQS values derived in 1984 (Mance et. al., 1984a) were for total dissolved chromium and the freshwater standards were banded according to water hardness. The data available for the effects of chromium on marine species indicated that the acute toxicity of hexavalent chromium was extremely variable. Fish appeared to be considerably less sensitive than invertebrates, although fish larvae were reported to be susceptible to chromium contamination. The limited information available did not entirely support the view that trivalent chromium was less toxic than the hexavalent form. Because of this and the possibility of transformation between the two species, the EQS was defined as being for total chromium. The standard was based on a chronic lowest adverse effects value of 30 µg l^{-1} for a polychaete worm. This value was halved to give the annual average standard. The EQSs were subsequently revised and new values are shown in Table 3 and 4.

Chromium is found in sediments and can pose a hazard to sediment dwelling organisms at concentrations above 52.3 mg kg^{-1} (CCREM, 1987).

Laboratory experiments on annelids, crustaceans and molluscs have resulted in bioconcentration factors (BCFs) in the range 158 to 596 for annelids and 383 to 620 (based on dry weights) for molluscs and crustaceans in the laboratory (Hunt and Hedgecott, 1992a). Much lower BCFs have been calculated in the field: 0.46 to 15 for annelids and <1 for molluscs and crustaceans. These BCFs indicate that chromium is unlikely to bioaccumulate under field conditions.

Copper

Uses of copper include electrical wiring and electroplating, the production of alloys, corrosion of copper piping, and roofing material. A number of copper-based products are also manufactured as antifouling paints, pesticide formulations, and preservatives for wood. Major industrial sources include mining, smelting, refining and coal-burning industries. Copper is also an essential nutrient and so is present in human and animal wastes. However, a few investigations (e.g. Young et. al., 1979; Claisse and Alzieu, 1993) have concluded that boat traffic may be a significant source of estuarine copper through its use in anti-fouling paints. The latter source has become more important since the late 1980s when the use of tributyltin-based antifouling paints on small vessels was phased out in Britain and elsewhere.

Copper may be present in a natural water system in a number of forms, either dissolved in solution, as a precipitate or absorbed to organic matter (Mance et. al., 1984b).

The high concentrations of particulate matter in most estuaries will facilitate the removal of copper from solution by adsorption to suspended particles, which in turn may be deposited and accumulate in sediments. Estuarine sediments are thought to be the most important depositional site for particulate copper transported from rivers, although remobilisation may occur when sediment is disturbed.

A review of toxicity data for copper to freshwater and saltwater organisms found that invertebrates exhibited slightly greater sensitivity to divalent copper than fish species tested (Mance et. al., 1984b). There were also indications of the moderation of toxicity in the presence of natural and manufactured chemicals such as humic acids and detergents.

A study of copper loadings from different sources in the Orwell, Ore and Deben indicated that docks (2874 kg y^{-1}), marinas and estuarine sewage works were important sources for the Orwell and marinas also made a significant contribution to the copper loading in the Deben and Ore although there was no data for sewage works for the latter two sites. The concentration range for copper for the three estuaries was 0.5-75 µg l^{-1} (Matthiessen et. al., 1999). The copper concentration measured in the sediments of the Orwell estuary in 1999 were > 20 ug g^{-1}dry weight at 15 of the 20 sites sampled. Higher concentrations were associated with port and marina facilities. The highest tissue concentrations of copper for organisms sampled from the Orwell estuary were recorded for the periwinkle *Littorina littorea*, 86.5 ug g^{-1}dry weight. The tissue concentration range for eight species sampled was 6.61-98.6 ug g^{-1}dry weight (Wright and Mason, 1999).

Lead

With the exception of Lead nitrate and chlorate, and, to a much lesser degree, chloride, the salts of lead are poorly soluble in water; it also forms stable organic compounds(Nordic Council of Ministers, 2003). Lead is primarily used in its elemental form but is also used for manufacture of lead oxide and alkyl lead (Pollution reduction plan for lead, 2008). Tetraethyllead and tetramethyllead were used extensively as fuel additives and the latter breaks down in the environment to form triakyllalkylleads. In contrast to tetraethyllead and tetramethyllead, rialkyl compounds are less volatile and more readily soluble in water. Lead still has a variety of uses e.g. it is used in batteries, lead sheet and as lead oxide as a PVC stabiliser.

Entry into the aquatic environment occurs through releases through atmospheric deposition from the the burning of coal and oil, through abrasion of lead containing products in domestic properties and through inputs via sewer which represents the largest source (Pollution reduction plan for lead, 2008).

Following a review of toxicity data in 1992 a standard of 10 µg Pb l^{-1} was proposed for saltwater but Lead becomes predominantly associated with particulates and so the transport of lead in estuaries and coastal waters is closely linked with the movement of particles. A study of the Orwell estuary in Suffolk showed sediment lead concentrations of > 50 ug g^{-1} at four of the sites on the Southern shore and one on the Northern shore of the outer estuary. Canadian interim marine sediment quality guidelines (CCREM, 1998) for lead recommend a threshold value of 30 mg kg^{-1} above which biological effects may be expected.

Bioconcentration factors (BCFs) of ~3000 times have been demonstrated in some studies using bivalves but generally fish had lower BCFs and in studies of organisms from contaminated sites BCFs were also lower than those found in the laboratory. Samples of a number of organisms collected from the Orwell estuary showed similar concentrations of lead for mussels *Mytilus edulis*,3.15 ug g^{-1} dry weight (range 0.81-5.93); cockles *Cerastroderma edule* 4.6 ug g^{-1} dry weight (range 0.95-9.99) and the polychaete worm *Nereis diversicolor* 3.26 (range 0.31-4.81), (Wright and Mason, 1999).

Iron

Iron is the fourth most abundant element in the Earth's crust. While it is naturally released into the environment from weathering, it may also be released into the aquatic environment through human activities, such as burning of coke and coal, sewage, iron related industries and the corrosion of iron and steel (CCREM, 1999).

In unpolluted oceanic seawater, concentrations of iron between 2.8 to 29 ng l^{-1} and 224 to 1,228 ng l^{-1} have been reported, although higher concentrations may be found in estuarine waters.

On reaching saltwater, suspended iron oxyhydroxides are rapidly precipitated such that at salinities of 10 ppt or greater, the vast majority of the iron present occurs in particulate form and is effectively removed from solution. In anoxic marine waters, ferrous iron is mobilised from sediments and diffuses into the water column.

Data reviewed on the toxicity of iron to fresh and saltwater species proposed the same EQSs for iron in solution of 1000 µg l^{-1} (as an annual average). Due to a lack of data, the derivation of an objective EQS based on iron toxicity was not considered possible. Therefore, the above values are based on observations of general water quality at various estuarine and marine sites. A further review in 1998 considered the current annual average of 1,000 µg l^{-1}, was still appropriate (Whitehouse et. al., 1998).

Marine organisms accumulate iron but also rapidly excrete it in clean water conditions. Normally, tissue concentrations of iron are related to the water and sediment concentrations, but there is considerable variability. Tissue concentrations vary seasonally, being lower in winter and spring than in summer and autumn and furthermore tissue and shell concentrations increase with increasing salinity (Whitehouse et. al.,1998). The bioaccumulation of iron by marine organisms does not appear to pose a hazard to higher trophic levels.

Mercury

Mercury is a metal, which is liquid at normal temperatures and pressures. It is present in the environment in three oxidation states and as inorganic (mercuric II chlorides, sulphides, hydroxides and oxides) or organic (e.g.methylmercury) form.

Atmospheric pollution from industrial production is probably low however the burning of fossil fuels is a source of mercury. Although the use of mercury is decreasing, high concentrations of the metal are still present in sediments associated with previous industrial applications of mercury.

Dissolved mercury associates with organic matter and particles suspended in the water column (up to 95%, Eurochlor,1999) and so will accumulate in sediments. Methylation of sediment bound mercury produces methylmercury and this form of mercury is bioavailable and is a hazard to aquatic life (Campbell et .al., 1986).

Based on 21 data for fish and amphibians, 68 data for invertebrates and 35 data for algae, a PNEC for inorganic mercury of 470 ng l^{-1} was derived. Based on 11 data for fish, 9 data for invertebrates and 7 data for algae a PNEC for organic mercury of 10 ng l^{-1} was estimated. For inorganic mercury, worst case concentrations in coastal waters and estuaries found recently are up to 170 ng l^{-1} giving a safety margin up to 3 between PEC and PNEC. For organic mercury, a worst case PEC of 8.5 ng l^{-1} was calculated leading nearly to no safety margin (Eurochlor, 1999).

In terms of bioconcentration of mercury from water Slooff et. al., (1995) give inorganic mercury BCF values of 190-5,300 l kg^{-1} for molluscs. Values derived for mussels (Mytilus edulis) and recalculated as part of a risk assessment for mercury gave a BCF of 13,061 l kg^{-1} dry weight. For methylmercury the reported BCF = 99,500 l kg^{-1}, based on recalculated data (Eurochlor, 1999).

Bioconcentration of methylmercury from sediments was estimated to be between 10 (*Fucus vesiculosus*) and 100 (*Mytilus edulis*) times higher than sediment concentrations at the sites they were collected from in the Mersey estuary (Langston et. al., 1995).

Data for the Orwell estuary indicate that for six out of a total of 20 sites sampled the sediment concentration of mercury was > 0.4 ug g^{-1}dry weight at four of 20 sites sampled and for a range of organisms sampled the tissue concentration range was 0.04 -0.59 ug g^{-1} dry weight. The highest tissue concentration was recorded for the cockle, *Cerastroderma edule* and the lowest for the seaweed *Enteromorpha* spp.

Nickel

Nickel is used extensively as a metal in alloys, as a plating material, in batteries manufacture and as a catalyst. Nickel releases to controlled waters reported to the Pollution Inventory for 2006 totalled 66 tonnes, mostly from sewage treatment works, the chemical industry and metal production and processing plants. Disused metal mines are thought to be a potentially significant source of release to water. Abrasion and erosion of nickel-containing products in households and commercial premises results in a diffuse source of nickel discharged to STWs and to land and water directly. Abrasion of road materials that incidentally contain nickel – such as slag, ashes and waste products – constitutes a diffuse source of runoff to surface water directly or to STWs for treatment. Road runoff will also contain nickel from engine oil containing an accumulation of abraded engine parts, dust from worn brake linings, wear losses from tyres, products of car body corrosion and deposits from vehicular emissions. It has been estimated that the rate of nickel released from abrasion of urban road surfaces in England is about 21 kg per kilometre per year (Luker and Montague, 1994). The distribution of deposited nickel between land, surface runoff to water and surface runoff to STWs is unknown.

Twenty sites sampled on the Orwell estuary in 1999, had Nickel concentrations of 9 - >30 ug g^{-1}dry weight. The highest concentrations of Nickel in the sediments were measured in samples from the Southern shore near the mouth of the estuary close to areas of port development but on the Northern shore the higher concentrations were closer to the riverine end of the estuary but again this is probably associated with the location of port facilities. Tissue concentrations of a range of organisms sampled from the Orwell ranged between mean values of 9.06 -96.2 ug g^{-1}dry weight. The highest tissue concentration was recorded for the polychaete worm *Arenicola marina*.

Zinc

Zinc is used in coating to protect iron and steel, in alloys for die casting, in brass, in strips for dry batteries, in roofing and in some print processes. It may enter the aquatic environment through natural or anthropogenic sources, including sewage and industrial discharges.

Concentrations of zinc have been measured in water, sediments and biota as part of the National Monitoring Programme at sites throughout the UK in estuaries and coastal waters (MPMMG, 1998). The biggest loading of zinc calculated for the Orwell, Deben and Ore was from sewage treatment works discharges, 1638 kg yr^{-1} on the Orwell (Matthiessen et. al., 1999). Zinc loading from marinas on the Deben and Orwell were about a quarter of this value.

Zinc is is transported in natural waters in dissolved form and associated with suspended particles (Mance and Yates, 1984). In river water, zinc is predominantly present in the dissolved form. In estuaries, where concentrations of suspended particles are higher, a greater proportion of the zinc is adsorbed to suspended particles (CCREM,1999). In seawater, much of the zinc is found is dissolved form as inorganic and organic complexes. In a survey of six Essex and three Suffolk estuaries there were 74 out of 138 year/location combinations where the concentration of zinc exceeded 10 µg l^{-1}. The marine EQS is 6.8 µg l^{-1} (expressed as a dissolved annual average concentration).

A review of toxicity data for zinc to freshwater and marine organisms showed that invertebrates were generally more sensitive than fish, while, effects on marine macro and microalgae were noted at concentrations slightly lower than those reported for invertebrates (Mance and Yates, 1984). The toxicity and bioaccumulation of zinc are also reported to be greater at lower salinity (Hunt and Hedgecott, 1992b).

Zinc accumulates in sediments and can pose a hazard to sediment dwelling organisms at concentrations above 124 mg kg^{-1} (CCREM, 1999) particularly as it is readily bioaccumulated. Several species of crustacean are able to regulate the uptake of zinc but, at higher concentrations, this process appears to breakdown leading to an influx of zinc. Zinc concentrations measured in sediments of the Orwell estuary were > 40 ug g^{-1} dry weight for all 20 sites sampled with maximum concentrations > 120 ug g^{-1} dry weight at sites associated with port activities (Wright and Mason, 1999). The tissue concentrations for zinc measured in eight species ranged between 40-269 ug g^{-1} dry weight with the algae *enteromorpha sp* at the low end of the range and the polychate worm *Nereis diversicolor* showing the highest concentrations particularly associated with moorings and marinas.

Arsenic

Arsenic is a commonly present element with metalloid properties. Its chemistry is complex and there are many different compounds of both inorganic and organic arsenic. Arsenic enters the aquatic environment from natural diffuse sources and from anthropogenic point and diffuse sources.

A data review of the aquatic toxicity of arsenic to freshwater and saltwater organisms derived an annual average EQS value of 50 and 25 µg l^{-1}, (expressed as a dissolved concentration) for freshwater, and coastal and estuarine waters respectively (Mance et. al., 1984c). Although limited data on the toxicity of arsenic to marine organisms was considered as part of this review it was concluded that invertebrate species appeared more sensitive than vertebrate species and in particular during the larval stages.

Arsenic is found in sediments and can pose a hazard to sediment dwelling organisms at concentrations above 7.24 mg kg^{-1} according to the Canadian interim marine sediment quality guidelines (CCREM, 1999). Sediment concentrations of arsenic measured in the sediments of the Orwell estuary were > 18 ug g^{-1}dry weight at 18 of 20 sites sampled which exceed the level at which Canadian guidelines suggest that biological quality could be compromised. A range of marine organisms has been found to accumulate arsenic from sediments and the water column, including bivalve molluscs and macro algae. While these species appear to accumulate arsenic to quite high levels, a large proportion may be present as arsenobetaine which is a water soluble compound that poses little hazard to organisms that ingest it (Smith and Edwards, 1992). Arsenic is bioconcentrated in organisms but is not biomagnified in food chains and so bioaccumulation is unlikely to be a problem in marine organisms.

Organotin

The tributyltin compounds act as fungicides, disinfectants, and microbiocides. They are used in water cooling towers, wood preservatives, hard surface disinfectants for farm premises; as materials preservatives in textiles, carpet backing, sponges, rope, fiberfill, foam, paper, and building materials (e.g., drywall, joint compound, grout); metal working fluids; and petrochemical injection fluids (EPA, 2008). The most well known use of tributyltin (TBT) in terms of environmental impacts was as an antifouling paint. On 1st July 1987 the use of TBT as an antifouling paint used on fish farming equipment and boats of <25 metres waterline length was banned. A ban on TBT use on all ships hulls began 1st January 2008. As a conseqence of these bans the environmental concentration of tributyltin concentration in the water column of estuaries has shown a downward trend (Dowson et. al., 1993, Matthiessen et. al., 1999). A survey of Essex and Suffolk estuaries in 1993 showed that for the Alde the concentration of TBT in sediments ranged from <3 – 653 ng g^{-1} in spring 1991 to <3 -186 ng g^{-1} in spring 1992 a similar decrease was shown for the sites monitored on the Alde <3 -466 in spring 1991 to <3 ng g^{-1}in spring 1993

Pesticides

Studies of pesticides in seawater have generally indicated a decreasing trend following the successive introduction various control measures (e.g. Power et. al., 1999).

Flounder from several UK estuaries were shown to have depressed acetyl- and butyl-cholinesterase (ChE) activity in muscle which is a response frequently associated with exposure to carbamate and organophosphate pesticides (Kirby et. al., 2000). Kirby et. al., have shown that flounder sampled from several locations on the Mersey, Tees, Humber, Tyne and Tamar estuaries in 1997 showed significant ChE inhibition compared with fish from the Alde, concentrations of up to eight organophosphates and six carbamate insecticides were above detection limits in all the surveyed estuaries except the Alde, so it is assumed that they were at least contributing to the observed effects.

The introduction of pesticide-based biocides to replace tributyltins for antifouling has lead to an increase in the presence of compounds such as diuron and the triazine herbicide irgarol in the freshwater and marine environment. Studies have detected a variety of these compounds in Norfolk and Suffolk broads as well as the rivers Bure and Yare (Lambert *et. al*., 2006).

Hydrocarons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are hydrophobic organic chemicals which are derived from the combustion of petroleum products and from various industrial processes. Many of these compounds are stable and highly toxic, some are carcinogens and others are mutagenic. The major route of entry of PAHs to the aquatic environment is through atmospheric deposition either directly onto the water surface or via material washed off of hard surfaces such as roads. PAHs are also present in various oils and are particularly enriched during use in lubricating oils.

PAHs are frequently considered as a group however they differ markedly in solubility, volatility and other physico-chemical characters which affect their distribution, bioavailability and toxicity.

Exposure to UV light present in natural sunlight may also increase the toxicity of PAHs and this effect has been widely reviewed (Arfsten et. al., 1996). Phototoxicity occurs in the presence of UV light by the formation of free radicals and oxidation of parent PAHs to more toxic forms which may damage a variety of macromolecules.

PAHs may also become more toxic due to enzymatic transformation within an organism to form highly reactive compounds which bond with protein and DNA; this may give rise to mutations which ultimately induce tumour formation or birth defects. Only certain PAHs are metabolically activated, not all organisms have the enzyme systems which metabolise them to the more reactive form and cellular DNA repair mechanisms vary between species.

An extensive survey analysed for 15 PAHs in water from UK estuarine and offshore locations between 1993 -1995 (Law et.al., 1997). The data showed that offshore sites had generally undetectable levels but 23 sites had total PAH concentrations greater than 1µg l^{-1}, these included the Thames and Great Ouse as well as a number of industrialised Northern estuaries. The PAHs detected in one sample on the Tees included, naphthalene, acenaphthene, fluorene and phenanthrene. Analysis of 15 PAHs in sediments around in estuaries, coastal and offshore waters (Woodhead et. al., 1999) also highlighted high concentrations in the more industrialised Northern estuaries. However relatively high concentrations of a number of PAHS including anthracene, pyrene, benz a anthracene, chrysene, benz e pyrene were measured in sediments from the River Blackwater in Essex. Four of the concentrations detected at this site were above predicted effects thresholds based on Canadian sediment quality guidelines (CCREM, 1999).

Studies that included a survey of the River Alde as well as industrialised estuaries in Southampton and at various Northern locations (Kirby et. al., 1999) showed that relative to fish from the Alde estuary those present in the industrialised sites had elevated levels of enzymes that are induced following exposure to PAHs. These data further support the conclusion that with the exception of a few point sources there are realtively low inputs of these contaminants in this area

Inorganics

Ammonia

Ammonia is excreted by animals and plants and is a product of the decomposition of all organisms. The intensification of agricultural practices and increased density of human populations in towns and cities has led to higher inputs of ammonia to rivers and estuaries. In the marine environment both ammonia in its ionised NH_4 and unionised NH_3 form may contribute to toxicity although it is the unionised form that is the most toxic. Ammonia may be lost from water by volatilisation or under aerobic conditions may be oxidised to nitrite and then nitrate. Various water quality parameters influence the toxicity of ammonia mainly by increasing the proportion of the most toxic, unionsed, form of ammonia. The pH of seawater has the most influence on ammonia toxicity, increasing it by 1 unit (e.g. pH 7 to 8) at 10^{o}C produces about a 10 fold increase in NH_3 concentration while increasing the temperature by 10^{o}C (10 to 20^{o}C) approximately doubles the NH_3 concentration. Increasing salinity from 0.5 to 32 ppt at 10^{o}C reduces the NH_3 concentration by about 15% (Eddy, 2005).

In a survey of water quality and nutrients in lowland rivers in Suffolk (Howden et. al., 2009) the mean NH_4 concentration and range for the period 1981-2005 were 1.75 (0.01-70), 0.78 (0.0-39) and 0.11(0.0-11.9) mg l^{-1} for the Loathingland Hundred river that joins the coast at Lowestoft and the Rivers Blyth that joins at Southwold, and the Ore/Alde that joins the sea approximately 16 kilometres South of Aldeburgh. The two higher mean values would result in unionised ammonia concentrations above the recommended standard for unionised ammonia 0.021 mg l^{-1} NH_3-N (assuming a salinity of 30 psu, a temperature of 18^{o}C and pH of 8).

Chlorine

Chlorine is used in the manufacture of a wide variety of products but its use in preventing biofouling in cooling water systems is the main focus here. Different chlorine dosing regimes may be used in cooling water systems with some focussing on the main settlement period of bivalve molluscs and others applying low level continuous chlorine dosing e.g. 0.5-1.5 mg l^{-1} (Jenner et. al., 1997). When chlorine is added to seawater it oxidises the bromide ions present to form the free oxidants - hypobromous acid and hypobromite. These free oxidants remain undissociated and more effective as a biocide in seawater. A number of non-oxidising chlorination byproducts (CBPs) may also result when chlorine is added to seawater and combines with organic matter:

(i) Volatile organohalogens – predominantly trihalomethanes e.g. bromoform and bromchloromethanes.

(ii) Semi-volatile bromoacetonitriles

(iii) Non volatile bromaceitic acids, bromphenols and other CBPs

In addition to the above, the presence of ammonia in seawater may also lead to the formation of monochloramine (NH_2Cl) and bromamines (NH_2Br, $NHBr_2$, NBr_3) (Taylor, 2006).

The main environmental concerns regarding cooling water chlorination are therefore the potential for any toxicological effects of residual oxidants much beyond the immediate discharge to the sea. Concerns regarding CBPs consider toxicity but are also focussed on their persistence and potential to bioaccumulate.

Studies conducted in 1981 to develop a model of chlorine decay used the discharge from the Sizewell A power station to vaildate the model (Davis and Coughlan,1983). Samples of the plume were taken along a transect based on disminishing temperature (dilution) away from the point of discharge. Two sampling occasions in September 1991 are described for which the total residual oxidants (TRO) produced by chlorine addtion have an initial concentration at the point of discharge of 0.05 and 0.1 mg l^{-1} decreasing to 0.01 mg l^{-1}

within 1000 and 1500 metres respectively. A similar study conducted in August 1993 (Jenner et. al., 1997), measured a TRO concentration of 0.02 mg l^{-1} at 375 metres from the discharge, this is comparable to the results described by Davis and Coughlan for the lower initial discharge concentration. At the time of the 1993 study, Sizewell was operating on a once through with a flow of 45 $m^3 s^{-1}$ and a chlorination regime from April to November of up to 1 mg l^{-1} dosed at the strainer outlet to maintain a residual of 0.2 mg l^{-1} at the condenser inlet.

During the plume studies in 1993, bromoform concentration was also measured in the discharge. The initial seawater concentration of bromoform was just over 9.85 µg l^{-1} and decreased by 966 metres from the discharge to 2.35 µg l^{-1} which is below the proposed reference level concentration for bromoform of 5 µg l^{-1} as a Maximum allowable concentration (MAC), Taylor, 2006. Under WFD, the MAC values are assessed as an annual 95 percentile (UKTAG, 2013). Compared to an existing standard for chloroform (trichlormethane, $CHCl_3$) 2.5 µg l^{-1} as an annual average if this is considered an equivalent the concentration of bromform measured within 1 km of the discharge is just below this value (Common Implementation Strategy, Substance datasheet 32, trichloromethane, 2005).

At this time of the other CBPs analysed for (Table 6), dibromoacetonitrile, was the only one detected and this was only present in a single plume sample at a concentration of 0.21 µg l^{-1}(Jenner et. al., 1997).

Table 6 - CBPs analysed for but below detection in Sizewell discharge in 1993 study

Haloforms	**Detection Limits**
chloroform, bromodichloromethane, chlorodibromomethane	<0.1µg l^{-1}
Haloacetonitriles	Detection Limits
dichloroacetonitrile, dibromoacetonitrile	<0.1µg l^{-1}
Halophenols	Detection Limits
2,4-dichlorophenol	0.4µg l^{-1}
2,4,6-trichlorophenol	<0.6µg l^{-1}
2,4-dibromophenol	<0.02µg l^{-1}
2,6-dibromophenol	<0.1µg l^{-1}
2,4,6-tribromophenol	<0.05µg l^{-1}

Nutrients

Nutrient additions to estuaries and coastal water bodies occur both naturally as a result of geological weathering, atmospheric deposition and nitrogen fixation by plants, but growth of human populations has led to increasing inputs of nutrients from sources such as agriculture, wastewater treatment plants, urban run-off, and consumption of fossil fuels. As a result, nutrient inputs have increased to many times their natural levels to the point that eutrophication is now regarded as one of the greatest threats to coastal ecosystems. Eutrophication is defined as ‘the enrichment of water by nutrients causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned’ (CEC 1991a, Urban Waste Water Treatment Directive, 91/271/EEC).

In a tidal estuary, the potential for nutrient enrichment to have an impact on the waterbody is determined by the water residence time, the tidal regime and growth rates of primary producers (Painting et. al., 2007). Elevated nutrient concentrations can lead to increased primary production by phytoplankton (indicated by concentration of chlorophyll a (Chl-a) and macroalgae that may in turn impact upon dissolved oxygen (DO) levels, pH and turbidity. These changes may lead to the development of localised hypoxic or anoxic conditions, and indirect effects such as changes in biological community structure and mortality of fish or benthic animals. Nitrogen (as nitrate, nitrite and ammonium) and phosphorus are the primary nutrients that contribute to increased plant growth and potential for eutrophication. However, nutrient enrichment or hyper-nutrification does not necessarily result in undesirable effects and therefore does not always result in eutrophication (de Jonge and Elliott 2001, Tett et al., 2007, Painting et al., 2007).

In terms of inputs to the Suffolk coastal waterbody, Howden et al., 2009 conducted a review and analysis of Environment Agency water quality data from 60 sampling sites for the period between August 1981 and October 2005. The analysis indicated that the long-term average nitrogen concentration for rivers in this area (7.85 mg l^{-1}) was similar to but slightly lower than that for other agriculturally-impacted eastern UK rivers such as the Great Ouse and Thames. Although the River Deben was described as having one of the highest nutrient inputs of Suffolk and Essex estuaries, its high turbidity is thought to limit growth of phytoplankton and macroalgae (Nedwell et. al., 2002).

For coastal and marine waterbodies the EU objectives for the protection and maintenance of water quality have been set under various Directives and Conventions. Directives include the Urban Waste Water Directive (UWWTD, CEC 1991a), the Nitrates Directive (ND, CEC 1991b), the Habitats Directive (HD, CEC 1992), the Water Framework Directive (WFD, CEC 2000) and the Marine Strategy Framework Directive (MSFD, CEC 2008). Conventions include the Oslo Paris Convention (OSPAR 2003a, b) and the Helsinki Commission (HELCOM, Andersen and Laamanen 2009). Methodologies developed across Europe and in the Mediterranean (e.g. the Trophic Index, TRIX, Vollenweider et al., 1998) all assess the impacts of nutrient enrichment using measurements of key indicators such as concentrations of nutrients, Chl-a and DO in the water column (Devlin et al., 2011). Some of the more recent Directives (WFD, MSFD) and OSPAR include the additional identification of secondary impacts and undesirable disturbance to the ecosystem (e.g. low DO events, toxic algal blooms).

The OSPAR Strategy to Combat Eutrophication seeks to achieve ‘a healthy marine environment where eutrophication does not occur’. The strategy requires that the eutrophication status of the maritime area be identified through the OSPAR Common Procedure (COMP, OSPAR Commission 2005), and the original target year was 2010. The first application of the OSPAR COMP by Contracting Parties was for the period 1996–2000 inclusive (OSPAR *Commission 2003)*; the second application was for the period 2000-2006 (OSPAR *Commission* 2008), and the third application (2006-2014) is due in 2017. Under OSPAR, water bodies are classified as Problem Areas or Non Problem Areas.

The MSFD aims to reach or maintain Good Environmental Status (GES) in marine waters by 2020. Eleven descriptors of the state of the environment have been defined, including Descriptor 5 on human-induced eutrophication. Assessments under the MSFD are anticipated to be broadly similar to those under OSPAR.

The WFD requires the classification of all surface waterbodies into one of five ecological status classes: High, Good, Moderate, Poor or Bad (UKTAG 2008). Development of the UK nutrient standards was based on the offshore values established for OSPAR and aligned with freshwater reference values assuming conservative behaviour between nutrients and salinity. At present, coastal and transitional waters are assessed using only the winter value for concentrations of dissolved inorganic nitrogen (DIN, the sum of nitrate, nitrite and ammonia, measured in micromoles per litre, µM), as DIN is recognised as the primary driver of eutrophication. Impacts of dissolved inorganic phosphorus and other limiting nutrients are under investigation.

The relationship between the OSPAR Common Procedure and the WFD has been set out by OSPAR (2005). The boundary between OSPAR’s Problem Areas and Non Problem Areas is the boundary between the WFD classes of Good and Moderate. The United Kingdom Technical Advisory Group (UKTAG, 2008) used this to define offshore thresholds and reference conditions for the WFD, and derived standards for coastal and transitional waters. These standards are related to salinity, and provide values for UK offshore, coastal and transitional waters (normalised for salinity). For assessment of ecological status, coastal waters extend to 1 or 3 nautical miles off the coast for England and Wales respectively, or have a salinity of 30 to 34.5. Transitional waters (estuaries) are generally described by a salinity of less than 30. The boundaries for WFD and MSFD assessments overlap in coastal waters (Figure 2). However, in coastal waters, the WFD assessment tools are used, and the MSFD is applied to descriptors which are not covered by the WFD (e.g. noise, litter, aspects of biodiversity).

WFD assessments of nutrients are based on winter (November to February inclusive) values of DIN, taking account of mitigation of impacts by light limitation. The concentration of suspended particulate matter (SPM) is used as a surrogate for light (UKTAG, in prep), and is used to designate waterbodies as “clear” or “not clear”. “Clear waters” are described as waters with an annual mean of SPM of <10 mg l^{-1}. “Not clear” waters are described as waterbodies with an annual mean SPM of >10 mg l^{-1}. Not clear waters are grouped further by the mean annual SPM value, and described along a continuous gradient of “intermediate” (10<SPM<100 mg l^{-1}), “turbid” (100<SPM<300 mg l^{-1}) or “very turbid” (>300 mg l^{-1}) conditions. The average winter DIN concentration from waterbodies designated as c*lear* is assigned to one of five classes along the WFD boundary conditions (high to bad) based on the value of the normalised winter DIN. For *not clear* water bodies (annual average SPM >10 mgl^{-1}), the 99th percentile of winter DIN is assigned to one of four classes. Although values are classified into five classes overall, they are only *reported* to Europe as one of three classes, i.e. high, good or moderate. The poor and bad classes are indicative only and used internally. At present, the nutrient assessment does not calculate a numerical ecological quality ratio (UKTAG, in prep).

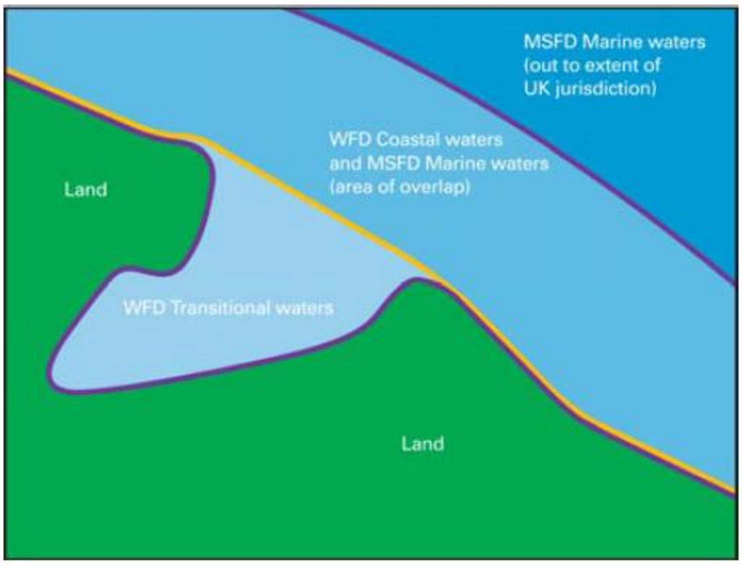

Figure 2 - Diagram to indicate overlap between the WFD and the MSFD. The WFD applies to estuaries and coastal water bodies out to 1nm (baseline + 1nm) for biological status, and 12nm for chemical status. The MSFD applies to marine waters and includes coastal waters not addressed by the WFD or other Community legislation, as well as the full extent of the territorial waters of Member States (HM Government 2012).

The WFD DIN tool requires the measurement of 4 separate statistics: mean winter DIN, mean salinity, 99th percentile winter DIN, Mean annual SPM (which can be derived from other measures such as turbidity or light extinction). The assessment is made in a conditional stepwise procedure:

Step 1. Compare mean winter DIN against OSPAR derived criteria
Step 2. Compare mean winter DIN against salinity derived thresholds for *clear waters*
Step 3. Compare 99th percentile DIN against SPM derived thresholds for *non- clear* waters

Winter DIN boundary (or threshold) values agreed by UKTAG (2008, in prep) for classifications of nutrient status as High, Good or Moderate are shown in Tables 7 and 8, below. For offshore waters, boundary values were set based on the OSPAR threshold of 15 µM between Non Problem Area and Problem Area (OSPAR 2003, Foden et al., 2011), which is equivalent to the WFD boundary between Good and Moderate (15 µM = 0.21 mg l^{-1}).

For 'clear' coastal waters (normalised to salinity 32), the winter DIN boundary between High/Good is 12 µM and between Good/Moderate is 18 µM (UKTAG 2008). These thresholds are equivalent to 0.168 and 0.252 mg l^{-1} expressed as nitrogen (N). For 'Not clear' waterbodies, the 99th percentile of the winter DIN values are used. Winter DIN thresholds for classification of these waterbodies (Table 8) are based on a sliding scale, depending on the mean annual SPM value measured in each waterbody. For the Suffolk coastal waterbody, the current classification under the WFD indicates that SPM is intermediate, and that nutrients are Moderate and could potentially be Poor.

Table 7 - For clear waterbodies: boundary/threshold values for offshore, coastal and transitional waters (from UKTAG, in prep) used by the WFD (Anon, 2008). These values were set based on the OSPAR threshold of 15 µM for Problem Area vs Non Problem Area (OSPAR 2003, Foden et al., 2011), equivalent to the WFD boundary between Good and Moderate. For coastal and transitional waters, winter DIN values are normalised to salinity 32 and 25 respectively.

Area	Assessment	Salinity	Dissolved Inorganic Nitrogen (Winter mean, µM)	
			High / Good boundary	Good / Moderate boundary
Offshore	OSPAR	More than 34.5	10	15
Coastal (at salinity 32)	OSPAR WFD	30 - 34.5	12	18
Transitional (at salinity 25)	OSPAR WFD	Less than 30	20	30

Table 8 - For ‘Not clear’ waterbodies: winter DIN thresholds (µmol) for classification of waterbodies as Good, Moderate, Poor or Bad using the 99th percentile of the winter DIN values. Thresholds are shown on a sliding scale, depending on the mean annual SPM value measured in each waterbody.

Annual SPM (mg l^{-1})	**DIN Threshold (99%ile) for Good / Mod**	**DIN Threshold (99%ile) for Mod / Poor**	**DIN Threshold (99%ile) Poor / Bad**
10	31.2	169.5	372.0
25	43.4	181.6	384.1
50	63.7	202.0	404.5
75	84.0	222.3	424.8
100	104.3	242.6	445.1
125	124.6	262.9	465.4
150	144.9	283.2	485.7
175	165.2	303.5	506.0
200	185.5	323.8	526.3
225	205.8	344.1	546.6
250	226.1	364.4	566.9
275	246.4	384.7	587.2
300	266.7	405.0	607.5

Dissolved oxygen

The presence of dissolved oxygen at sufficient levels in all waterbodies including estuaries and coastal waters is essential to the survival and normal functioning of biological communities. In the marine environment chronic and acute oxygen deficiency occurs when levels fall between 2.0 and 6.0 mg l^{-1} O_2 and below 2.0 mg l^{-1} O_2 (levels <2.0 mg l^{-1} defined as hypoxic), respectively (OSPAR, 2005). Dissolved oxygen levels in parts of the marine environment have shown rapid change since the 1950s, and there is strong evidence that hypoxia in coastal areas is becoming more frequently linked to human activities (Diaz and Rosenberg, 2008). Anoxic or ‘no-oxygen’ conditions occur when levels fall below 0.2 mg l^{-1} O_2. These low oxygen levels can have adverse effects on marine organisms.

Oxygen depletion may occur over a number of timescales influenced by both seasonal and anthropogenic factors (Kemp et al., 2009). The solubility of oxygen varies with salinity, temperature and pressure (Garcia and Gordon, 1992) and an increase in water temperature will lead to a decrease in oxygen saturation. The other major factor controlling dissolved oxygen concentration is biological activity: photosynthesis producing oxygen while respiration and nitrification consume oxygen. The proposed provisional Water Framework Directives standards for dissolved oxygen reflect these issues, while remaining generally compatible with previous recommendations. They are all 5%ile, i.e. they should be exceeded for 95% of the time Table 9.

Table 9 - Dissolved oxygen standards for transitional and coastal waters (Best et al., 2007)

WFD Status	**Freshwater 5%ile (mg l^{-1})**	**Marine 5%ile (mg l^{-1})**	**Objectives**
High	7.0	5.7	Protects all life stages of salmonid fish
Good	5.0–7.0	4.0–5.7	Resident salmonid fish
Moderate	3.0–5.0	2.4–4.0	Protects most life stages of non-salmonid adults
Poor	2.0–3.0	1.6–2.4	Resident non-salmonid fish, poor survival of salmonid fish
Bad	2.0	1.6	No salmonid fish. Migration survival of resident species

Survey data (2001- 2005) for the OSPAR East Anglia marine region did not indicate dissolved oxygen depletion, with a reported mean value of 7.87 mg l^{-1} and range 2.55 – 10.90 mg l^{-1} (n=382) (Foden et al., 2010)

Temperature

The effect of thermal inputs from power station cooling water upon the temperature regime of the receiving water must be assessed with respect to baseline conditions for the water body concerned. In this summary, temperature records from sources relevant to the Sizewell power station have been collated into time-series for the previous 48 years. Individuals on behalf of Cefas, councils, companies and other organisations have obtained records of coastal sea surface temperatures, for some stations, of more than 100 years duration. Approximately half of the stations started recording coastal temperatures in the mid 1960s. There are 30 stations in England and 8 stations in Wales and the Isle of Man where 25 out of 38 are still in operation. These datasets include records for Lowestoft, Southwold, Sizewell Power station. Near surface temperature and salinity samples have also been collected by ferries, the most recent, the Stena Partner,along 52°N between Harwich (formerly Felixstowe) and Rotterdam, from August 1970 onwards. Throughout the year, at weekly intervals, temperature data are recorded and water samples are taken at 9 standard station positions across the Southern Bight of the North Sea. The dataset for the end member location for this transect approximately 8 nautical miles offshore from Felixstowe was included with the above datasets to derive 98% values and to produce the data plot.

Data Collection

Cefas observers record coastal sea surface temperatures using calibrated thermometers approximately 6 – 14 times per month, usually close to the time of high water. Other organisations record sea surface temperature ranging from daily values to monthly means. The Cefas instruments are calibrated at Lowestoft to an accuracy of ±0.1°C. The accuracy of other instruments is not known, but is thought to be at least to an accuracy of ±0.2°C.

The ferry route observers record offshore sea surface temperature from the ships main seawater pipe using a calibrated thermometer 4 times a month. The temperatures are recorded to at least an accuracy of ±0.2°C. The seawater samples are taken from the sea water main pipe to the harbour pump about 1.5 metres inboard.

Quality Assurance

Quality assurance checks are applied to the data for each station by comparing the current dataset with either a 5 or 10 year running mean for each month. The data is first tested to see whether it is normally distributed i.e. whether all the data are close to average. The standard deviation is calculated to see how tightly the data are clustered around the mean; three standard deviations are then calculated to account for 99% of the data. If the data is outside of this range (3 standard deviations) then the value is flagged and removed from subsequent analysis.

Derivation of temperature statistics

Figure 3 shows the range of temperature data fo four locations in the Suffolk coastal waterbody from 1963 – 2013. Yearly averages are only derived from those years which have a complete set of monthly values. Table 10 and Figure 4 show the locations from which the temperature datasets were acquired.

The annual range of temperature for this region (based on mean monthly data for 2009 to 2013, Table 11) is bounded by a lower limit above 2 percentile of readings of 3.5ºC and an upper limit of 98 percentile of all readings of 19.4ºC, with occasional values exceeding these limits.

The main concern regarding water temperature elevation from cooling water input to suffolk coastal water is that exceedance of specific standard values may result, or there may be an impact on the biology to the extent that (as this area is classified as heavily modified based on coastal protection) good ecological potential cannot be attained under the Water Framework Directive, or that protected species or habitats are impacted. Taking account of the most recent temperature data covering the five year period between 2009 - 2013 the 98 percentile is 19.4°C. Heat excess from the discharge of cooling water from Sizewell will need to be considered in relation to this value.

Table 10 - Data Summary _Sizewell PS & Adjacent Areas: Long Term Surface Sea Water Temperature Observations_ 1966 - 2013

SITE	SOURCE	SAMPLE TYPE	FREQUENCY	TIME SERIES
Lowestoft (52.450°N; 1.750°E)	(Source: CEFAS)	CTSLOWESTO CTN – CEFAS LOGGER	Monthly mean Daily Mean	1966 - 2013 2010 -2013
Southwold (52.316°N; 1.683°E)	(Source: CEFAS)	CTSSIZEWEL/ CTSSIZEWEL	Daily Mean	1967 - 2013
Sizewell PS (52.216°N; 1.633°E)	(Source: EDF, British Energy Generation Ltd., BNFL, CEGB)	CTMSIZEWEL/ CTSSIZEWEL	Daily Mean	1966 - 2013
Felixstowe-Rotterdam_ Pos 2 ((52.033°N; 1.666°E)	(Source: CEFAS)	FERRY ROUTE	Weekly	1970-2010

Table 11 - Summary statistics for the Suffolk Waterbody based on mean monthly temperature data for the period 2009 – 2013 (details in Appendix)

Measurement statistic	**Temperature °C**
Mean	11.43
Max	19.9
Min	3.0
98%	19.39
2%	3.53

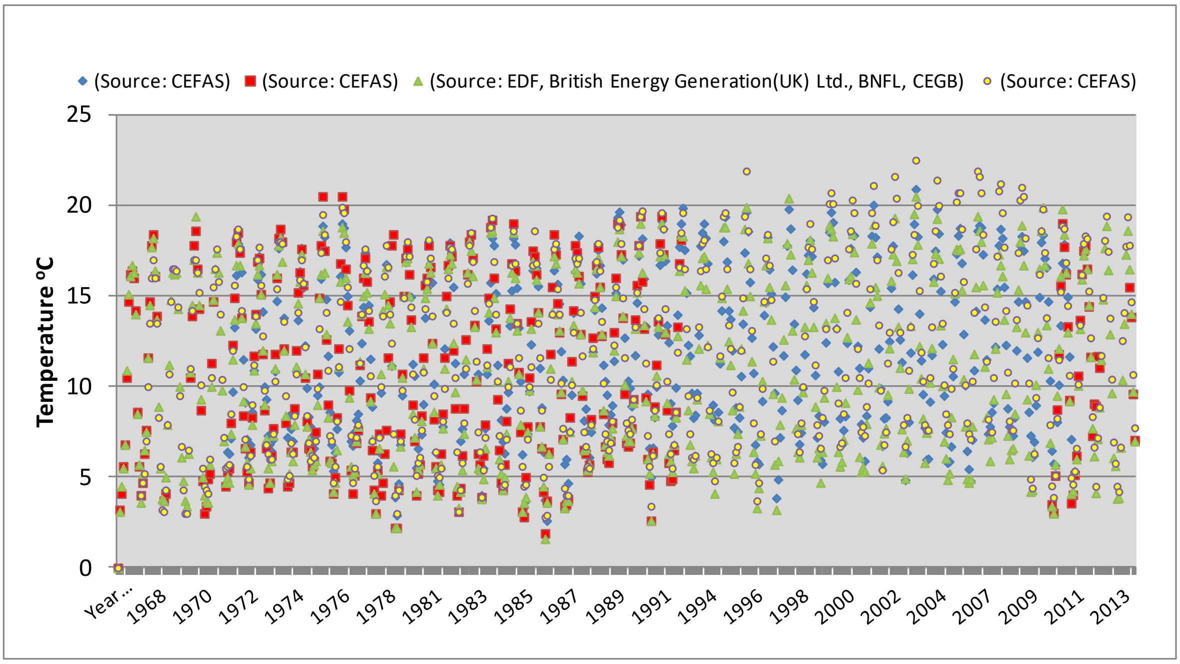

Figure 3 Monthly Sea Temperatures (°C) for four locations in the Suffolk coastal water 1966 – 2013

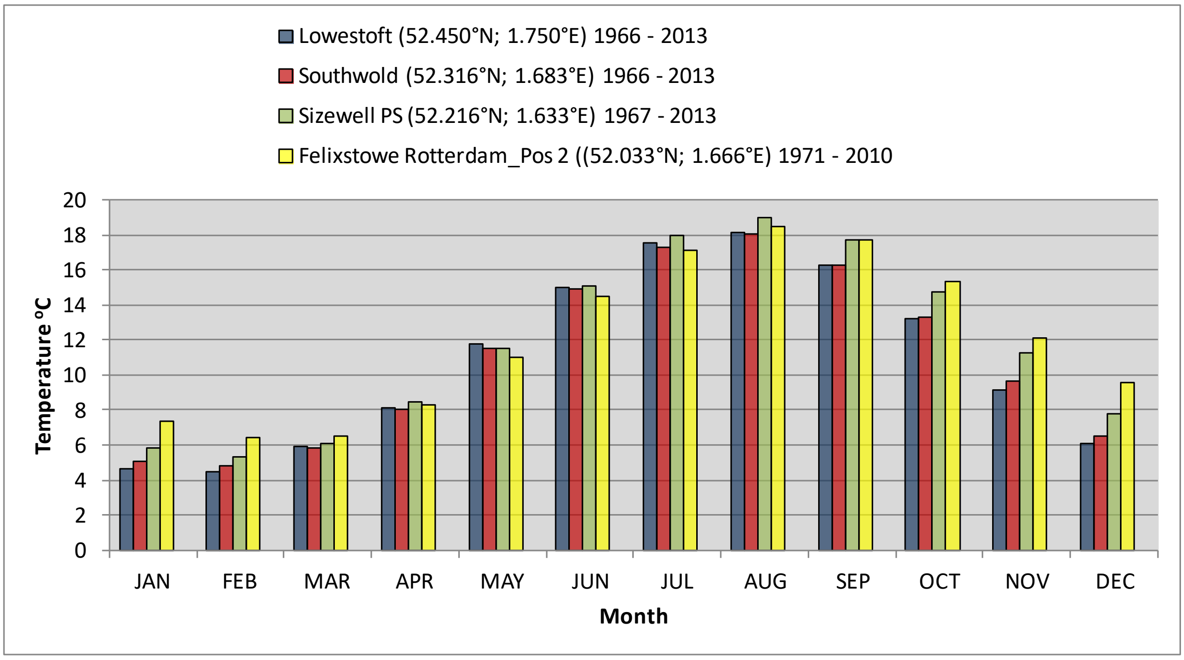

Figure 4 - Monthly mean Sea Temperatures (°C) for four locations in the Suffolk coastal water 1966 -2013

3.2 Environment agency data

This section describes Environment Agency monitoring surveys for compliance. The sites for which data are reported include a range of sites along the Suffolk coast of which those marked in bold in the Tables are within the Suffolk waterbody. However monitoring sites specifically associated to the Suffolk waterbody are only identified for the nutrient monitoring data. The data for dissolved metals covers the period 1989 to 2006 but the nutrients and inorganics data includes samples collected between 1991 and the early part of 2014. The EQS are derived from Directive 2013/39/EU as regards priority substances, cadmium, lead, nickel and mercury (Table 12).

Table 12 - Mean water column concentration (as annual average) for cadmium, lead and mercury from Environment Agency surveys 1989-2006. The years covered for specific determinands are shown at the second row right-hand column. Sample locations shown in bold are within the Suffolk waterbody

Sampling Location	**Chemical mean concentration µg l^{-1} as annual average**	**Concentration Range µg l^{-1}**
	Cadmium dissolved AA EQS 0.2	1993-2006
Mouth of Orwell	0.104 (0.124[1])	<0.02-0.7(2.59[1])
Off Orwell	<0.25	<0.25
Off Deben	0.21 (0.29[1])	<0.25 – 0.42(1.11[1])
Mouth Deben	NA	NA
Off Alde/Ore	<0.25	<0.25
Off Aldeburgh	<0.25	<0.25
Off Dunwich	<0.25	<0.25
Off Kessingland	<0.25	<0.25
Off Yare	<0.25	<0.25
	Lead dissolved AA EQS 1.3	1991-2006
Mouth of Orwell	0.99	<0.02 -18
Off Orwell	-	<1.25
Off Deben	-	<1.25
Mouth Deben	NA*	NA
Off Alde/Ore	-	<1.25
Off Aldeburgh	-	<1.25
Off Dunwich	-	<1.25
Off Kessingland	-	<1.25
Off Yare	-	<1.25
	Mercury dissolved MAC-EQS 0.07	1991-2006
Mouth of Orwell	-	<0.01 -0.16
Off Orwell	-	<0.01 -0.27
Off Deben	NA	NA
Mouth Deben	NA	NA
Off Alde/Ore	-	<0.01-0.09
Off Aldeburgh	-	<0.01
Off Dunwich	-	<0.01-0.12
Off Kessingland	-	<0.01
Off Yare	-	<0.01
	Nickel dissolved AA EQS 8.6	1991-2006
Mouth of Orwell	1.56	<1-3.77
Off Orwell	1.49	<1-4.9
Off Deben	0.69	0.4-1.13
Mouth Deben	NA	NA
Off Alde/Ore	0.80	0.37-0.96
Off Aldeburgh	1.20	<3-4.1
Off Dunwich	0.69	0.34-0.88
Off Kessingland	-	<0.01
Off Yare	-	<0.01

*NA – not analysed; [1] At the mouth of the Orwell a single value of 2.59 µg l^{-1} was recorded in September 1993 and a single value of 1.11 µg l^{-1} was recorded Off the Deben, for comparison the mean has been derived with and without these values included

For some compounds as detection limits have improved earlier data often includes higher limits of detection. Values below detection are halved and included in the calculation of the mean. More values below detection are present from earlier dates which reflects improved analytical methods. These data are compared to environmental quality standards (EQS) to provide an indication of the potential for biological effects.

The Water Framework Directive requires that Member States identify Specific Pollutants and set standards for them. Specific Pollutants are toxic substances that are discharged in significant quantities into the water environment. Previous work by the UKTAG has led to standards for 19 Specific Pollutants. For substances classified as specific pollutants the EQS are referenced from UKTAG, 2013. Measured values for selected substances classified as Specific pollutants are shown in Table 13.

Table 13 - Mean water column concentration of arsenic, chromium, copper and zinc from Environment Agency surveys µg l-1 1989-2006. The years covered for specific determinands are shown at the second row right-hand column. Sample locations shown in bold are within the Suffolk waterbody

Sampling Location	**Chemical mean concentration or MAC µg l^{-1}**	**Concentration range µg l^{-1}**
	Arsenic dissolved AA EQS 25	1991-1999
Mouth of Orwell	1.13	<1.0 -1.5 (n=7)
Off Orwell	1.14	<1.0 -2.4 (n=12)
Off Deben	0.65	<1.0 -1.4 (n=6)
Mouth Deben	NA*	NA
Off Alde/Ore	0.95	<1.0 -1.3 (n=13)
Off Aldeburgh	0.97	<1.0 -1.4 (n=14)
Off Dunwich	1.03	<1.0 -1.3 (n=14)
Off Kessingland	1.04	<1.0 -2.2 (n=18)
	Chromium VI dissolved AA EQS 0.6	1989-2006
Mouth of Orwell	0.68	<1.5 -13 (n=116)
Off Orwell	-	<1.5 (n=13)
Off Deben	<1.5	<1.5 (n=6)
Mouth Deben	NA	NA
Off Alde/Ore	1.57	<1.5 – 4.9 (n=20)
Off Aldeburgh	0.87[1]	<1.5 – 2.4 (n=13)
Off Dunwich	1.09[1]	<1.5 - 3.2 (n=14)
Off Kessingland	0.86[1]	<1.5 – 2.1 (n=22)
	Copper dissolved AA EQS 3.76[2]	1989-2005
Mouth of Orwell	3.32	0.63 -4.88 (n=128)
Off Orwell	1.41	<0.25 -2.2 (n=12)
Off Deben	1.27	0.76 -1.5 (n=6)
Mouth Deben	NA	NA
Off Alde/Ore	2.03	0.87-1.08 (n=20)
Off Aldeburgh	1.12	<1-1.4 (n=15)
Off Dunwich	1.51	<0.25-7.47 (n=14)
Off Kessingland	1.08	0.84-1.45 (n=4)
	Zinc dissolved AA EQS 6.8[3]	1989-2006
Mouth of Orwell	15.8	<1-131 (n=127)
Off Orwell	5.3	<4-11.4 (n=11)
Off Deben	2.84	<4-4.98 (n=6)
Mouth Deben	NA	NA
Off Alde/Ore	7.31	<4-33 (n=14)
Off Aldeburgh	4.28	<4-9.8 (n=14)
Off Dunwich	7.19	<4-26.6 (n=16)
Off Kessingland	5.25	<4-14.6 (n=4)

NA – not analysed; [1]These means are based on relatively few measured values with the majority of values below detection [2]The copper EQS includes a modification of the standard when dissolved organic carbon > 1mg l^{-1}. [3]Zinc dissolved plus Ambient Background Concentration (ug/l) - Ambient Background Concentration (ABC) is an estimate of background levels of zinc based on a low percentile of monitoring data. For zinc in saltwater, an ABC of 1.1 µg/l is recommended. ABC is the environmental concentration expected where no (or only minor) anthropogenic inputs are present.

All of the metals data relates to samples collected between 1989 and 2006 and there is no clear trend in concentrations measured and values below detection are interspersed with high values. For the concentrations of metals in seawater from various sites within the Suffolk Waterbody zinc exceeded its EQS at the mouth of the Orwell and Off the Alde/Ore although high values were also measured in samples Off Dunwich. Chromium concentrations were also high at the mouth of the Orwell and in a few samples at other sites. For other determinands for sample points outside the waterbody cadmium exceeds its EQS value Off the River Deben. The lower revised EQS for cadmium, chromium VI and zinc relative to the high detection limits at the time of the original analysis means that it is not possible to determine the numbers of sites that might have breached the standard. Copper is also close to its EQS at the mouth of the Orwell but dissolved organic carbon values were not available and would need to be taken account of in assessing the EQS.

Zinc is a naturally occurring substance and is ubiquitous in aquatic environments where it tends to occur at higher concentrations than most metals. Therefore to best assess compliance with the environmental quality standard (EQS) we need to take account of ambient background concentrations (ABCs); the EQS applies only to the additional contribution over and above the ambient background level (i.e. the value at which toxic effects occur, ignoring contributions from background concentrations).

Saltwater ABCs have been derived by assessing around 43000 samples and a low percentile has been used to exclude significant anthropogenic influences. There are limited variations in ABCs around most of the UK coast, and hence a national ABC value of 1.1 ug l^{-1} dissolved zinc is recommended for all coastal and estuarine waters.

From 1990 - 2007 there is evidence of an overall decline in the concentration of a number of metals in riverine and direct discharges to the marine environment (Charting Progress 2, 2010). However data collected in 2007 for metals concentrations under the EU Shellfish Waters Directive were used for comparison against the relevant standards for dissolved metals in water. Copper is the trace metal with the greatest number of results above the EQS (6%) in this survey and zinc the next highest at 1.5% above EQS (Charting Progress 2, 2010). Both these metals have a range of input sources from the urban environment which mean that their concentration in surface waters may not show any significant decline over the next decade.

Within the Suffolk Waterbody data for designated sampling points was available for measured values of ammonia, unionised ammonia and dissolved inorganic nitrogen and these are shown in Tables 14 - 18. The chlorophyll concentration measured from the some of the same sampling points is shown in Tables 19 and 20.

On account of its greater toxicity unionised ammonia (NH_3) has a specific EQS value set (21 µg l^{-1} NH_3-N). In some cases direct measures of unionised ammonia have been made but the percentage of NH_3 may also be calculated from the ammonium ion (NH_4^+) concentration based on knowledge of seawater pH, salinity and temperature. Overall the mean NH_4^+ concentrations measured are similar at all of the sampling sites and are relatively low (Table 14). For example the EQS value of 21 µg l^{-1} NH_3-N. (at pH 8, 32 ppt salinity at 20°C) corresponds to a total ammonia concentration of c. 670 µg l^{-1} NH_4-N. The mean unionised ammonia concentration is relatively high at several sites and exceeds the EQS most notably just off Lowestoft (Table 16).

For dissolved inorganic nitrogen (DIN) the SPM levels in the Suffolk Waterbody should be taken account of in deriving a reference 99 percentile value indicative of status (see Table 8). SPM in the vicinity of Sizewell can be considered to be around 50 mg l^{-1} this is a conservative value based on monitoring data in the vicinity of Sizewell in 2010 (Beems TR 189). Based on an SPM of 50 mg l^{-1} the 99 percentile DIN should at or below 63 µmol for Good/Moderate status. Reference to data on the Mean dissolved inorganic nitrogen concentrations (Table 17) indicates that all sites sampled within the waterbody meet the threshold value which means they would be considered at Good/Moderate status.

For nearshore waters, where the level of production may be expected to be higher, 15 µg l^{-1} chlorophyll is adopted as the reference value (implying a background value of 10 µg l^{-1}, Devlin et al., 2007). The 90th percentile chlorophyll concentrations during the growing season (March to September) should remain below thresholds set for the high/good (10 µg l^{-1}) and good/moderate boundaries (15 µg l^{-1}) for type specific conditions (UKTAG, 2014). Reference to the data in Table 19 and 20 indicates that values at most sites meet the high/good threshold and all the good/moderate.

Table 14 - Mean water column concentration of ammonia filtered as N from Environment Agency surveys. The years covered are shown at the second row right-hand column. Sample locations shown in bold are within the Suffolk waterbody

Sampling Location	**Mean concentration μg l^{-1}**	**Concentration range μg l^{-1}**
	Ammonia total	1992 - 2007
Mouth of Orwell	-	-
Off Orwell	32	<2.0 – 110 (n=77)*
Off Deben	20	<5.0 – 144 (n=188)
Mouth Deben	23	0.0 – 180 (n=218)**
Off Alde/Ore	24	<2.0 – 111 (n=79)
Off Aldeburgh	27	<7.0 – 146 (n=78)
Off Dunwich	31	<7.0 – 141 (n=79)***
Off Kessingland	35	<5.0 – 156 (n=82)
Off Yare	-	-

*1992 -2005; **2002-Q12014; ***1992-2004

Table 15 - Mean water column concentration of ammonia un-ionised as N from Environment Agency surveys. The years covered are shown at the second row right-hand column. Sample locations shown in bold are within the Suffolk waterbody

Approximate Sampling Location	**Mean concentration μg l^{-1}**	**Concentration range μg l^{-1}**
	Ammonia un-ionised AA EQS 21	1997-2014*
Mouth of Orwell	2.6	<1.0 – 11.2 (n=47)
Off Orwell	-	-
Off Deben	-	-
Mouth Deben	1.3	<1.0 – 5.0 (n=48)
Off Alde/Ore	-	-
Off Aldeburgh	-	-
Off Dunwich	-	-
Off Kessingland	-	-
Off Yare	-	-

* Samples taken up to beginning of April 2014

Table 16 - Mean water column concentration of ammonia un-ionised as N (filtered) from Environment Agency surveys for the Suffolk waterbody sites the years covered are shown at the second row right-hand column.

Approximate Sampling Location	**Approximate location**	**Mean concentration μg l^{-1}**	**Concentration range μg l^{-1}**
		Ammonia un-ionised AA EQS 21	1991 - 2013
North Sea NO. 51	Off Deben	9.0	<7.0 - 25.2 (n=5)*
North Sea NO. 46	Just above Alde/Orr	6.8	<7.0 - 20.0 (n=5)*
North Sea NO. 43B	Just below Aldeburgh	17.5	<7.0 - 108 (n=54)
North Sea NO. 34	Just below Lowestoft	25.9	<1.0 - 114 (n=20)
North Sea NO. 33	Just Off Lowestoft	26.9	<5.0 – 122 (n=60)

* 2012-2013

Table 17 - Mean (and 99 percentile) water column concentration of Winter (November – February) dissolved inorganic nitrogen (DIN: nitrate, nitrite and ammonia) µg l-1 as N (and µmol) from Environment Agency surveys. The years covered are shown at the second row right-hand column. Sample locations shown in bold are within the Suffolk waterbody

Approximate Sampling Location	**Mean (and 99 percentile) concentration µg l^{-1}**	**Mean (and 99 percentile) concentration µmol**	**Concentration range µg l^{-1}**
			1992-2007
Mouth of Orwell	-		-
Off Orwell	449 (833)	32 (60)	190 - 865 (n=20)
Off Deben	373 (578)	27 (41)	183 - 582 (n=23)
Mouth Deben	-	-	-
Off Alde/Ore	335 (462)	24 (33)	132 - 463 (n=23)
Off Aldeburgh	305 (529)	22 (38)	<9.0 - 545 (n=21)
Off Dunwich	333 (562)	24 (40)	118 - 565 (n=23)
Off Kessingland	-	-	-
Off Yare	415 (781)	30 (56)	102 - 799 (n=20)

Table 18 - Mean (and 99 percentile) water column concentration of Winter (November – February) dissolved inorganic nitrogen (DIN: nitrate, nitrite and ammonia) from Environment Agency surveys µg l-1 as N (and µmol) for the Suffolk waterbody sites the years covered are shown at the second row right-hand column.

Approximate Sampling Location	**Mean (and 99 percentile) concentration µg l^{-1}**	**Mean (and 99 percentile) concentration µmol**	**Concentration range µg l^{-1}**
North Sea			1992 - 2013
NO. 51 Off Deben	277 (351)	20 (25)	185 – 352 (n=4)*
NO. 46 Just above Alde/Orr	253 (348)	18 (25)	211 – 351 (n=4)*
NO. 43B Just below Aldeburgh	272 (486)	19 (35)	121 – 502 (n=20)
NO. 34 Just below Lowestoft	394 (585)	28 (42)	88 – 586 (n=9)
NO. 33 Just Off Lowestoft	397 (699)	28 (50)	97 – 723 (n=15)

*2012 – 2013

Table 19 - Mean water column concentration chlorophyll µg l-1 March – September from Environment Agency surveys. The years covered are shown at the second row right-hand column. Sample locations shown in bold are within the Suffolk waterbody

Approximate Sampling Location	**Mean (90 percentile) concentration µg l^{-1}**	**Concentration range µg l^{-1}**
	Chlorophyll	1992-2005
Mouth of Orwell	4.8 (8.0)	0.4 – 9.5 (n=22)
Off Orwell	4.0 (6.7)	<1.0 -11.1 (n=63)*
Off Deben	4.3 (7.8)	<1.0-15.4 (n=134)
Mouth Deben	5.4 (9.6)	<1.4 – 18.6 (n=108)**
Off Alde/Ore	-	-
Off Aldeburgh	-	-
Off Dunwich	3.8 (6.5)	0.3 – 11.5 (n=46)
Off Kessingland	-	-
Off Yare	5.1 (9.1)	<0.3 – 33.0 (n=58)

*1992-1994; ** 2002-2013;

Table 20 - Mean water column concentration of chlorophyll March – September from Environment Agency surveys µg l-1 for the Suffolk waterbody sites the years covered are shown at the second row right-hand column.

Approximate Sampling Location	**Approximate location**	**Mean (90 percentile) concentration µg l^{-1}**	**Concentration range µg l^{-1}**
		Chlorophyll	1992 - 2013
North Sea NO. 51	Off Deben	7.3 (9.2)	<1.5 – 45.0 (n=45)*
North Sea NO. 46	Just above Alde/Orr	4.3 (7.7)	<1.25 – 9.9 (n=18)*
North Sea NO. 43B	Just below Aldeburgh	4.3 (8.0)	<0.8 – 15.2 (n=42)
North Sea NO. 34	Just below Lowestoft	6.4 (13.2)	1.5 – 18.5 (n=24)
North Sea NO. 33	Just Off Lowestoft	5.3 (10.1)	<0.3 – 19.7 (n=56)

*2012 – 2013

4 Discussion and Conclusions

With a particular focus on data relevant to the Suffolk coastal waterbody within which the Sizewell nuclear power station is situated this review has gathered information on various chemical and physical parameters that can influence water quality.

The concentration of contaminants 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 lead to a legacy of 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/Orr) exceeding respective EQS for these metals in seawater samples collected 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 is potentially linked to sewage works inputs. Upgrades to a number of sewage works that discharge to the Orwell were however due to completed by 2005 (Stour and Orwell Estuaries management plan, 2004) 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 not exceeding current or indicative standards beyond 1-2 kilometres 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^{o}C) to not result in major areas failing to meet the temperature boundary for Good/Moderate status (20 – 23 ^{o}C). The boundary value for the Thames SPA for the Habitats Directive criteria (28^{o}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 in particular has contributed to the elevation of nutrient concentrations in rivers and estuaries in the region.

During power station construction and operation there will be increased numbers of people on site with associated production of wastewater that may require discharge to the marine environment. Wastewater discharge will make a contribution to nutrient concentrations within the local marine environment and this will need to be assessed against the current status of the Suffolk waterbody.

Assessing the status of coastal waters with respect to specific discharges of nutrients is mandated under the Urban Waste Water Treatment Directive (Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment) which now forms a basic measure under the Water Framework Directive. The Water Framework Directive requires an assessment of Good Ecological Status for those ‘biological quality elements’ that are sensitive to particular pressures. In the case of the coastal water off Sizewell, the relevant biological quality elements are phytoplankton and macrophytes (including macroalgae) for which the EA has developed classification tools. In addition, nutrients are a ‘supporting element’ for the biology and nutrient standards have been set for waters moderated for the inherent turbidity of the water (different standards are set for turbid waters that are less likely to respond to the nutrient pressure). These coastal waters are also subject to assessment under the OSPAR Common Procedure which will be the primary method for assessment under the Marine Strategy Framework Directive.

The coastal waters of East Anglia are enriched by nutrients derived from a number of sources including Urban Waste Water 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 (OSPAR) for eutrophication there are coastal water bodies (within the 1 nm 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.

In summary the natural background temperatures at Sizewell meet the required standards under the Water Framework Directive for Good status and also the requirements under the Habitats Directive for the outer Thames SPA with sufficient temperature margin relative to additional predicted inputs from power station development to have a low likelihood of resulting in large areas of exceedance. Contaminant inputs to the waterbody are limited and general trends in the Southern North Sea indicate declining inputs of most metals and a number of organic chemicals. Against this background the main chemical inputs from the new build power station are chlorine produced oxidants and bromoform. Data for these substances associated to the Sizewell B discharge indicate relatively limited areas of exceedance of the relevant EQS or surrogate concentrations. During construction and operation the potential wastewater inputs from the workforce and from permanent staffing of the site will need to be assessed in terms of nutrient inputs but the current background levels have limited impacts because of light limitation on phytoplankton growth due to the higher suspended particulate matter (SPM) levels present in the waterbody. The impact of additional nutrient inputs will need to be assessed against the SPM background and this may limit the extent of any effects.

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6 Appendix

Table 21 - Monthly mean seawater temperature distribution 1966 – 2013 for four sites in the Suffolk coastal waterbody

Monthly Mean Sea Temperature for LOWESTOFT at 52 27 N, 1 45 E

1966 - 2013	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
mean	4.6	4.5	5.9	8.1	11.8	15.0	17.6	18.2	16.3	13.2	9.1	6.1
count	28	29	29	28	28	28	27	26	27	26	25	25
sd	1.4	1.5	1.5	1.1	0.9	0.9	1.1	1.0	0.8	0.9	0.9	1.0
98%	7.78	7.79	9.45	10.80	13.69	16.80	19.73	20.15	17.74	14.46	11.24	7.40
2%	2.63	2.07	3.76	5.85	10.50	13.60	15.86	16.75	14.86	11.15	7.90	3.77
2010 - 2011												
mean	3.8	4.1	5.6	9.7	12.7	15.9	18.3	17.8	16.4	13.9	10.4	5.4
count	2	2	2	2	2	2	2	2	2	2	2	2
sd	0.4	1.5	0.8	1.3	1.3	0.5	1.1	0.0	0.2	0.8	1.7	2.6
98%	4.02	5.09	6.16	10.56	13.64	16.20	18.98	17.78	16.50	14.40	11.59	7.21
2%	3.5	3.1	5.1	8.8	11.8	15.6	17.5	17.7	16.2	13.3	9.3	3.6

Monthly Mean Sea Temperature for SOUTHWOLD at 52 19 N, 1 41 E

1966 - 2013	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
mean	5.0	4.8	5.8	8.0	11.5	15.0	17.3	18.1	16.3	13.3	9.7	6.5
count	48	48	48	48	48	48	48	48	48	48	48	48
sd	1.2	1.3	1.3	1.2	1.0	0.9	1.1	1.1	0.9	0.9	1.0	1.0
98%	7.01	7.43	7.90	10.11	13.36	16.53	19.55	20.41	18.02	15.33	11.41	8.32
2%	3.05	2.16	3.59	5.89	9.75	13.29	15.09	16.29	14.47	11.45	7.80	4.48
2009 - 2013												
mean	4.7	4.1	5.8	9.0	12.0	15.4	18.1	18.7	16.5	13.6	10.2	6.4
count	30	30	30	30	30	30	30	30	30	30	30	30
sd	1.1	0.8	1.2	1.4	1.2	1.2	1.1	0.8	0.1	0.7	1.0	1.4
98%	6.12	5.26	7.06	10.10	13.17	16.47	19.70	19.82	16.68	14.46	11.59	7.65

2%	3.46	3.07	4.01	6.81	10.46	13.58	17.25	17.66	16.31	12.90	9.24	4.26

Monthly Mean Sea Temperature for SIZEWELL PS at 52 13 N, 1 38 E

1967 - 2013	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
mean	5.9	5.3	6.1	8.5	11.6	15.1	18.0	19.0	17.7	14.8	11.3	7.8
count	46	46	46	46	46	46	46	46	46	46	46	45
sd	1.4	1.5	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.7	1.5
98%	8.23	7.81	8.32	10.94	14.10	17.60	20.91	21.96	20.70	18.43	14.63	10.87
2%	3.19	2.80	2.99	5.96	9.75	12.81	15.89	16.77	15.58	12.20	8.39	4.96
2009 - 2013												
mean	5.3	4.5	5.9	8.7	12.4	15.3	18.2	19.1	17.5	14.4	11.2	7.2
count	5	5	5	5	5	5	5	5	5	5	5	5
sd	0.9	0.5	1.2	1.3	0.8	0.9	0.5	0.6	0.5	0.6	1.0	1.3
98%	6.59	5.27	7.13	10.08	13.35	16.20	18.84	19.77	18.15	15.22	12.61	8.31
2%	4.53	3.93	4.28	6.79	11.51	14.15	17.76	18.35	16.89	13.78	10.43	5.13

Monthly Mean Sea Temperature for Felixstowe Rotterdam_Pos 2 (52.033°N; 1.666°E)

1971 - 2010	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
mean	7.3	6.4	6.5	8.3	11.0	14.5	17.2	18.5	17.7	15.4	12.1	9.6
count	36	39	38	38	38	36	38	37	35	39	36	37
sd	1.5	1.5	1.4	1.0	1.2	1.5	1.2	1.0	1.0	1.1	1.1	1.5
98%	9.88	9.14	8.68	10.18	13.19	17.73	19.08	20.25	19.03	17.22	14.00	12.14
2%	3.90	3.28	3.41	6.62	9.15	11.61	14.62	16.77	15.64	13.44	9.97	6.83
2005 - 2010												
mean	7.2	6.4	6.5	8.1	11.3	14.6	17.7	18.4	17.8	16.0	12.8	9.4
count	6	6	6	6	6	6	6	6	6	6	6	6
sd	0.5	0.9	1.4	1.0	0.9	0.7	0.6	0.3	0.9	1.1	1.2	1.5
98%	7.77	7.75	8.47	9.09	12.18	15.35	18.54	18.88	18.80	17.25	14.60	11.38
2%	6.50	5.53	4.88	6.74	10.15	13.48	16.85	17.94	16.56	14.73	11.61	7.25

VOLUME 2 APPENDIX 21B

SIZEWELL MARINE WATER QUALITY MONITORING FINAL SUMMARY REPORT.

2019. BEEMS TECHNICAL REPORT TR189.

TR189 Sizewell Marine Water Quality Monitoring

Final Summary Report

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List of Tables and Figures

Tables

Please note that the red line boundary was amended after this document was finalised, therefore figures in this document do not reflect the boundaries in respect of which development consent has been sought in this application. However, amendments to the red line boundary does not have any impact on the findings set out in this document and all other information remains correct.

Figures

Executive summary

A marine water quality monitoring programme was established off the Suffolk coast in the vicinity of Sizewell B power station to assess the concentrations of a large number of elements and compounds and their variation over a range of time scales. The programme ran from February 2010 to February 2011, and the programme's results are presented in this report. On 17 March 2010 Sizewell B had an outage which continued until 30 September 2010. Cefas does not know what effect the outage has had on the discharge of chemicals into the reduced cooling water flow from the station.

A spatial survey was conducted at twelve sampling stations (see chart below). The sampling was centred upon the existing cooling water outfall for the Sizewell B, at station 5. A tidal-cycle survey was carried out during which water samples were acquired at hourly intervals at station 5 over an ebb/flood tidal cycle during spring tide conditions. A seasonal survey was also carried out by acquiring water samples near slack water at stations 5 and 11 on 21 occasions throughout the programme.

Conductivity, temperature and depth sensor (CTD) profiles showed that the waters sampled were well mixed with regard to 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 (stations 1 to 9) and offshore (stations 10 to 12) were noted.

Concentrations of dissolved copper, arsenic, zinc, mercury and cadmium exceeded EQS levels on occasions. Some exceedance of the Environmental Quality Standard (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 (DEHP), 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.

Total residual oxidant (TRO) concentrations varied between 0.01 and 0.16 $mg.l^{-1}$. The EQS for TRO is 10 $\mu g.l^{-1}$ (0.01 $mg.l^{-1}$). The mean of all TRO measurements (n = 725) was 0.04 $mg.l^{-1}$, with a value of 0.01 $mg.l^{-1}$ (half the limit of detection) used to represent negative results. Slight localised elevation of TRO was observed near the cooling water outfall, and was below the level of detection within 2.4 km to the north and 500 m to the south. Elevated TRO was observed at the southern extremity of the survey area (at stations 9 and 12) but there was no spatial pattern to indicate that this elevation was connected to the power station outfall.

A wide range of hydrazine concentrations were initially measured. Doubts about the validity of the ultraviolet-visible spectrophotometry results, based on the limits of quantification of the technique and potential interference, led to the use of an alternative analytical method. For the final three months of the programme a gas chromatography mass spectrometry (GC-MS) technique was used on water samples to measure hydrazine concentrations in addition to the spectrophotometric technique. The GC-MS technique was far more sensitive and indicated that hydrazine concentrations were generally below the limit of detection (0.01 $\mu g.l^{-1}$). Prior hydrazine results are therefore not considered valid.

Three positive results were obtained from morpholine analyses conducted on water samples from stations 5 and 11. Morpholine is not used by Sizewell power station as a conditioning product. No concentrations of environmental concern were measured in the analyses carried out on sediment samples acquired at stations 5 and 11. All radionuclide concentrations measured in seawater samples were very low and were consistent with routine local radionuclide monitoring by the Environment Agency.

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.

1 Introduction and Objectives

During 2009, EDF requested that Cefas design a monitoring programme to assess marine water quality off the Suffolk coast near the Sizewell B power station. The programme's purpose was to establish the environmental concentrations of certain chemical additives and their derivatives that are discharged from the existing cooling water outfall at Sizewell B, as well as establishing the local baseline environmental concentrations of numerous substances. Sampling was designed to assess the variation in water quality over the following spatial and temporal ranges:

- Spatially, over an area of approximately 80 km^2 at 12 sampling stations
- Temporally, over a tidal cycle during spring tide conditions
- Temporally, over an annual seasonal cycle

This report presents the results of sampling conducted between 25 February 2010 and 14 February 2011.

Measurements of a wide range of chemical concentrations and water quality parameters were undertaken to provide information likely to be useful to potential future engineering projects associated with the power station infrastructure at Sizewell. During the design of the survey a seawater desalination plant at the proposed Sizewell C power station was under consideration, so samples were acquired and analysed for silt density and modified foiling indices (SDI and MFI respectively). It is no longer considered that a desalination plant is required. In addition to water sampling a limited program of benthic sediment samples were acquired and chemically analysed and a small number of water samples were acquired and subjected to radionuclide analysis.

1.1 The physical environment near Sizewell

The coastline near Sizewell B consists of a coarse beach of sand and gravel. The shore slopes down to a depth of 7 to 11 m below chart datum. A subtidal sand bank exists approximately 1.5 km offshore. This feature is charted as two separate entities, Sizewell Bank and Dunwich Bank, though in reality it is a single, continuous feature aligned parallel to the shore and with minimum depths of less than 3 m at its southern end. The whole bank extends for approximately 8 km from north to south and isolates the shallow coastal channel from deeper water offshore of the bank where depths fall to below 15 m.

The tides in the area are rectilinear and flood-dominated, with the flood tide currents travelling to the south and the ebb tide currents travelling to the north. Tidal ranges are approximately 3 m during spring tides and 1.5 m during neap tides. Mean tidal current speeds of 0.5 ms^{-1} are experienced and the maximum current speeds are approximately 1.5 ms^{-1}.

Waves at Sizewell come predominantly from the ENE and the SSE. The mean significant wave height is between 0.5 and 1 m with an annual expected maximum wave height of around 4 m. The maximum expected significant wave height during a 100-year period is approximately 5.5 m, rising to approximately 6.5 m in 1,000 years.

1.2 Data location

The data presented in this report are available on the BEEMS shared drive. The location of the data is summarised in **Table 1**.

Table 1 The location of data presented in this report

Data	File name	Location
Total residual oxidant (TRO) on-board analyses conducted by Cefas	BEEMS WP7a SZ Marine water quality monitoring TRO and on-board results Feb2010 to Feb2011.xls	beems_data$:\10 BEEMS DATA CENTRE - SITES\SIZEWELL\ SZ_WP7a_ Marine water quality monitoring data Feb2010 to Feb 2011
Chemical analyses conducted by Scientifics Ltd on water samples	BEEMS WP7a SZ Marine water quality monitoring Scientifics Ltd results Feb2010 to Feb2011.xls	
Chemical analyses conducted by Scientifics Ltd on sediment samples	BEEMS WP7a SZ Marine water quality monitoring Scientifics Ltd sediment analysis results.xls	
Conductivity, temperature and depth (CTD) data	BEEMS WP7a SZ Marine water quality monitoring CTD results Feb2010 to Feb 2011.xls	

2 Methods

2.1 Sampling strategy

Water sampling was conducted at 12 stations to investigate the temporal and spatial variation of environmental levels of the analytes of interest. A comprehensive suite of analytes was selected in order to satisfy likely future licensing and engineering requirements. It is Cefas' understanding that chlorination of cooling water takes place year-round at Sizewell and that dosing is controlled to achieve a total residual oxidant (TRO) concentration at the condenser of 0.3 mg.l^{-1} maximum.

Sampling was organised to establish the variability in analyte concentrations over a number of different spatial and temporal scales:

- A spatial survey acquired surface and near-bed water samples from 12 stations (**Table 2**) extending approximately 12 km to the north and south of the cooling water outfall and 3 km offshore. Maximum concentrations of compounds from the cooling water were expected to be found in surface waters due to the thermally buoyant nature of the outfall plume. Surface waters were therefore intensively sampled. In order to ensure that the full water column was investigated, certain stations were selected for the acquisition of near-bed samples in addition to surface water samples.

- A tidal cycle survey acquired hourly surface water samples from a vessel anchored as close as possible to the cooling water outfall (Station 5) during an ebb/flood cycle on spring tide conditions (**Table 3**).

- A seasonal survey acquired surface water samples at the cooling water outfall (Station 5) and a reference site (Station 11) at intervals of approximately two weeks from February 2010 to February 2011.

Details of the water sampling conducted are shown in **Table 4**

For the spatial survey, the samples were acquired from the stations shown in **Figure 1**. Sampling took place during both neap and spring tidal conditions, though neap tidal conditions were favoured as the environmental concentrations of analytes were likely to be at their highest; increased mixing and dispersion is likely to result in lower concentrations during spring tidal conditions. The closest potential sources (other than the power station itself) of the analytes identified were Lowestoft to the north and Felixstowe and Harwich to the south. These potential sources are all distant from Sizewell by multiples of the spring tidal excursion distance and many multiples of the residual current drift distance associated with a tidal cycle. Modelling work conducted during the survey period indicated that the combined Sizewell B and Sizewell C thermal plume may extend further south than the most southerly survey station. Extra survey stations were, however, considered unnecessary as the plume area and the area beyond the plume were well sampled.

Temporal variation during an ebb/flood tidal cycle was assessed by acquiring surface water samples from a vessel anchored in the outfall plume at Station 5 (**Figure 1**), as close to the outfall as practicable. Care was taken to ensure that the vessel was positioned downstream of the outfall with regard to the direction of tidal flow. This procedure was followed during a tidal cycle in spring tide conditions during the 2nd March 2010.

Seasonal variation in the concentrations of interest was assessed by acquiring surface water samples at Station 5 (at the cooling water outfall) and Station 11 (used here as a reference site). Sampling was carried out at approximately fortnightly intervals from February 2010 to February 2011. The exact timing and intervals between sampling was influenced by the requirement for suitable weather conditions.

In addition to water sampling a limited program of benthic sediment samples were acquired and chemically analysed. Triplicate benthic samples were acquired from Stations 5 and 11. A small number of water samples were acquired from Stations 5 and 11 and subjected to radionuclide analysis.

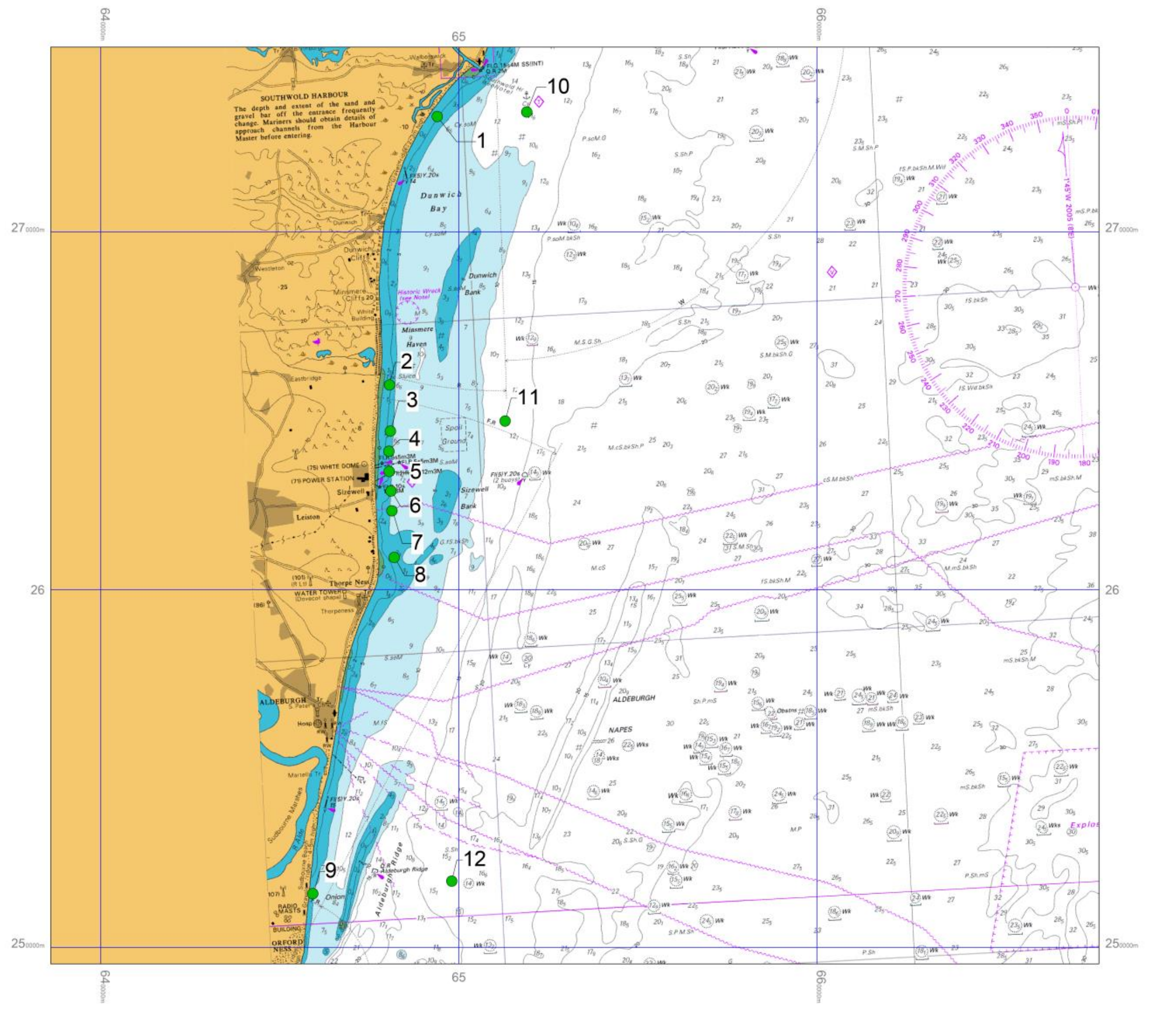

Figure 1 The locations of the sampling stations off Sizewell

The locations of the sampling stations are shown in **Figure 1** and Table 1. Surface samples were acquired at all stations as the outfall waters are thermally buoyant. Near-bed samples were also acquired at certain stations in order that concentrations from the entire water column could be assessed. Details of the samples acquired are shown in **Table 4**.

Tide times for Lowestoft and Felixstowe during the tidal cycle survey undertaken on 2 March 2010 are shown in **Table 3**. Lowestoft and Felixstowe are the nearest standard ports to the north and south of Sizewell respectively.

Figure 2 Station 5, the cooling water outfall at Sizewell. The outfall is marked at the surface by the mast visible to the left of the image.

Table 2 The positions of the sampling stations

Station	OSGB36 coordinates (m)		WGS84	
	E	N	Latitude (N)	Longitude (E)
1	649397	273225	52° 18.02’	001° 39.39’
2	648065	265724	52° 14.03’	001° 37.89
3	648088	264432	52° 13.33’	001° 37.85’
4	648048	263871	52° 13.03’	001° 37.79’
5	648054	263305	52° 12.73’	001° 37.77’
6	648104	262761	52° 12.43’	001° 37.79’
7	648131	262205	52° 12.13’	001° 37.79’
8	648196	260902	52° 11.42’	001° 37.79’
9	645922	251507	52° 06.43’	001° 35.39’
10	651897	273352	52° 18.02’	001° 41.59’
11	651293	264715	52° 13.40’	001° 40.68’
12	649802	251857	52° 06.51’	001° 38.80’

Table 3 Tide times at Felixstowe and Lowestoft during the tidal cycle survey at Station 5 on 2 March 2010 (data from Proudman Oceanographic Laboratory). The tidal cycle survey was conducted between 11:00 and 23:00.

Tide	Lowestoft	Felixstowe
HW	10:36	12:45
LW	16:36	18:19
HW	23:45	00:58 (03/02/2010)

2.2 Sampling operations

2.2.1 Water sampling

Water samples were acquired using a total of three different survey vessels operated by Gardline Environmental Ltd. The survey vessel *Melanie D* (**Figure 3**) is an 8.5 m catamaran with a low freeboard ideal for water sampling operations. The *George D* (**Figure 4**) is a 19.8 m steel-hulled ex-Trinity House buoy tender and the *Meriel D* is an aluminium-hulled catamaran of 16.0 m (**Figure 5**).

Figure 3 The *Melanie D* survey vessel

Figure 4 The *George D* survey vessel

Figure 5 The *Meriel D* survey vessel

Sampling operations were carried out at the sampling stations as shown in **Table 2**. Surface samples were acquired using a bucket of material appropriate to the analysis planned for the sample. Near-bed samples were acquired using a Niskin water sampler mounted on a stainless steel wire. The Niskin sampler was activated using a messenger weight, with samples acquired approximately 1 m above the seabed.

When sampling at Station 5 (the cooling water outfall, **Figure 2**), the vessel was positioned as close to the outfall as practical (typically within 50 to 100 m). The vessel was positioned to the south of the outfall during the flood phase of the tide and to the north during the ebb phase. Positioning in this manner ensured that the waters sampled contained the maximum possible proportion of expelled cooling water.

A SAIV CTD (model SD204) was lowered from the vessel to the seabed at each sampling station when sampling was being undertaken. A profile of the water column (with respect to salinity and temperature) was measured to assess the degree to which the water column was mixed.

A total of 81 water samples were acquired from Stations 1 to 12. The details of these samples are shown in **Table 4**.

Table 4 Details of acquired water samples

Date	Station	Time (UTC)	Samples acquired	Sample depth (m)	Survey
25/02/2010	2	09:45	Surface	0	Spatial
25/02/2010	3	10:38	Surface	0	Spatial
25/02/2010	3	11:25	Near-bed	4	Spatial
25/02/2010	4	12:20	Surface	0	Spatial
25/02/2010	5	13:05	Surface	0	Spatial/Seasonal
25/02/2010	5	13:25	Near-bed	5	Spatial
02/03/2010	5	11:00	Surface	0	Tidal cycle (spring tide)
02/03/2010	5	12:00	Surface	0	Tidal cycle (spring tide)
02/03/2010	5	13:00	Surface	0	Tidal cycle (spring tide)
02/03/2010	5	14:00	Surface	0	Tidal cycle (spring tide)
02/03/2010	5	15:00	Surface	0	Tidal cycle (spring tide)
02/03/2010	5	16:00	Surface	0	Tidal cycle (spring tide)
02/03/2010	5	17:00	Surface	0	Tidal cycle (spring tide)
02/03/2010	5	18:00	Surface	0	Tidal cycle (spring tide)
02/03/2010	5	19:00	Surface	0	Tidal cycle (spring tide)
02/03/2010	5	20:00	Surface	0	Tidal cycle (spring tide)
02/03/2010	5	21:00	Surface	0	Tidal cycle (spring tide)
02/03/2010	5	22:00	Surface	0	Tidal cycle (spring tide)
02/03/2010	5	23:00	Surface	0	Tidal cycle (spring tide)
07/04/2010	10	10:20	Surface	0	Spatial
07/04/2010	10	10:20	Near-bed	11	Spatial
07/04/2010	1	11:50	Surface	0	Spatial
07/04/2010	1	11:50	Near-bed	5	Spatial
07/04/2010	6	13:15	Surface	0	Spatial
07/04/2010	11	13:45	Surface	0	Spatial/Seasonal
08/04/2010	12	11:30	Surface	0	Spatial
08/04/2010	12	13:00	Near-bed	17	Spatial
08/04/2010	9	14:00	Surface	0	Spatial
08/04/2010	9	14:30	Near-bed	5	Spatial
08/04/2010	8	15:45	Surface	0	Spatial
08/04/2010	7	16:15	Surface	0	Spatial
08/04/2010	7	16:30	Near-bed	7	Spatial
08/04/2010	5	17:30	Surface	0	Spatial/Seasonal
21/04/2010	5	09:45	Surface	0	Seasonal
21/04/2010	11	10:45	Surface	0	Seasonal
19/05/2010	5	08:45	Surface	0	Seasonal
19/05/2010	11	09:45	Surface	0	Seasonal
07/06/2010	5	11:20	Surface	0	Seasonal
07/06/2010	11	10:10	Surface	0	Seasonal
22/06/2010	5	09:30	Surface	0	Seasonal

Date	Station	Time (UTC)	Samples acquired	Sample depth (m)	Survey
22/06/2010	11	10:00	Surface	0	Seasonal
06/07/2010	5	12:30	Surface	0	Seasonal
06/07/2010	11	10:15	Surface	0	Seasonal
20/07/2010	5	13:45	Surface	0	Seasonal
20/07/2010	11	13:00	Surface	0	Seasonal
11/08/2010	11	10:08	Surface	0	Seasonal
11/08/2010	5	09:20	Surface	0	Seasonal
18/08/2010	5	12:05	Surface	0	Seasonal
18/08/2010	11	13:05	Surface	0	Seasonal
09/09/2010	5	09:45	Surface	0	Seasonal
09/09/2010	11	10:40	Surface	0	Seasonal
14/09/2010	5	10:45	Surface	0	Seasonal
14/09/2010	11	10:15	Surface	0	Seasonal
28/09/2010	5	10:50	Surface	0	Seasonal
28/09/2010	11	10:00	Surface	0	Seasonal
14/10/2010	5	10:15	Surface	0	Seasonal
14/10/2010	11	11:15	Surface	0	Seasonal
15/11/2010	5	12:00	Surface	0	Seasonal
15/11/2010	11	11:00	Surface	0	Seasonal
06/12/2010	5	10:02	Surface	0	Seasonal
06/12/2010	3	10:40	Surface	0	Spatial
06/12/2010	1	11:30	Surface	0	Spatial
06/12/2010	11	09:30	Surface	0	Seasonal
15/12/2010	11	10:38	Surface	0	Seasonal
15/12/2010	4	12:35	Surface	0	Spatial
15/12/2010	6	11:15	Surface	0	Spatial
15/12/2010	2	12:10	Surface	0	Spatial
15/12/2010	5	11:40	Surface	0	Seasonal
17/01/2011	11	15:55	Surface	0	Seasonal
17/01/2011	5	15:25	Surface	0	Seasonal
17/01/2011	12	12:20	Surface	0	Spatial
17/01/2011	12	12:20	Near-bed	17	Spatial
17/01/2011	9	14:35	Surface	0	Spatial
31/01/2011	10	09:20	Surface	0	Spatial
31/01/2011	11	10:10	Surface	0	Seasonal
31/01/2011	8	10:50	Surface	0	Spatial
31/01/2011	7	11:20	Surface	0	Spatial
31/01/2011	5	14:00	Surface	0	Seasonal
14/02/2011	10	11:00	Near-bed	12	Spatial
14/02/2011	11	12:45	Surface	0	Seasonal
14/02/2011	5	13:30	Surface	0	Seasonal

2.2.2 Sediment sampling

Triplicate sediment samples were acquired from Station 11 on the 17 June 2010 and from Station 5 on 18 June 2010. Samples were acquired using a Day grab from the *MV Nicola Ann*. Acquired sub-samples were sent to Scientifics Ltd and subjected to the analyses listed in **Table 7** and **Table 6**.

2.2.3 Radionuclide sampling

Surface water samples were acquired from Station 5 (the cooling water outfall) and Station 11 and subjected to radionuclide analysis. Each radionuclide sample consisted of three 1 litre plastic bottles. The sampling dates are shown in **Table 5**. The analyses carried out are detailed in **Table 8**. Surface water samples were acquired for radionuclide analysis using a clean plastic bucket and transferred into clean plastic containers. The containers were placed in an insulated box and kept cool before being submitted to the Cefas Radioanalytical Service Laboratory for analysis.

Table 5 Details of the acquired water samples for radionuclide analysis. (The station was undergoing an outage during the sampling undertaken on 19/05/2010.)

Date	Time	Station
19/05/2010	08:45	5
19/05/2010	09:45	11
17/01/2011	15:25	5
14/02/2011	13:30	5

2.3 Water sample handling and analysis

All the water samples acquired were subjected to the following types of analyses:

- Immediate measurement of total residual oxidant (TRO) and water quality parameters on board the survey vessel by Cefas personnel
- Chemical analysis for a suite of analytes by Scientifics Ltd.
- Silt Density Index (SDI) and Modified Fouling Index (MFI) analysis by WRc Ltd.

From 15 November 2010 to the end of the programme samples were also acquired for analysis for hydrazine by DVGW-Technologiezentrum Wasser (TZW).

2.3.1 On-board water sample analysis by Cefas

TRO is known to degrade rapidly and prompt analysis is therefore required to measure realistic environmental concentrations. All water samples were analysed for TRO onboard the survey vessel immediately after acquisition. Water samples for TRO analysis were acquired at each site using a stainless steel bucket (for surface samples) or a Niskin water sampler (for near-bed samples). In each case, three samples were acquired and the temperature, salinity, pH and dissolved oxygen saturation recorded using a WTW Oxi 30 meter. Three 10 ml replicate sea water sub-samples were taken from each water sample using a 10 ml pipette. Each 10 ml sub-sample was transferred to a 10 ml syringe and filtered through a 0.2 µm filter into a test tube containing a sachet of N,N-diethyl-p-phenylenediamine (DPD) total chlorine reagent. The samples were left in the test tube for the minimum duration of three minutes to allow full colour development before absorbance at 528 nm was measured using a HACH pocket colorimeter II. The colorimeter was blanked with a sample of filtered sea water without DPD before each reading. Before use the colorimeter and meters were calibrated, and reference standards were used to check that the colorimeter values were within the manufacturer’s specification. The limit of detection of this method was 0.02 mg.l^{-1}.

2.3.2 Water sampling for laboratory chemical analysis by Scientifics Ltd

Scientifics Ltd provided sample containers for a suite of chemical analyses (see **Table 6**). Surface samples were acquired using a bucket and near-bed samples were acquired using a Niskin water sampler. Surface samples destined for analysis for organic compounds were acquired using a stainless steel bucket. They were transferred to the sample containers using a stainless steel pouring jug. All other samples were acquired using a plastic bucket and transferred into the sample containers using a plastic pouring jug. All samples acquired were marked with the station number, date and time of acquisition and (if required) a “B” to denote a near-bed sample. Following acquisition all samples were placed in an insulated box and stored in a cool (< 10ºC), dark environment. They were transported to the analysing laboratory as soon as possible once ashore, typically reaching the laboratory within 24 hours of acquisition. The 1-litre glass container containing the sample for hydrazine analysis was pre-dosed with 10 ml of 1M hydrochloric acid to retard the degradation of hydrazine. Hydrazine has a relatively short half-life in sea water. In order to ensure that sample acidification was effective in preventing the degradation of hydrazine, some acidified control samples were spiked with a measured concentration of hydrazine and sent to the laboratory for analysis. Samples spiked with an initial concentration of 1,000 µ.gl^{-1} and immediately acidified gave laboratory analysis results of 918 µg.l^{-1}, while identical samples acidified after incubation periods of up to 23 hours showed much lower hydrazine concentrations (< 50 µg.l^{-1}), indicating that immediate acidification is an effective measure in retarding the degradation of hydrazine.

Table 6 The analyses conducted on water samples by Scientifics Ltd (entries marked with “MS” are subcontracted by Scientifics Ltd to Mountainheath Services). Detections limits are given as µg.l-1 unless otherwise stated. A key to method acronyms is provided at the end of the table.

Analysis	Method	Limit of detection (µg.l^{-1})
pH units	pH electrode	
Suspended solids	Filtration and gravimetric analysis	5 mg.l^{-1}
Total alkalinity as $CaCO_3$	Titrimetry	2 mg.l^{-1}
Bicarbonate alkalinity as $CaCO_3$	Titrimetry	2 mg.l^{-1}
Carbonate alkalinity as $CaCO_3$	Titrimetry	2 mg.l^{-1}
Chloride as Cl	Colorimetric analysis	1 mg.l^{-1}
Fluoride as F	Fluoride ISE	0.1 mg.l^{-1}
Total Sulphur as SO_4 (Dissolved)	ICPOES	3 mg.l^{-1}
Calcium as Ca (Total)	ICPOES	1 mg.l^{-1}
Calcium as Ca (Dissolved)	ICPOES	1 mg.l^{-1}
Magnesium as Mg (Total)	ICPOES	1 mg.l^{-1}
Magnesium as Mg (Dissolved)	ICPOES	1 mg.l^{-1}
Strontium as Sr (Total)	ICPOES	10

Analysis	Method	Limit of detection (µg.l^{-1})
Hexachlorocyclo-pentadiene	L/LE GCMS	5
2,4,6-Trichlorophenol	L/LE GCMS	20
2,4,5-Trichlorophenol	L/LE GCMS	20
2-Chloronaphthalene	L/LE GCMS	2
Biphenyl	L/LE GCMS	2
Diphenyl ether	L/LE GCMS	2
2-Nitroaniline	L/LE GCMS	5
Acenaphthylene	L/LE GCMS	2
Dimethylphthalate	L/LE GCMS	5
2,6-Dinitrotoluene	L/LE GCMS	5
Acenaphthene	L/LE GCMS	2
3-Nitroaniline	L/LE GCMS	5
2,4-Dinitrophenol	L/LE GCMS	10

Analysis	**Method**	**Limit of detection (µg.l^{-1})**
Strontium as Sr (Dissolved)	ICPOES	10
Sodium as Na (Dissolved)	ICPOES	1 mg.l^{-1}
Potassium as K (Total)	ICPOES	1 mg.l^{-1}
Potassium as K (Dissolved)	ICPOES	1 mg.l^{-1}
Nickel as Ni (Total)	ICPMS	1
Nickel as Ni (Dissolved)	ICPMS	1
Chromium as Cr (Total)	ICPMS	1
Chromium as Cr (Dissolved)	ICPMS	1
Cadmium as Cd (Total)	ICPMS	0.1
Cadmium as Cd (Dissolved)	ICPMS	0.1
Copper as Cu (Total)	ICPMS	1
Copper as Cu (Dissolved)	ICPMS	1
Lead as Pb (Total)	ICPMS	1
Lead as Pb (Dissolved)	ICPMS	1
Zinc as Zn (Total)	ICPMS	2
Zinc as Zn (Dissolved)	ICPMS	2
Manganese as Mn (Dissolved)	ICPMS	2
Iron as Fe (Total)	ICPOES	10
Iron as Fe (Dissolved)	ICPOES	10
Aluminium as Al (Dissolved)	ICPOES	10
Arsenic as As (Total)	ICPMS	1
Arsenic as As (Dissolved)	ICPMS	1
Boron as B (Total)	ICPOES	10
Boron as B (Dissolved)	ICPOES	10
Mercury as Hg (Total)	ICPMS	0.1
Mercury as Hg (Dissolved)	ICPMS	0.1

Analysis	**Method**	**Limit of detection (µg.l^{-1})**
Dibenzofuran	L/LE GCMS	5
4-Nitrophenol	L/LE GCMS	50
2,4-Dinitrotoluene	L/LE GCMS	5
Fluorene	L/LE GCMS	2
Diethylphthalate	L/LE GCMS	5
4-Chlorophenyl-phenylether	L/LE GCMS	5
4,6-Dinitro-2-methylphenol	L/LE GCMS	50
4-Nitroaniline	L/LE GCMS	5
N-Nitrosodiphenylamine	L/LE GCMS	5
4-Bromophenyl-phenylether	L/LE GCMS	5
Hexachlorobenzene	L/LE GCMS	5
Pentachlorophenol	L/LE GCMS	50
Phenanthrene	L/LE GCMS	2
Anthracene	L/LE GCMS	2
Di-n-butylphthalate	L/LE GCMS	5
Fluoranthene	L/LE GCMS	2
Pyrene	L/LE GCMS	2
Butylbenzylphthalate	L/LE GCMS	5
Benzo[a]anthracene	L/LE GCMS	2
Chrysene	L/LE GCMS	2
3,3'-Dichlorobenzidine	L/LE GCMS	20
Bis (2-Ethylhexyl) phthalate	L/LE GCMS	5
Di-n-octylphthalate	L/LE GCMS	2
Benzo[b]fluoranthene	L/LE GCMS	2
Benzo[k]fluoranthene	L/LE GCMS	2
Benzo[a]pyrene	L/LE GCMS	2

Analysis	Method	Limit of detection (µg.l^{-1})
Selenium as Se (Dissolved)	ICPMS	1
Selenium as Se (Total)	ICPMS	1
Molybdenum as Mo (Total)	ICPMS	1
Molybdenum as Mo (Dissolved)	ICPMS	1
Cobalt as Co (Total)	ICPMS	1
Cobalt as Co (Dissolved)	ICPMS	1
Ammoniacal Nitrogen as N	Colorimetric analysis	10
Nitrite as N	Colorimetric analysis	10
Nitrate as N	Calculated from total oxidised nitrogen and nitrite	0.3 mg.l^{-1}
Phosphate as P	Colorimetric analysis	10
Chemical Oxygen Demand (Settled)	Oxygen digestion	5 mg.l^{-1}
Total Organic Carbon	UV-IR	0.1 mg.l^{-1}
Salinity	Salinity probe	0.1 mg.l^{-1}
Turbidity N.T.U	Turbidity cell	1 NTU
Bromide as Br	Bromide electrode	0.1 mg.l^{-1}
Iodide as I	ISE	1 mg.l^{-1}
Barium as Ba (Total)	ICPOES	10
Barium as Ba (Dissolved)	ICPOES	10
Lithium as Li (Total)	ICPOES	10
Lithium as Li (DIssolved)	ICPOES	10
Silicon as Si (Total)	ICPOES	10
MBAS as Lauryl Sulphate	Methylene blue/ chloroform extraction and colorimetry	20

Analysis	Method	Limit of detection (µg.l^{-1})
Indeno[1,2,3-cd]pyrene	L/LE GCMS	2
Dibenzo[a,h]anthracene	L/LE GCMS	2
Benzo[g,h,i]perylene	L/LE GCMS	2
Tentatively identified semi-volatile organic compounds (SVOCs)	L/LE GCMS	variable
Dichlorodifluoro-methane	HS GCMS	1
Chloromethane	HS GCMS	1
Vinyl Chloride	HS GCMS	1
Bromomethane	HS GCMS	5
Chloroethane	HS GCMS	5
Trichlorofluoro-methane	HS GCMS	1
1,1-Dichloroethene	HS GCMS	1
trans 1,2-Dichloroethene	HS GCMS	1
1,1-Dichloroethane	HS GCMS	1
2,2-Dichloropropane	HS GCMS	1
cis 1,2-Dichloroethene	HS GCMS	1
Bromochloromethane	HS GCMS	1
Chloroform	HS GCMS	5
1,1,1-Trichloroethane	HS GCMS	1
Carbon Tetrachloride	HS GCMS	1
1,1-Dichloropropene	HS GCMS	1
Benzene	HS GCMS	1
1,2-Dichloroethane	HS GCMS	1

Analysis	Method	Limit of detection ($\mu g.l^{-1}$)
Chlorophyll A **(MS)**	Acetone extraction and UV Spectro-photometry	
Biochemical Oxygen Demand	Dissolved Oxygen measurement before and after 5-day incubation	2 $mg.l^{-1}$
Dissolved Organic Carbon	UV-IR	0.1 $mg.l^{-1}$
Total Petroleum Hydrocarbons (TPH)	FTIR	0.3 $mg.l^{-1}$
Total Petroleum Hydrocarbons	GC FID	10
Total Viable Count @ 22ºC /ml	Incubation and colony counting	1 colony
2,4,6-tribromophenol **(MS)**	Liquid/liquid extraction and GCMS	0.2
Cationic Detergents	UV spectrophotometry	1 $mg.l^{-1}$
Dibromoacetic acid **(MS)**	L/LE GCMS	1
Dibromoacetonitrile **(MS)**	L/LE GCMS	0.1
Dichloroacetonitrile **(MS)**	L/LE GCMS	0.1
Ethanolamine **(MS)**	GCMS	20
Hydrazine **(MS)**	UV-VS	1
Morpholine **(MS)**	GCMS	2
Phenol	L/LE GCMS	20
Bis (2-Chloroethyl) ether	L/LE GCMS	5
2-Chlorophenol	L/LE GCMS	20
1,3-Dichlorobenzene	L/LE GCMS	5
1,4-Dichlorobenzene	L/LE GCMS	5
Benzyl alcohol	L/LE GCMS	5
1,2-Dichlorobenzene	L/LE GCMS	5
2-Methylphenol	L/LE GCMS	5

Analysis	Method	Limit of detection ($\mu g.l^{-1}$)
Trichloroethene	HS GCMS	5
1,2-Dichloropropane	HS GCMS	1
Dibromomethane	HS GCMS	1
Bromodichloro-methane	HS GCMS	1
cis 1,3-Dichloropropene	HS GCMS	1
Toluene	HS GCMS	1
trans 1,3-Dichloropropene	HS GCMS	1
1,1,2-Trichloroethane	HS GCMS	1
Tetrachloroethene	HS GCMS	5
1,3-Dichloropropane	HS GCMS	1
Dibromochloro-methane	HS GCMS	1
1,2-Dibromoethane	HS GCMS	1
Chlorobenzene	HS GCMS	1
Ethylbenzene	HS GCMS	1
1,1,1,2-Tetrachloroethane	HS GCMS	1
m and p-Xylene	HS GCMS	1
o-Xylene	HS GCMS	1
Styrene	HS GCMS	1
Bromoform	HS GCMS	1
iso-Propylbenzene	HS GCMS	1
1,1,2,2-Tetrachloroethane	HS GCMS	1
Propylbenzene	HS GCMS	1

Analysis	Method	Limit of detection ($\mu g.l^{-1}$)
Bis (2-Chloroisopropyl) ether	L/LE GCMS	5
Hexachloroethane	L/LE GCMS	5
N-Nitroso-di-n-propylamine	L/LE GCMS	5
3- & 4-Methylphenol	L/LE GCMS	20
Nitrobenzene	L/LE GCMS	5
Isophorone	L/LE GCMS	5
2-Nitrophenol	L/LE GCMS	20
2,4-Dimethylphenol	L/LE GCMS	20
Benzoic Acid	L/LE GCMS	100
Bis (2-Chloroethoxy) methane	L/LE GCMS	5
2,4-Dichlorophenol	L/LE GCMS	20
1,2,4-Trichlorobenzene	L/LE GCMS	5
Naphthalene	L/LE GCMS	2
4-Chlorophenol	L/LE GCMS	20
4-Chloroaniline	L/LE GCMS	5
Hexachlorobuta-diene	L/LE GCMS	5
4-Chloro-3-methylphenol	L/LE GCMS	5
2-Methylnaphthalene	L/LE GCMS	2
1-Methylnaphthalene	L/LE GCMS	2

Analysis	Method	Limit of detection ($\mu g.l^{-1}$)
Bromobenzene	HS GCMS	1
1,2,3-Trichloropropane	HS GCMS	1
2-Chlorotoluene	HS GCMS	1
1,3,5-Trimethylbenzene	HS GCMS	1
4-Chlorotoluene	HS GCMS	1
tert-Butylbenzene	HS GCMS	1
1,2,4-Trimethylbenzene	HS GCMS	1
sec-Butylbenzene	HS GCMS	1
p-Isopropyltoluene	HS GCMS	1
1,3-Dichlorobenzene	HS GCMS	1
1,4-Dichlorobenzene	HS GCMS	1
n-Butylbenzene	HS GCMS	1
1,2-Dichlorobenzene	HS GCMS	5
1,2-Dibromo-3-chloropropane	HS GCMS	5
1,2,4-Trichlorobenzene	HS GCMS	5
Hexachlorobutadiene	HS GCMS	5
Naphthalene	HS GCMS	5
1,2,3-Trichlorobenzene	HS GCMS	5
Tentatively identified volatile organic compounds (VOCs)	HS GCMS	variable

Method key:

ISE	Ion-specific electrode
ICPOES	Inductively coupled plasma atomic emission spectroscopy
ICPMS	Inductively coupled plasma mass spectroscopy
UV-IR	uv-persulphate oxidation/IR detection
FTIR	Fourier transform infrared spectroscopy
UV-VS	Ultraviolet-visible spectrophotometry
GC FID	Gas chromatography flame ionisation detection
GCMS	Gas chromatography-mass spectroscopy
HS GCMS	Head space gas chromatography mass spectroscopy
L/LE GCMS	Liquid/liquid extraction followed by gas chromatography-mass spectroscopy

2.3.3 Water sampling for laboratory analysis by DVGW-Technologiezentrum Wasser (TZW)

Following concerns regarding the validity of the relatively high concentrations of hydrazine apparently being obtained using ultraviolet-visible spectrophotometry (see BEEMS Technical Report TR130); a more sensitive analytical method was sought. DVGW-Technologiezentrum Wasser (TZW) of Germany offered a analysis using liquid-liquid-extraction and subsequent GC-MS detection with a detection limit of 0.01µg.l^{-1}.

Sample for analysis by TZW were acquired from 15 November 2010 until the completion of fieldwork on 14 February 2011. Water samples were acquired using a stainless steel bucket and transferred to 1 litre bottles pre-dosed with 10 ml of 1 molar hydrochloric acid. Initially glass bottles were used, but following investigation by TZW, plastic bottles were also found to be suitable and were subsequently used because of the reduced likelihood of breakage in transit.

2.3.4 Water sampling for laboratory SDI/MFI analysis by WRc Ltd

Samples for SDI/MFI analysis were acquired using a bucket (for surface samples) or a Niskin water sampler (for near-bed samples). The samples were transferred to 1 litre plastic bottles and stored in insulated boxes, ensuring that the samples were in a dark, cool environment. The samples were transferred to WRc Ltd's laboratory at the earliest opportunity once ashore. All samples acquired were marked with the station number, date and time of acquisition and (if required) a "B" to denote a near-bed sample.

2.4 Sediment sample handling and analysis

Sediment samples were acquired using a Day grab. Sub-samples were taken using either plastic spatulas (for metals analyses) or metal spatulas (for hydrocarbon analyses). Metal and plastic spatulas were not used in the same grab sample. Sub-samples were not taken from near the edge or bottom of the grab to avoid contamination. A vertical cross-section of sediment from the surface to near to the bottom of the grab was sub-sampled. Sub-samples were then sent to Scientifics Ltd and subjected to the analyses shown in **Table 7**.

Table 7 The analyses conducted on sediment samples by Scientifics Ltd. Detections limits are given as mg.kg^{-1} unless otherwise stated. A key to method acronyms is provided at the end of the table.

Analysis	Method	Limit of detection (mg.kg^{-1})
Boron (H_20 Soluble)	ICPOES	0.5
Fluoride	ISEFSS	0.1
pH	PH probe	
Total petroleum hydrocarbons	GC FID	10
Exchange.Ammonium	AMMAR	0.5
Total petroleum hydrocarbons	FTIR SWPER	50
Arsenic	ICPMSSD	0.5
Cadmium	ICPMSSD	0.1
Chromium	ICPMSSD	0.5
Cobalt	ICPMSSD	0.1
Copper	ICPMSSD	0.5
Lead	ICPMSSD	0.5
Manganese	ICPMSSD	1.0
Molybdenum	ICPMSSD	0.5
Nickel	ICPMSSD	0.5
Selenium	ICPMSSD	0.5
Zinc	ICPMSSD	3.0
Chloride	KONECL	1.0
Nitrate	KoneNO3	0.2
Nitrite as N:	KONENS.	0.1
2,4,6-tribromophenol	AE GCMS	
Dibromoacetic Acid	AE GCMS	
Dibromoacetonitrile	L/LE GCMS	
Ethanolamine	GCMS	
Hydrazine	UV-SPEC	
Morpholine	GCMS	
Mercury (Total)	TMMS1	0.1
Aluminium (Total)	TMOES	10
Barium (Total)	TMOES	5
Calcium (Total)	TMOES	100
Iron (Total)	TMOES	10
Lithium (Total)	TMOES	10
Magnesium (Total)	TMOES	100
Phosphorous (Total)	TMOES	100
Potassium (Total)	TMOES	100
4-Chlorophenyl-phenylether	SVOCSW	0.5
4,6-Dinitro-2-methylphenol	SVOCSW	5
4-Nitroaniline	SVOCSW	0.5
N-Nitrosodiphenylamine	SVOCSW	0.5
4-Bromophenyl-phenylether	SVOCSW	0.5
Hexachlorobenzene	SVOCSW	0.5
Pentachlorophenol	SVOCSW	5
Phenanthrene	SVOCSW	0.2
Anthracene	SVOCSW	0.2
Di-n-butylphthalate	SVOCSW	0.5
Fluoranthene	SVOCSW	0.2
Pyrene	SVOCSW	0.2
Butylbenzylphthalate	SVOCSW	0.5
Benzo[a]anthracene	SVOCSW	0.2
Chrysene	SVOCSW	0.2
3,3'-Dichlorobenzidine	SVOCSW	2
bis(2-Ethylhexyl) phthalate	SVOCSW	0.5
Di-n-octylphthalate	SVOCSW	0.2
Benzo[b]fluoranthene	SVOCSW	0.2
Benzo[k]fluoranthene	SVOCSW	0.2
Benzo[a]pyrene	SVOCSW	0.2
Indeno[1,2,3-cd]pyrene	SVOCSW	0.2
Dibenzo[a,h]anthracene	SVOCSW	0.2
Benzo[g,h,i]perylene	SVOCSW	0.2
Dichlorodifluoro-methane	VOCSW8100	5 µg.kg^{-1}
Chloromethane	VOCSW8100	5 µg.kg^{-1}
Vinyl Chloride	VOCSW8100	5 µg.kg^{-1}
Bromomethane	VOCSW8100	25 µg.kg^{-1}
Chloroethane	VOCSW8100	25 µg.kg^{-1}
Trichlorofluoromethane	VOCSW8100	5 µg.kg^{-1}
1,1-Dichloroethene	VOCSW8100	5 µg.kg^{-1}
trans 1,2-Dichloroethene	VOCSW8100	5 µg.kg^{-1}
1,1-Dichloroethane	VOCSW8100	5 µg.kg^{-1}
2,2-Dichloropropane	VOCSW8100	5 µg.kg^{-1}
cis 1,2-Dichloroethene	VOCSW8100	5 µg.kg^{-1}

Analysis	Method	Limit of detection (mg.kg^{-1})
Strontium (Total)	TMOES	3
Sulphur.(Total)	TSBRE1	0.005 %
Total Organic Carbon	WSLM59	0.01 %
Phenol	SVOCSW	2
bis(2-Chloroethyl)ether	SVOCSW	0.5
2-Chlorophenol	SVOCSW	2
1,3-Dichlorobenzene	SVOCSW	0.5
1,4-Dichlorobenzene	SVOCSW	0.5
Benzyl alcohol	SVOCSW	0.5
1,2-Dichlorobenzene	SVOCSW	0.5
2-Methylphenol	SVOCSW	0.5
bis(2-Chloroisopropyl) ether	SVOCSW	0.5
Hexachloroethane	SVOCSW	0.5
N-Nitroso-di-n-propylamine	SVOCSW	0.5
3- & 4-Methylphenol	SVOCSW	2
Nitrobenzene	SVOCSW	0.5
Isophorone	SVOCSW	0.5
2-Nitrophenol	SVOCSW	2
2,4-Dimethylphenol	SVOCSW	2
Benzoic Acid	SVOCSW	10
bis(2-Chloroethoxy) methane	SVOCSW	0.5
2,4-Dichlorophenol	SVOCSW	2
1,2,4-Trichlorobenzene	SVOCSW	0.5
Naphthalene	SVOCSW	0.2
4-Chlorophenol	SVOCSW	2
4-Chloroaniline	SVOCSW	0.5
Hexachlorobutadiene	SVOCSW	0.5
4-Chloro-3-methylphenol	SVOCSW	0.5
2-Methylnaphthalene	SVOCSW	0.2
1-Methylnaphthalene	SVOCSW	0.2
Hexachlorocyclo-pentadiene	SVOCSW	0.5
2,4,6-Trichlorophenol	SVOCSW	2
2,4,5-Trichlorophenol	SVOCSW	2
2-Chloronaphthalene	SVOCSW	0.2
Biphenyl	SVOCSW	0.2
Diphenyl ether	SVOCSW	0.2
2-Nitroaniline	SVOCSW	0.5
Acenaphthylene	SVOCSW	0.2
Dimethylphthalate	SVOCSW	0.5

Analysis	Method	Limit of detection (mg.kg^{-1})
Bromochloromethane	VOCSW8100	5 µg.kg^{-1}
Chloroform	VOCSW8100	5 µg.kg^{-1}
1,1,1-Trichloroethane	VOCSW8100	5 µg.kg^{-1}
Carbon Tetrachloride	VOCSW8100	5 µg.kg^{-1}
1,1-Dichloropropene	VOCSW8100	5 µg.kg^{-1}
Benzene	VOCSW8100	5 µg.kg^{-1}
1,2-Dichloroethane	VOCSW8100	5 µg.kg^{-1}
Trichloroethene	VOCSW8100	5 µg.kg^{-1}
1,2-Dichloropropane	VOCSW8100	5 µg.kg^{-1}
Dibromomethane	VOCSW8100	5 µg.kg^{-1}
Bromodichloromethane	VOCSW8100	5 µg.kg^{-1}
cis 1,3-Dichloropropene	VOCSW8100	5 µg.kg^{-1}
Toluene	VOCSW8100	5 µg.kg^{-1}
trans 1,3-Dichloropropene	VOCSW8100	5 µg.kg^{-1}
1,1,2-Trichloroethane	VOCSW8100	5 µg.kg^{-1}
Tetrachloroethene	VOCSW8100	25 µg.kg^{-1}
1,3-Dichloropropane	VOCSW8100	5 µg.kg^{-1}
Dibromochloromethane	VOCSW8100	5 µg.kg^{-1}
1,2-Dibromoethane	VOCSW8100	5 µg.kg^{-1}
Chlorobenzene	VOCSW8100	5 µg.kg^{-1}
Ethylbenzene	VOCSW8100	5 µg.kg^{-1}
1,1,1,2-Tetrachloroethane	VOCSW8100	5 µg.kg^{-1}
m and p-Xylene	VOCSW8100	5 µg.kg^{-1}
o-Xylene	VOCSW8100	5 µg.kg^{-1}
Styrene	VOCSW8100	5 µg.kg^{-1}
Bromoform	VOCSW8100	5 µg.kg^{-1}
iso-Propylbenzene	VOCSW8100	5 µg.kg^{-1}
1,1,2,2-Tetrachloroethane	VOCSW8100	5 µg.kg^{-1}
Propylbenzene	VOCSW8100	5 µg.kg^{-1}
Bromobenzene	VOCSW8100	5 µg.kg^{-1}
1,2,3-Trichloropropane	VOCSW8100	5 µg.kg^{-1}
2-Chlorotoluene	VOCSW8100	5 µg.kg^{-1}
1,3,5-Trimethylbenzene	VOCSW8100	5 µg.kg^{-1}
4-Chlorotoluene	VOCSW8100	5 µg.kg^{-1}
tert-Butylbenzene	VOCSW8100	5 µg.kg^{-1}
1,2,4-Trimethylbenzene	VOCSW8100	5 µg.kg^{-1}
sec-Butylbenzene	VOCSW8100	5 µg.kg^{-1}
p-Isopropyltoluene	VOCSW8100	5 µg.kg^{-1}
1,3-Dichlorobenzene	VOCSW8100	5 µg.kg^{-1}

Analysis	**Method**	**Limit of detection ($mg.kg^{-1}$)**
2,6-Dinitrotoluene	SVOCSW	0.5
Acenaphthene	SVOCSW	0.2
3-Nitroaniline	SVOCSW	0.5
2,4-Dinitrophenol	SVOCSW	1
Dibenzofuran	SVOCSW	0.5
4-Nitrophenol	SVOCSW	5
2,4-Dinitrotoluene	SVOCSW	0.5
Fluorene	SVOCSW	0.2
Diethylphthalate	SVOCSW	0.5

Analysis	**Method**	**Limit of detection ($mg.kg^{-1}$)**
1,4-Dichlorobenzene	VOCSW8100	5 $\mu g.kg^{-1}$
n-Butylbenzene	VOCSW8100	5 $\mu g.kg^{-1}$
1,2-Dichlorobenzene	VOCSW8100	5 $\mu g.kg^{-1}$
1,2-Dibromo-3-chloropropane	VOCSW8100	25 $\mu g.kg^{-1}$
1,2,4-Trichlorobenzene	VOCSW8100	25 $\mu g.kg^{-1}$
Hexachlorobutadiene	VOCSW8100	25 $\mu g.kg^{-1}$
Naphthalene	VOCSW8100	25 $\mu g.kg^{-1}$
1,2,3-Trichlorobenzene	VOCSW8100	25 $\mu g.kg^{-1}$

Method Key:

AE GCMS	Aqueous extraction followed by gas chromatography mass spectroscopy
AMMAR	Determination of Exchangeable Ammonium in Soil using potassium chloride extraction, discrete colorimetric detection
FTIRSWPER	Determination of Tetrachloroethylene extractable aliphatic hydrocarbons by Fourier Transform Infrared spectroscopy (FTIR)
GCMS	Direct injection gas chromatography mass spectroscopy
ICPBOR	Determination of Boron in soil samples by hot water extraction followed by ICPOES detection
ICPMS	Inductively coupled plasma mass spectroscopy
ICPMSSD	Determination of Metals in soil samples by Hydrofluoric Acid digestion followed by ICPMS
ICPOES	Inductively coupled plasma atomic emission spectroscopy
ISEFSS	Determination of Fluoride by Ion Selective Electrode in 5:1 water soil extract
KONECL	Determination of Chloride in Soil using water extraction at the stated water: soil ratio, discrete colorimetric detection
KoneNO3	Determination of Nitrate in soil samples by water extraction followed by colorimetric detection
KONENS	Determination of Nitrate in soil samples by water extraction followed by colorimetric detection
L/LE GCMS	Liquid/liquid extraction followed by gas chromatography-mass spectroscopy
PHSOIL	Determination of pH of 2.5:1 deionised water to soil extracts using pH probe.
SVOCMSUS	Determination of Semi Volatile Organic Compounds in soil samples by hexane / acetone extraction followed by GCMS detection
SVOCSW	Determination of Semi Volatile Organic Compounds in soil samples by DCM extraction followed by GCMS detection
TMMS1	Determination of total Metals in sediment samples by Nitric Acid and Hydrogen Peroxide digestion followed by ICPMS detection
TMOES	Determination of total Metals in samples by Hydrofluoric and Boric Acid digestion followed by ICPOES
TMSS	Determination of the Total Moisture content at 105ºC by loss on oven drying gravimetric analysis
TPHFIDUS	Determination of hexane/acetone extractable Hydrocarbons in soil with GCFID detection.
TSBRE1	Determination of Total Carbon and/or Total Sulphur in solid samples by high temperature combustion/infrared detection

UV-SPEC	p-Dimethylaminobenzaldehyde is added to the acidified aqueous sample. The resulting azine concentration is determined using UV-visible spectrophotometry.
VOCSW8100	Determination of Volatile Organic Compounds (VOC) by purge and trap followed by GCMS detection
WSLM59	Determination of Organic Carbon in soil using sulphurous Acid digestion followed by high temperature combustion and IR detection

2.5 Radionuclide sample handling and analysis

Surface water samples were acquired for radionuclide analysis using a clean plastic bucket and transferred into clean plastic containers. The containers were placed in a cool box and kept cool (< 5 ºC) before being transferred to the Cefas Radioanalytical Service Laboratory for the analyses shown in **Table 8**.

Table 8 The radionuclide analyses conducted on surface sea water samples by Cefas Radioanalytical Laboratory.

Analysis	Method
Gross Alpha activity	Acetone extraction followed by analysis using a low background gas flow proportional counter.
Gross Beta activity	
Tritium activity	Oxidant reflux and alkaline distillation followed by liquid scintillation spectrometry
Gamma spectrometry	Analysis using hyper-pure germanium detectors
Carbon-14 activity	Gel scintillation using a liquid scintillation spectrometer.

3 Results and Discussion

The results of the on-board analyses and CTD profiles conducted by Cefas are shown in Section **3.1** below. Section **3.2** contains the results of the chemical analyses conducted by Scientifics Ltd and TZW. The results of the SDI and MFI analyses conducted by WRc Ltd are contained in a report produced by WRc Ltd and presented here in Appendix B.

3.1 On-board analysis results

The on-board analyses conducted by Cefas were designed to measure the levels of TRO present in waters off the Suffolk coast near Sizewell. Dissolved oxygen, temperature, salinity and pH were also measured. The results of these analyses are shown in **Table 9** and **Figure 10** and **Figure 11**. Omitted values indicate failure of the relevant sensor (dissolved oxygen, temperature, salinity or pH) whilst offshore. Each TRO measurement is the mean of nine separate analyses: triplicate analyses carried out on three separate water sub-samples. Individual analysis results of zero were considered as 0.01 mg.l^{-1}, half of the limit of detection. The EQS for TRO is 0.01 mg.l^{-1} (Defra, 2010).

3.1.1 CTD profiles

The CTD profiles acquired (see **Figure 6**) indicated that the water samples were well mixed with respect to salinity. The water expelled from the cooling water outfall is warmer than the surrounding waters. This results in a thermally buoyant plume, and this was evident in the surface water temperature measurements observed in some of the CTD profiles. In **Figure 6**, the surface water temperature is clearly elevated by several degrees at Station 5 (the cooling water outfall). At Station 2 (2.4 km distant) no temperature elevation is observed. The data from the CTD are not presented in this report but are available in the BEEMS data centre (see Table 1).

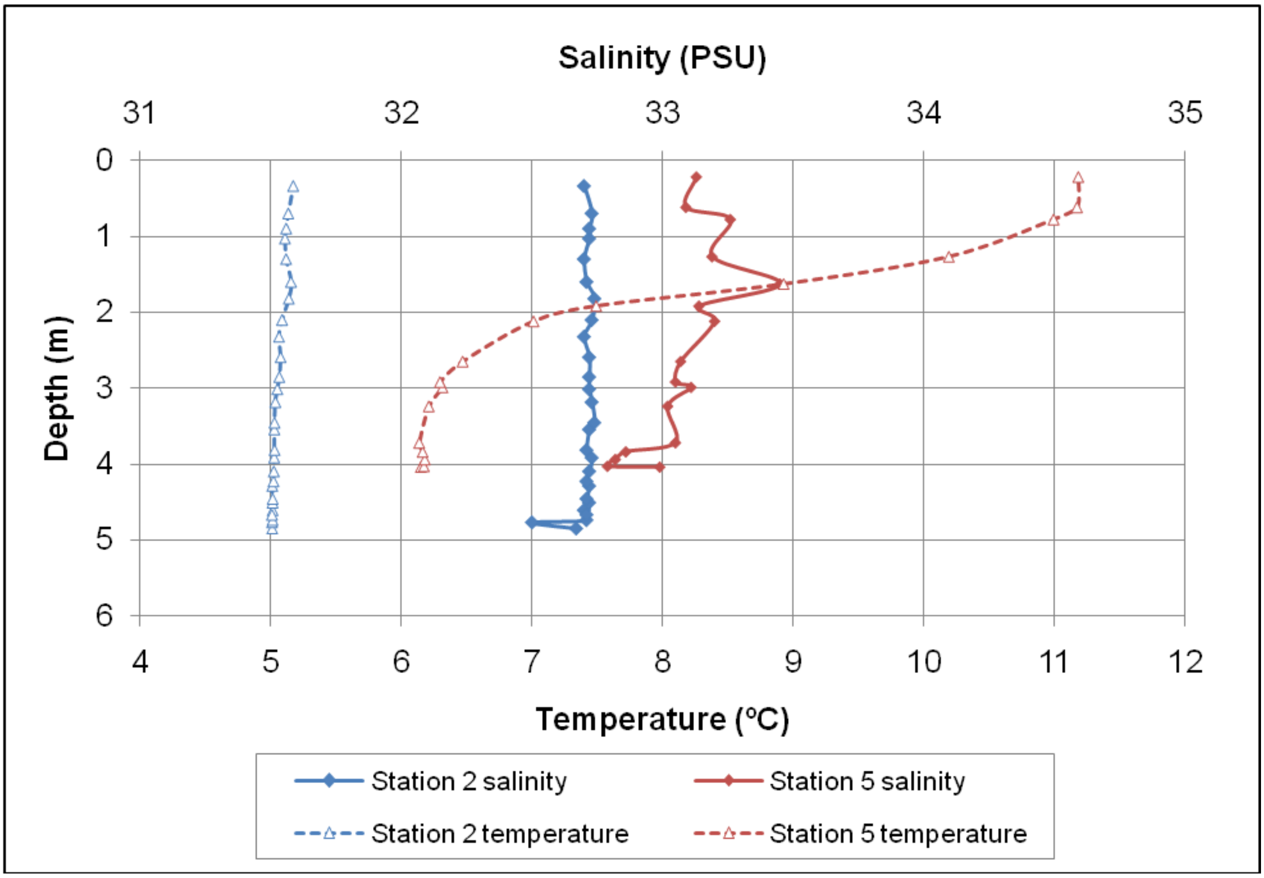

Figure 6 Example CTD profiles acquired on 25 February 2010

Table 9 Water quality and TRO measurement results. TRO concentrations of ≤ 0.01 $mg.l^{-1}$ are below the limit of detection with zero values counted as 0.01 $mg.l^{-1}$. Trends in TRO concentration are shown in **Figure 10** and **Figure 11**.

Station	Date acquired	Time (GMT)	Sample depth (m)	Dissolved oxygen (%)	Temp (°C)	Salinity (PSU)	pH	TRO ($mg.l^{-1}$)
1	07/04/10	11:40	0.0					0.07
1	07/04/10	11:50	4.8					0.05
1	06/12/10	12:30	0.0	98.5	5.3	34.4	8.40	0.01
2	25/02/10	09:45	0.0	106.0	4.7	31.8	7.86	0.03
2	15/12/10	12:10	0.0	99.2	4.9	34.1	7.97	0.01
3	25/02/10	10:38	0.0	108.0	7.4	31.9	7.93	0.03
3	25/02/10	11:25	3.7	107.0	7.2	31.8	7.95	0.04
3	06/12/10	11:40	0.0	100.8	7.2	34.0	8.20	0.01
4	25/02/10	12:20	0.0	119.0	9.8	32.2	7.89	0.06
4	15/12/10	12:40	0.0	100.2	5.3	34.1	8.08	0.01
5	25/02/10	13:05	0.0	118.0	10.9	32.3	8.03	0.02
5	25/02/10	13:25	4.4	112.0	8.7	32.2	7.93	0.03
5	02/03/10	11:00	0.0	91.7	4.9	31.5	7.42	0.04
5	02/03/10	12:00	0.0	98.3	8.9	32.0	7.96	0.03
5	02/03/10	13:00	0.0	93.0	8.2	31.8	7.93	0.04
5	02/03/10	14:00	0.0		9.2	31.9	7.90	0.02
5	02/03/10	15:00	0.0		8.3	32.6	7.96	0.07
5	02/03/10	16:00	0.0		10.1	32.5	8.01	0.02
5	02/03/10	17:00	0.0		11.8	32.4	7.97	0.02
5	02/03/10	18:00	0.0		11.6	32.2	8.04	0.03
5	02/03/10	19:00	0.0		5.9	32.2	7.92	0.03
5	02/03/10	20:00	0.0		9.2	32.3	7.88	0.02
5	02/03/10	21:00	0.0		7.5	31.9	7.87	0.02
5	02/03/10	22:00	0.0		7.4	32.0	7.92	0.04
5	02/03/10	23:00	0.0		6.8	31.9	7.87	0.07
5	08/04/10	17:30	0.0	104.5	7.7	33.4	8.16	0.02
5	21/04/10	09:45	0.0	102.9	8.9		8.00	0.05
5	19/05/10	08:45	0.0	102.9	11.6	33.7	8.15	0.10
5	07/06/10	11:10	0.0	108.3	14.4	33.9	8.23	0.10
5	22/06/10	09:15	0.0	99.3	14.9	32.8	8.12	0.01
5	06/07/10	01:20	0.0	103.4	18.4	32.2	8.06	0.01
5	20/07/10	13:45	0.0	94.3	19.5	33.0	8.02	0.05
5	11/08/10	09:20	0.0	98.4	19.2	34.2	7.77	0.12
5	18/08/10	10:15	0.0	97.6	17.8	34.3	7.85	0.05
5	09/09/10	10:00	0.0	94.0	18.2	33.8	7.07	0.07
5	14/09/10	10:45	0.0	97.2	17.0	30.2	8.27	0.07
5	28/09/10	10:50	0.0	97.2	15.4	33.6	8.16	0.08
5	14/10/10	10:15	0.0	96.9	15.3	32.2	8.06	0.03
5	15/11/10	12:00	0.0	108.8	15.4	32.3	8.03	0.10

Station	Date acquired	Time (GMT)	Sample depth (m)	Dissolved oxygen (%)	Temp (°C)	Salinity (PSU)	pH	TRO (mg.l^{-1})
5	06/12/10	11:08	0.0	100.9	5.9	34.1	8.17	0.01
5	15/12/10	11:40	0.0	99.8	5.9	34.1	8.12	0.01
5	17/01/11		0.0	102.7	5.5	34.4	8.12	0.02
5	31/01/11	14:00	0.0	112.6	10.6	33.5	8.02	0.03
5	14/02/11	13:30	0.0	112.5	10.1	34.5	8.10	0.07
6	07/04/10	13:15	0.0					0.03
6	15/12/10	11:15	0.0	98.7	5.2	34.2	8.05	0.02
7	08/04/10	16:15	0.0	105.0	7.8	33.2	8.15	0.01
7	08/04/10	16:30	7.0	107.8	7.7	33.1	8.14	0.04
7	31/01/11	11:20	0.0	101.3	4.9	33.4	8.00	0.01
8	08/04/10	15:45	0.0	109.4	8.7	32.8	8.11	0.03
8	31/01/11	10:55	0.0	101.7	4.9	33.3	8.05	0.02
9	08/04/10	14:00	0.0	101.8	9.1	32.7	8.12	0.10
9	08/04/10	14:30	5.0	104.4	8.6	33.4	8.10	0.02
9	17/01/11	14:30	0.0	100.1	4.5	34.1	8.13	0.06
10	07/04/10	10:20	0.0					0.01
10	07/04/10	10:30	11.0					0.06
10	31/01/11	09:20	0.0	99.4	3.7	33.3	7.89	0.01
10	14/02/11	11:00	10	103.0	6.1	35.2	8.03	0.01
11	07/04/10	13:45	0.0					0.05
11	21/04/10	10:45	0.0	100.8	8.5		7.99	0.03
11	19/05/10	09:45	0.0	100.1	10.5	33.8	8.18	0.03
11	07/06/10	10:35	0.0	109.1	13.3	34.0	8.23	0.06
11	22/06/10	09:45	0.0	95.0	14.5	33.0	8.16	0.01
11	06/07/10	10:00	0.0	94.3	17.9	31.6	8.02	0.08
11	20/07/10	13:00	0.0	102.6	19.1	33.1	8.09	0.04
11	11/08/10	10:08	0.0	97.8	18.9	34.3	8.01	0.05
11	18/08/10	11:10	0.0	97.3	17.7	34.5	7.98	0.05
11	09/09/10	10:45	0.0	95.3	17.7	34.3	7.22	0.09
11	14/09/10	10:15	0.0	97.4	17.2	30.2	8.29	0.04
11	28/09/10	10:00	0.0	98.5	15.8	33.8	8.14	0.02
11	14/10/10	11:15	0.0	95.8	14.7	32.3	8.05	0.05
11	15/11/10	11:15	0.0	97.6	10.4	32.2	8.08	0.04
11	06/12/10	10:30	0.0	97.5	5.2	34.2	7.97	0.03
11	15/12/10	10:38	0.0	97.0	4.8	34.1	8.13	0.01
11	17/01/11	16:00	0.0	99.8	4.4	34.6	8.12	0.04
11	31/01/11	10:10	0.0	98.5	3.8	33.4	8.04	0.02
11	14/02/11	12:45	0.0	101.4	5.1	34.5	8.08	0.04
12	08/04/10	11:30	0.0	108.6	8.8	33.2	8.07	0.16
12	08/04/10	13:00	17.0	102.5	8.2	33.6	8.11	0.02
12	17/01/11	12:20	14.0	100.3	4.8	34.2	8.21	0.09
12	17/01/11	12:20	0.0	100.1	4.7	34.3	8.10	0.09

3.2 Chemical analysis results

A range of chemical analyses were conducted by Scientifics Ltd (see Table 5). Some analyses for hydrazine were also conducted by DVGW-Technologiezentrum Wasser (TZW). Many of these analyses gave negative results, indicating that the analyte of interest was either absent from the sample or present at a concentration lower than the limit of detection. Those analyses for which no positive results were recorded for any of the samples in this report are shown in

Table 10, together with the relevant Environmental Quality Standard (EQS). EQS values were obtained from the Environmental Quality Standards Directive 2008/105/EC (2008) and the European Union Dangerous Substances Directive 76/464/EEC (1976). The Dangerous Substances Directive was codified as 2006/11/EC (2006) and has been integrated into the Water Framework Directive. The EQS values shown are marine standards relating to annual average levels. Positive results obtained are shown by station from **Table 11** to **Table 22**. **Table 23** shows the positive results from the tidal cycle survey. It should be noted that for some analyses (e.g. chloroform, mercury) the limit of detection is greater than the EQS.

3.2.1 Spatial and seasonal survey chemical analysis results

Many of the analytes were not detected, indicating that they were either not present or were present at concentrations below the limits of detection. These analytes are shown in Table 10. The results of analyses that gave results exceeding or equal to the relevant EQS concentrations (or where the EQS was lower than the limit of detection) are shown in **Table 11** to **Table 22** . Hydrazine analyses conducted by DVGW-Technologiezentrum Wasser (TZW) are marked “TZW”. Full results are shown in **Appendix A**. For mass spectrometry techniques, certain compounds may be detected but their identification may be tentative. Where these results are reported (**Table 35** to **Table 46**) negative results are marked as “ND” indicating “none detected”, as the limits of detection may not be readily quantifiable.

The spatial survey provide measurements indicating background conditions against which the results obtained near the cooling water outfall can be compared. For most of the analyses no clear trend was evident when surface and near-bed samples were compared. This is consistent with a well-mixed water column as indicated by the CTD profiles acquired. Nitrate and phosphate were detected in surface water samples only. Total petroleum hydrocarbons were also present in surface samples at higher concentrations than in near-bed samples. Concentrations of zinc, nickel and cadmium were higher in near-bed samples than in surface samples. The possibility that benthic sediments are a source of these metals is supported by the fact that these metals are present in the sediments at concentrations two or three orders of magnitude greater than those measured in the water samples. In general, little difference was evident between the analysis results from Stations 1 to 9 (inshore of Sizewell Bank) and Stations 10 to 12 (offshore of Sizewell Bank). The concentrations of lead measured inside Sizewell Bank were higher than outside, and bromoform was detected on seven occasions, always at Station 5, the cooling water outfall.

Table 10 Water sample analyses with no positive results; the analyte was either not present or present at undetectable levels. Detections limits are given as µg.l^{-1} unless otherwise stated.

Analysis	Limit of detection (µg.l^{-1})	EQS (µg.l^{-1})
Lead as Pb (Dissolved)	1	7.2
Barium as Ba (Dissolved)	10	
Dichloroacetonitrile	10	
Ethanolamine	20 mg.l^{-1}	
Phenol	20	
Bis (2-Chloroethyl) ether	5	
2-Chlorophenol	20	50
1,3-Dichlorobenzene	5	
1,4-Dichlorobenzene	5	
Benzyl alcohol	5	
1,2-Dichlorobenzene	5	
2-Methylphenol	5	
Hexachloroethane	5	
N-Nitroso-di-n-propylamine	5	
3- & 4-Methylphenol	20	
Nitrobenzene	5	
Isophorone	5	
2-Nitrophenol	20	
2,4-Dimethylphenol	20	
Benzoic Acid	100	
Bis (2-Chloroethoxy) methane	5	
2,4-Dichlorophenol	20	20
1,2,4-Trichlorobenzene	5	0.4
Naphthalene	2	5
4-Chlorophenol	20	
4-Chloroaniline	5	
Hexachloro-butadiene	5	0.1
4-Chloro-3-methylphenol	5	40
Hexachlorocyclo-pentadiene	5	
2,4,6-Trichlorophenol	20	
2,4,5-Trichlorophenol	20	
2-Chloronaphthalene	2	
Diphenyl ether	2	
2-Nitroaniline	5	
Chrysene	2	
3,3'-Dichlorobenzidine	20	
Di-n-octylphthalate	2	
Benzo[b]fluoranthene	2	0.03
Dichlorodifluoro-methane	1	
Chloromethane	1	
Vinyl Chloride	1	
Bromomethane	5	
Chloroethane	5	
Trichlorofluoro-methane	1	
1,1-Dichloroethene	1	
trans 1,2-Dichloroethene	1	
1,1-Dichloroethane	1	
2,2-Dichloropropane	1	
cis 1,2-Dichloroethene	1	
Bromochloro-methane	1	
Chloroform	5	2.5
1,1,1-Trichloroethane	1	100
Carbon Tetrachloride	1	12
1,1-Dichloropropene	1	
Benzene	1	8
1,2-Dichloroethane	1	10
Trichloroethene	5	10
1,2-Dichloropropane	1	
Dibromomethane	1	
Bromodichloro-methane	1	
cis 1,3-Dichloropropene	1	
trans 1,3-Dichloropropene	1	
1,1,2-Trichloroethane	1	300
Tetrachloroethene	5	10
1,3-Dichloropropane	1	
Dibromochloro-methane	1	
1,2-Dibromoethane	1	
Chlorobenzene	1	

Analysis	Limit of detection ($\mu g.l^{-1}$)	EQS ($\mu g.l^{-1}$)
Acenaphthylene	2	
Dimethylphthalate	5	
2,6-Dinitrotoluene	5	
3-Nitroaniline	5	
2,4-Dinitrophenol	10	
4-Nitrophenol	50	
2,4-Dinitrotoluene	5	
Diethylphthalate	5	
4-Chlorophenyl-phenylether	5	
4,6-Dinitro-2-methylphenol	50	
4-Nitroaniline	5	
N-Nitrosodiphenyl-amine	5	
4-Bromophenyl-phenylether	5	
Hexachlorobenzene	5	0.01
Pentachlorophenol	50	0.4
Di-n-butylphthalate	5	
Butylbenzyl-phthalate	5	
Benzo[a]anthracene	2	

Analysis	Limit of detection ($\mu g.l^{-1}$)	EQS ($\mu g.l^{-1}$)
1,1,1,2-Tetrachloroethane	1	
Styrene	1	
1,1,2,2-Tetrachloroethane	1	
Bromobenzene	1	
1,2,3-Trichloropropane	1	
2-Chlorotoluene	1	
4-Chlorotoluene	1	
tert-Butylbenzene	1	
1,3-Dichlorobenzene	1	
1,4-Dichlorobenzene	1	
n-Butylbenzene	1	
1,2-Dichlorobenzene	5	
1,2-Dibromo-3-chloropropane	5	
1,2,4-Trichlorobenzene	5	0.4
Hexachlorobutadiene	5	0.1
Naphthalene	2	5
1,2,3-Trichlorobenzene	5	0.4

Table 11 Station 1 spatial survey water sample analysis results which exceed the relevant EQS or where the limit of detection is greater than the EQS. Negative results are presented as less than the limit of detection. Station 1 was located 10 km from the cooling water outfall.

Analysis – Station 1	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**		
			7/4/10 Surface	**7/4/10 Near-bed**	**6/12/10 Surface**
Copper as Cu (Dissolved)	$mg.l^{-1}$	0.005	0.003	0.006	0.003
Zinc as Zn (Dissolved)	$mg.l^{-1}$	0.04	0.012	0.046	0.008
Arsenic as As (Dissolved)	$mg.l^{-1}$	0.025	0.016	0.016	0.031
Mercury as Hg (Dissolved)	$mg.l^{-1}$	0.00005	< 0.0001	< 0.0001	0.0001
Anthracene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002	< 0.002
Fluoranthene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002	< 0.002
bis(2-ethylhexyl)phthalate	$mg.l^{-1}$	0.0013	< 0.005	< 0.005	< 0.005
Benzo[k]fluoranthene	$mg.l^{-1}$	0.000003	0.002	< 0.002	< 0.002
Benzo[a]pyrene	$mg.l^{-1}$	0.000005	0.002	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	$mg.l^{-1}$	0.000002 (sum of concns)	0.003	< 0.002	< 0.002
Benzo[g,h,i]perylene	$mg.l^{-1}$		0.003	< 0.002	< 0.002

Table 12 Station 2 spatial survey water sample analysis results which exceed the relevant EQS or where the limit of detection is greater than the EQS. Negative results are presented as less than the limit of detection. Station 2 was located 2.4 km from the cooling water outfall.

Analysis – Station 2	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**	
			25/2/10 Surface	**15/12/10 Surface**
Mercury as Hg (Dissolved)	$mg.l^{-1}$	0.00005	< 0.0001	< 0.0001
Anthracene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002
Fluoranthene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002
bis(2-Ethylhexyl)phthalate	$mg.l^{-1}$	0.0013	< 0.005	< 0.005
Benzo[k]fluoranthene	$mg.l^{-1}$	0.000003	< 0.002	< 0.002
Benzo[a]pyrene	$mg.l^{-1}$	0.000005	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	$mg.l^{-1}$	0.000002 (sum of concns)	< 0.002	< 0.002
Benzo[g,h,i]perylene	$mg.l^{-1}$		< 0.002	< 0.002

Table 13 Station 3 spatial survey water sample analysis results which exceed or equal the relevant EQS or where the limit of detection is greater than the EQS. Negative results are presented as less than the limit of detection. Station 3 was located 1.1 km from the cooling water outfall.

Analysis – Station 3	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)		
			25/2/10 Surface	25/2/10 Near-bed	6/12/10 Surface
Arsenic as As (Dissolved)	$mg.l^{-1}$	0.025	0.011	0.011	0.031
Mercury as Hg (Dissolved)	$mg.l^{-1}$	0.00005	0.0001	0.0001	0.0001
Anthracene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002	< 0.002
Fluoranthene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002	< 0.002
bis(2-Ethylhexyl)phthalate	$mg.l^{-1}$	0.0013	< 0.005	< 0.005	< 0.005
Benzo[k]fluoranthene	$mg.l^{-1}$	0.000003	< 0.002	< 0.002	< 0.002
Benzo[a]pyrene	$mg.l^{-1}$	0.000005	< 0.002	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	$mg.l^{-1}$	0.000002 (sum of concns)	< 0.002	< 0.002	< 0.002
Benzo[g,h,i]perylene	$mg.l^{-1}$		< 0.002	< 0.002	< 0.002

Table 14 Station 4 spatial survey water sample analysis results which exceed or equal the relevant EQS or where the limit of detection is greater than the EQS. Negative results are presented as less than the limit of detection. Station 4 was located 0.6 km from the cooling water outfall.

Analysis – Station 4	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)	
			25/2/10 Surface	15/12/10 Surface
Copper as Cu (Dissolved)	$mg.l^{-1}$	0.005	0.003	0.005
Mercury as Hg (Dissolved)	$mg.l^{-1}$	0.00005	0.0002	< 0.0001
Anthracene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002
Fluoranthene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002
bis(2-ethylhexyl)phthalate	$mg.l^{-1}$	0.0013	< 0.005	< 0.005
Benzo[k]fluoranthene	$mg.l^{-1}$	0.000003	< 0.002	< 0.002
Benzo[a]pyrene	$mg.l^{-1}$	0.000005	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	$mg.l^{-1}$	0.000002 (sum of concns)	< 0.002	< 0.002
Benzo[g,h,i]perylene	$mg.l^{-1}$		< 0.002	< 0.002

Table 15 Station 5 spatial survey water sample analysis results which exceed or equal the relevant EQS or where the limit of detection is greater than the EQS. Negative results are presented as less than the limit of detection. Station 5 was located at the cooling water outfall.

Analysis – Station 5	Units	EQS (annual average concn.)	Concentration/value (ND = none detected)																				
			25/2/10 surface	25/2/10 near-bed	8/4/10 surface	21/4/10 surface	19/5/10 surface	07/06/10 surface	22/06/10 surface	06/07/10 surface	20/07/10 surface	11/08/10 surface	18/08/10 surface	09/09/10 surface	14/09/10 surface	28/09/10 surface	14/10/10 surface	15/11/10 surface	06/12/10 surface	15/12/10 surface	17/01/11 surface	31/01/11 surface	14/02/11 surface
Cadmium as Cd (Dissolved)	mg.l^{-1}	0.0002	0.0003	<0.0001	<0.0001	<0.0001	<0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Copper as Cu (Dissolved)	mg.l^{-1}	0.005	0.004	0.004	0.003	0.003	0.004	0.003	0.004	0.002	0.004	0.003	0.008	0.007	0.006	0.004	0.005	0.004	0.003	0.004	0.005	0.005	0.004
Arsenic as As (Dissolved)	mg.l^{-1}	0.025	0.011	0.011	0.018	0.017	0.018	0.014	0.022	0.014	0.023	0.017	0.016	0.014	0.015	0.017	0.02	0.019	0.03	0.017	0.025	0.025	0.027
Mercury as Hg (Dissolved)	mg.l^{-1}	0.00005	0.0002	0.0002	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001	< 0.0001	0.0001	0.0001	< 0.0001
Biphenyl	mg.l^{-1}	0.025	< 0.002	< 0.002	< 0.002	< 0.002	0.026	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Anthracene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002	< 0.002	0.007	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Fluoranthene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002	< 0.002	0.004	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
bis(2-ethylhexyl) phthalate	mg.l^{-1}	0.0013	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.007	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Benzo[k] fluoranthene	mg.l^{-1}	0.000003	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Benzo[a]pyrene	mg.l^{-1}	0.000005	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Indeno[1,2,3-cd] pyrene	mg.l^{-1}	0.000002 (sum of concn.)	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Benzo[g,h,i] perylene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002

Table 16 Station 6 spatial survey water sample analysis results which exceed or equal the relevant EQS or where the limit of detection is greater than the EQS. Station 6 was located 0.5 km from the cooling water outfall.

Analysis – Station 6	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)	
			07/04/10 Surface	15/12/10 Surface
Mercury as Hg (Dissolved)	$mg.l^{-1}$	0.00005	< 0.0001	< 0.0001
Anthracene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002
Fluoranthene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002
bis(2-ethylhexyl)phthalate	$mg.l^{-1}$	0.0013	< 0.005	< 0.005
Benzo[k]fluoranthene	$mg.l^{-1}$	0.000003	< 0.002	< 0.002
Benzo[a]pyrene	$mg.l^{-1}$	0.000005	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	$mg.l^{-1}$	0.000002 (sum of concns)	< 0.002	< 0.002
Benzo[g,h,i]perylene	$mg.l^{-1}$		< 0.002	< 0.002

Table 17 Station 7 spatial survey water sample analysis results which exceed or equal the relevant EQS or where the limit of detection is greater than the EQS. Negative results are presented as less than the limit of detection. Station 7 was located 1.1 km from the cooling water outfall.

Analysis – Station 7	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)		
			08/04/10 Surface	08/04/10 Near-bed	31/01/11 Surface
Copper as Cu (Dissolved)	$mg.l^{-1}$	0.005	0.003	0.003	0.006
Mercury as Hg (Dissolved)	$mg.l^{-1}$	0.00005	< 0.0001	< 0.0001	0.0001
Anthracene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002	< 0.002
Fluoranthene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002	< 0.002
bis(2-ethylhexyl)phthalate	$mg.l^{-1}$	0.0013	< 0.002	< 0.002	< 0.005
Benzo[k]fluoranthene	$mg.l^{-1}$	0.000003	< 0.002	< 0.002	< 0.002
Benzo[a]pyrene	$mg.l^{-1}$	0.000005	< 0.002	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	$mg.l^{-1}$	0.000002 (sum of concns)	< 0.002	< 0.002	< 0.002
Benzo[g,h,i]perylene	$mg.l^{-1}$		< 0.002	< 0.002	< 0.002

Table 18 Station 8 spatial survey water sample analysis results which exceed or equal the relevant EQS or where the limit of detection is greater than the EQS. Negative results are presented as less than the limit of detection. Station 8 was located 2.4 km from the cooling water outfall.

Analysis – Station 8	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)	
			08/04/10 Surface	31/01/11 Surface
Copper as Cu (Dissolved)	$mg.l^{-1}$	0.005	0.003	0.006
Arsenic as As (Dissolved)	$mg.l^{-1}$	0.025	0.018	0.025
Mercury as Hg (Dissolved)	$mg.l^{-1}$	0.00005	< 0.0001	0.0001
Anthracene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002
Fluoranthene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002
bis(2-ethylhexyl)phthalate	$mg.l^{-1}$	0.0013	< 0.005	< 0.005
Benzo[k]fluoranthene	$mg.l^{-1}$	0.000003	< 0.002	< 0.002
Benzo[a]pyrene	$mg.l^{-1}$	0.000005	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	$mg.l^{-1}$	0.000002 (sum of concns)	< 0.002	< 0.002
Benzo[g,h,i]perylene	$mg.l^{-1}$		< 0.002	< 0.002

Table 19 Station 9 spatial survey water sample analysis results which exceed or equal the relevant EQS or where the limit of detection is greater than the EQS. Negative results are presented as less than the limit of detection. Station 9 was located 12 km from the cooling water outfall.

Analysis – Station 9	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)		
			08/04/10 Surface	08/04/10 Near-bed	17/01/11 Surface
Copper as Cu (Dissolved)	$mg.l^{-1}$	0.005	0.003	0.004	0.005
Zinc as Zn (Dissolved)	$mg.l^{-1}$	0.04	0.018	0.054	0.022
Arsenic as As (Dissolved)	$mg.l^{-1}$	0.025	0.019	0.019	0.028
Mercury as Hg (Dissolved)	$mg.l^{-1}$	0.00005	< 0.0001	< 0.0001	0.0001
Anthracene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002	< 0.002
Fluoranthene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002	< 0.002
bis(2-ethylhexyl)phthalate	$mg.l^{-1}$	0.0013	< 0.005	< 0.002	< 0.005
Benzo[k]fluoranthene	$mg.l^{-1}$	0.000003	< 0.002	< 0.002	< 0.002
Benzo[a]pyrene	$mg.l^{-1}$	0.000005	< 0.002	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	$mg.l^{-1}$	0.000002 (sum of concns)	0.004	< 0.002	< 0.002
Benzo[g,h,i]perylene	$mg.l^{-1}$		0.004	< 0.002	< 0.002

Table 20 Station 10 spatial survey water sample analysis results which exceed or equal the relevant EQS or where the limit of detection is greater than the EQS. Negative results are presented as less than the limit of detection. Station 10 was located 10.8 km from the cooling water outfall.

Analysis – Station 10	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)			
			07/04/10 Surface	07/04/10 Near-bed	31/01/11 Surface	14/02/11 Near-bed
Copper as Cu (Dissolved)	$mg.l^{-1}$	0.005	0.003	0.003	0.007	0.007
Zinc as Zn (Dissolved)	$mg.l^{-1}$	0.04	0.013	0.043	0.018	0.516
Arsenic as As (Dissolved)	$mg.l^{-1}$	0.025	0.017	0.017	0.023	0.029
Mercury as Hg (Dissolved)	$mg.l^{-1}$	0.00005	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Anthracene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002	< 0.002	< 0.002
Fluoranthene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002	< 0.002	< 0.002
bis(2-ethylhexyl) phthalate	$mg.l^{-1}$	0.0013	< 0.005	< 0.005	< 0.005	< 0.005
Benzo[k]fluoranthene	$mg.l^{-1}$	0.000003	< 0.002	< 0.002	< 0.002	< 0.002
Benzo[a]pyrene	$mg.l^{-1}$	0.000005	< 0.002	< 0.002	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	$mg.l^{-1}$	0.000002 (sum of concns)	< 0.002	< 0.002	< 0.002	< 0.002
Benzo[g,h,i]perylene	$mg.l^{-1}$		< 0.002	< 0.002	< 0.002	< 0.002

Table 21 Station 11 spatial survey water sample analysis results which exceed or equal the relevant EQS or where the limit of detection is greater than the EQS. Negative results are presented as less than the limit of detection. Station 11 was located 3.5 km from the cooling water outfall.

Analysis – Station 11	**Units**	**EQS (annual average concn.)**	**Concentration/value (ND = none detected)**																		
			07/04/10 surface	**21/04/10 surface**	**19/05/10 surface**	**07/06/10 surface**	**22/06/10 surface**	**06/07/10 surface**	**20/07/10 surface**	**11/08/10 surface**	**18/08/10 surface**	**09/09/10 surface**	**14/09/10 surface**	**28/09/10 surface**	**14/10/10 surface**	**15/11/10 surface**	**06/12/10 surface**	**15/12/10 surface**	**17/01/11 surface**	**31/01/11 surface**	**14/02/11 surface**
Copper as Cu (Dissolved)	mg.l^{-1}	0.005	0.002	0.003	0.003	0.004	0.004	0.002	0.004	0.003	0.005	0.007	0.016	0.004	0.005	0.01	0.003	0.007	0.005	0.01	0.004
Zinc as Zn (Dissolved)	mg.l^{-1}	0.04	0.012	0.009	0.007	0.008	0.006	0.003	0.006	0.008	0.006	0.009	0.009	0.009	0.007	0.007	0.008	0.02	0.041	0.011	0.022
Arsenic as As (Dissolved)	mg.l^{-1}	0.025	0.018	0.018	0.018	0.015	0.022	0.015	0.023	0.018	0.016	0.014	0.015	0.016	0.02	0.019	0.031	0.017	0.024	0.025	0.03
Mercury as Hg (Dissolved)	mg.l^{-1}	0.00005	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Anthracene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Fluoranthene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
bis(2-ethylhexyl)phthalate	mg.l^{-1}	0.0013	< 0.005	< 0.005	< 0.005	0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Benzo[k]fluoranthene	mg.l^{-1}	0.000003	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Benzo[a]pyrene	mg.l^{-1}	0.000005	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	mg.l^{-1}	0.000002 (sum of concn.)	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Benzo[g,h,i]perylene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002

Table 22 Station 12 spatial survey water sample analysis results which exceed or equal the relevant EQS or where the limit of detection is greater than the EQS. Negative results are presented as less than the limit of detection. Station 12 was located 11.6 km from the cooling water outfall.

Analysis – Station 12	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)			
			08/04/10 Surface	08/04/10 Near-bed	17/01/11 Surface	17/01/11 Near-bed
Copper as Cu (Dissolved)	mg.l^{-1}	0.005	0.003	0.004	0.007	0.007
Zinc as Zn (Dissolved)	mg.l^{-1}	0.04	0.009	0.08	0.158	0.182
Arsenic as As (Dissolved)	mg.l^{-1}	0.025	0.02	0.02	0.027	0.028
Mercury as Hg (Dissolved)	mg.l^{-1}	0.00005	< 0.0001	< 0.0001	0.0001	0.0001
Anthracene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002	< 0.002
Fluoranthene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002	< 0.002
bis(2-ethylhexyl) phthalate	mg.l^{-1}	0.0013	< 0.005	0.009	< 0.005	0.015
Benzo[k]fluoranthene	mg.l^{-1}	0.000003	< 0.002	< 0.002	< 0.002	< 0.002
Benzo[a]pyrene	mg.l^{-1}	0.000005	< 0.002	< 0.002	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	mg.l^{-1}	0.000002 (sum of concns)	< 0.002	< 0.002	< 0.002	< 0.002
Benzo[g,h,i]perylene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002

3.2.2 Tidal cycle survey results

On 2 March 2010 surface water samples were acquired at station 5 (the cooling water outfall, see **Figure 1**) at hourly intervals between 11:00 and 23:00 UTC. The results are shown in **Table 23**. This survey provided results (see **Table 23**) indicating that most parameters do not show a tidally-driven pattern of variation. Exceptions to this are turbidity and suspended solids. The concentration of suspended solids was at its lowest shortly after local high and low water, and maxima occurred during the mid-tide periods of peak flow when resuspension of sediments would be expected to be greatest, a pattern also followed by turbidity (**Figure 7**). The concentration of total petroleum hydrocarbons (TPH) measured by Fourier transform infrared spectroscopy (FTIR) also displays a tidal signal, showing a peak during the mid-ebb flow (**Figure 8**), though this peak is the result of a single high reading obtained at 15:00. Concentrations of arsenic and copper exceeded EQS levels for all or part of the tidal cycle survey, though neither showed a tidal signal (**Figure 9**).

Table 23 Station 5 tidal cycle survey water sample analysis results. Negative results are presented as less than the limit of detection or “ND” (none detected) for tentatively identified compounds, for which the limits of detection vary. All of the samples represented in this table were surface water samples acquired during 2 March 2010.

Analysis – Station 5 (ND = None detected)	**Units**	**EQS**	**Time sampled (UTC)**												
			11:00	**12:00**	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**
pH	pH units		7.7	7.7	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
Suspended Solids	$mg.l^{-1}$		127	118	332	381	221	215	278	180	108	328	437	134	182
Total Alkalinity as $CaCO_3$	$mg.l^{-1}$		121	121	121	123	123	127	123	125	126	128	124	126	130
Bicarbonate Alkalinity as $CaCO_3$	$mg.l^{-1}$		121	121	121	123	123	127	123	125	126	128	124	126	130
Carbonate Alkalinity as $CaCO_3$	$mg.l^{-1}$		0	0	0	0	0	0	0	0	0	0	0	0	0
Chloride as Cl	$mg.l^{-1}$		9730	11800	12900	13400	15300	15000	10200	12200	14100	13900	12600	11700	13500
Fluoride as F	$mg.l^{-1}$		1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.6	1.3	1.3	1.3
Total Sulphur as SO_4 (Dissolved)	$mg.l^{-1}$		2550	2580	2600	2520	2590	2640	2630	2680	2690	2570	2570	2720	2640
Calcium as Ca (Total)	$mg.l^{-1}$		241	251	243	254	247	243	247	243	258	240	232	211	248
Calcium as Ca (Dissolved)	$mg.l^{-1}$		240	242	240	237	237	243	240	241	240	240	239	233	239
Magnesium as Mg (Total)	$mg.l^{-1}$		1270	1240	1210	1250	1230	1200	1250	1280	1360	1240	1350	1140	1340
Magnesium as Mg (Dissolved)	$mg.l^{-1}$		1200	1220	1190	1200	1220	1200	1200	1250	1330	1210	1190	1250	1240
Strontium as Sr (Total)	$mg.l^{-1}$		4.38	4.45	4.35	4.57	4.41	4.39	4.43	4.39	4.65	4.36	4.26	3.88	4.52
Strontium as Sr (Dissolved)	$mg.l^{-1}$		4.26	4.32	4.33	4.32	4.36	4.37	4.35	4.33	4.27	4.32	4.29	4.24	4.25
Sodium as Na	$mg.l^{-1}$		10500	10300	10500	10500	10300	10900	10900	10900	10300	10700	10600	10500	11000

Analysis – Station 5 (ND = None detected)	**Units**	**EQS**	**Time sampled (UTC)**												
			11:00	**12:00**	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**
(Dissolved)															

Analysis – Station 5 (ND = None detected)	**Units**	**EQS**	**Time sampled (UTC)**												
			11:00	**12:00**	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**
Potassium as K (Total)	mg.l^{-1}		559	584	560	601	565	567	578	592	622	576	585	519	606
Potassium as K (Dissolved)	mg.l^{-1}		551	554	547	541	549	562	567	580	589	561	555	574	572
Nickel as Ni (Total)	mg.l^{-1}		0.005	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.005	0.004	0.004	0.004	0.004
Nickel as Ni (Dissolved)	mg.l^{-1}	0.02	0.006	0.007	0.005	0.005	0.005	0.004	0.004	0.004	0.005	0.004	0.005	0.005	0.005
Chromium as Cr (Total)	mg.l^{-1}		0.002	0.002	0.003	0.001	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.002	0.002
Chromium as Cr (Dissolved)	mg.l^{-1}	0.015	0.005	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.003	0.002	0.002
Cadmium as Cd (Total)	mg.l^{-1}		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cadmium as Cd (Dissolved)	mg.l^{-1}	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Copper as Cu (Total)	mg.l^{-1}		0.015	0.011	0.009	0.007	0.007	0.006	0.007	0.007	0.006	0.007	0.007	0.006	0.005
Copper as Cu (Dissolved)	mg.l^{-1}	0.005	0.005	0.025	0.012	0.009	0.009	0.009	0.009	0.009	0.009	0.008	0.008	0.007	0.006
Lead as Pb (Total)	mg.l^{-1}		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc as Zn (Total)	mg.l^{-1}		0.009	0.007	0.008	0.007	0.012	0.008	0.009	0.007	0.007	0.008	0.011	0.009	0.008
Zinc as Zn (Dissolved)	mg.l^{-1}	0.04	0.008	0.007	0.007	0.007	0.009	0.009	0.009	0.008	0.009	0.008	0.011	0.009	0.008
Manganese as Mn (Dissolved)	mg.l^{-1}		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Iron as Fe (Total)	mg.l^{-1}		0.07	0.11	0.9	0.14	1.07	0.07	0.4	0.06	0.25	0.06	0.06	0.13	0.3
Iron as Fe (Dissolved)	mg.l^{-1}	1	0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Aluminium as Al	mg.l^{-1}		0.01	< 0.01	< 0.01	0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01

Analysis – Station 5 (ND = None detected)	Units	EQS	Time sampled (UTC)												
			11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
(Dissolved)															

Analysis – Station 5 (ND = None detected)	**Units**	**EQS**	**Time sampled (UTC)**												
			11:00	**12:00**	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**
Arsenic as As (Total)	$mg.l^{-1}$		0.018	0.018	0.017	0.016	0.017	0.023	0.015	0.023	0.018	0.03	0.028	0.003	0.021
Arsenic as As (Dissolved)	$mg.l^{-1}$	0.025	0.021	0.024	0.025	0.027	0.029	0.031	0.031	0.033	0.035	0.035	0.036	0.039	0.039
Boron as B (Total)	$mg.l^{-1}$		4.71	4.39	4.42	4.63	4.43	4.28	4.55	4.54	4.74	4.38	4.77	4.02	4.66
Boron as B (Dissolved)	$mg.l^{-1}$		4.44	4.32	4.2	4.22	4.2	4.2	4.19	4.35	4.61	4.22	4.14	4.34	4.32
Mercury as Hg (Total)	$mg.l^{-1}$		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Mercury as Hg (Dissolved)	$mg.l^{-1}$	0.00005	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Selenium as Se (Dissolved)	$mg.l^{-1}$		0.044	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium as Se (Total)	$mg.l^{-1}$		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Molybdenum as Mo (Total)	$mg.l^{-1}$		0.011	0.008	0.009	0.008	0.008	0.008	0.009	0.008	0.006	0.009	0.009	0.008	0.007
Molybdenum as Mo (Dissolved)	$mg.l^{-1}$		0.011	0.011	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cobalt as Co (Total)	$mg.l^{-1}$		<0.001	0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001
Cobalt as Co (Dissolved)	$mg.l^{-1}$		<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001
Ammoniacal Nitrogen as N	$mg.l^{-1}$		0.46	0.46	0.46	0.46	0.2	0.45	0.45	0.2	0.2	0.45	0.43	0.2	0.43
Nitrite as N	$mg.l^{-1}$		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Nitrate as N	$mg.l^{-1}$		0.4	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Phosphate as P	$mg.l^{-1}$		0.07	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02
Chemical Oxygen Demand (Settled)	$mg.l^{-1}$		160	150	180	160	220	190	180	160	190	220	120	210	210

Analysis – Station 5 (ND = None detected)	**Units**	**EQS**	**Time sampled (UTC)**												
			11:00	**12:00**	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**
Total Organic Carbon	mg.l^{-1}		0.49	0.57	0.48	0.55	0.52	0.44	0.48	0.47	0.49	0.55	0.54	0.5	0.54
Salinity	ppt		38	38	38.4	38.4	38.9	38.8	39.1	38.8	38.3	38.6	38.3	38.5	38.7
Turbidity N.T.U	NTU		78	200	220	250	200	150	200	120	110	190	310	140	110
Bromide as Br	mg.l^{-1}		185	230	188	170	190	191	199	210	204	170	172	190	168
Iodide as I	mg.l^{-1}		< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Barium as Ba (Total)	mg.l^{-1}		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Lithium as Li (DIssolved)	mg.l^{-1}		0.07	0.07	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Silicon as Si (Total)	mg.l^{-1}		0.4	0.5	1.2	0.5	1.2	0.4	0.8	0.4	0.5	0.4	0.4	0.4	0.6
MBAS as Lauryl Sulphate	µg.l^{-1}		< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
Chlorophyll A	µg.l^{-1}		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Biochemical Oxygen Demand	mg.l^{-1}		3.0	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Dissolved Organic Carbon	mg.l^{-1}		0.55	0.58	0.54	0.5	0.52	0.46	0.53	0.54	0.58	0.53	0.54	0.47	0.52
Total petroleum hydrocarbons (FTIRPER)	mg.l^{-1}		< 0.3	< 0.3	0.3	0.4	15.8	0.5	0.4	0.3	< 0.3	< 0.3	< 0.3	< 0.3	1
Total Viable Count @ 22°C	Counts .ml^{-1}		1504	1376	704	352	288	320	608	416	296	528	456	576	688
Total petroleum hydrocarbons (GC)	mg.l^{-1}		0.05	< 0.01	0.04	< 0.01	< 0.01	< 0.01	0.01	0.03	0.02	0.02	0.01	< 0.01	< 0.01
2,4,6-tribromophenol	µg.l^{-1}		< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Cationic Detergents	mg.l^{-1}		< 1	< 1	< 1	< 1	< 1	< 1	1.6	3.2	< 1.0	< 1.0	< 1.0	< 1.0	1.6

Analysis – Station 5 (ND = None detected)	**Units**	**EQS**	**Time sampled (UTC)**												
			11:00	**12:00**	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**
Dibromoacetic acid	µg.l^{-1}		< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Dibromoacetonitrile	µg.l^{-1}		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Hydrazine	µg.l^{-1}		0.5	0.5	0.5	10	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Morpholine	mg.l^{-1}		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Bis (2-Chloroisopropyl) ether	mg.l^{-1}		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
2-Methylnaphthalene	mg.l^{-1}		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
1-Methylnaphthalene	mg.l^{-1}		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Biphenyl	mg.l^{-1}	0.025	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Acenaphthene	mg.l^{-1}		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Dibenzofuran	mg.l^{-1}		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fluorene	mg.l^{-1}		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Phenanthrene	mg.l^{-1}		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Anthracene	mg.l^{-1}	0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Fluoranthene	mg.l^{-1}	0.0001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Pyrene	mg.l^{-1}		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
bis(2-Ethylhexyl) phthalate	mg.l^{-1}		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Benzo[k] fluoranthene	mg.l^{-1}		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Benzo[a]pyrene	mg.l^{-1}		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Indeno[1,2,3-cd]pyrene	mg.l^{-1}		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Dibenzo[a,h]	mg.l^{-1}		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002

Analysis – Station 5 (ND = None detected)	**Units**	**EQS**	**Time sampled (UTC)**												
			11:00	**12:00**	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**
anthracene															
Benzo[g,h,i] perylene	$mg.l^{-1}$		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Toluene	$\mu g.l^{-1}$	10	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Ethylbenzene	$\mu g.l^{-1}$		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
m and p-Xylene	$\mu g.l^{-1}$	30	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
o-Xylene	$\mu g.l^{-1}$	30	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Bromoform	$\mu g.l^{-1}$		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
iso-Propylbenzene	$\mu g.l^{-1}$		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Propylbenzene	$\mu g.l^{-1}$		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,3,5-Trimethylbenzene	$\mu g.l^{-1}$		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,2,4-Trimethylbenzene	$\mu g.l^{-1}$		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
sec-Butylbenzene	$\mu g.l^{-1}$		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
p-Isopropyltoluene	$\mu g.l^{-1}$		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0

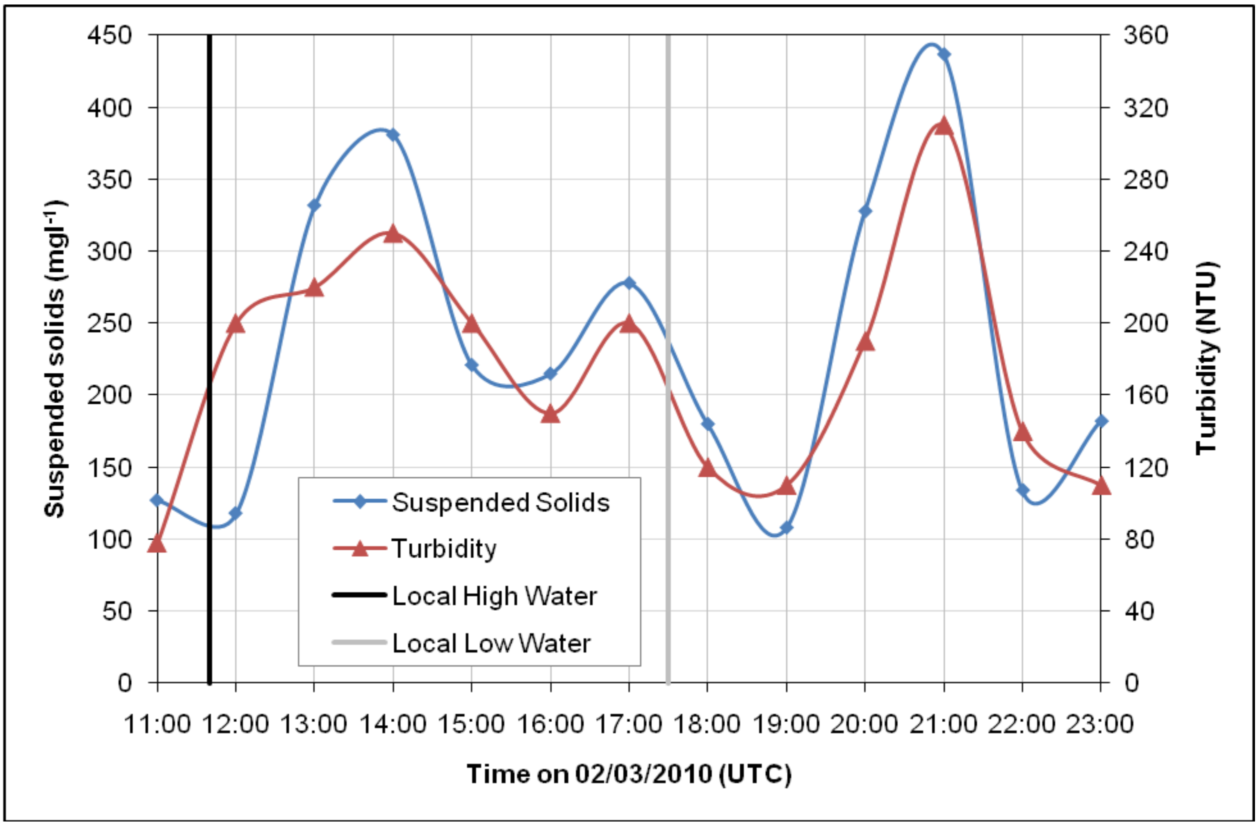

Figure 7 Suspended solids concentration and turbidity obtained during the tidal cycle survey (spring tide conditions) conducted at Station 5 (the cooling water outfall).

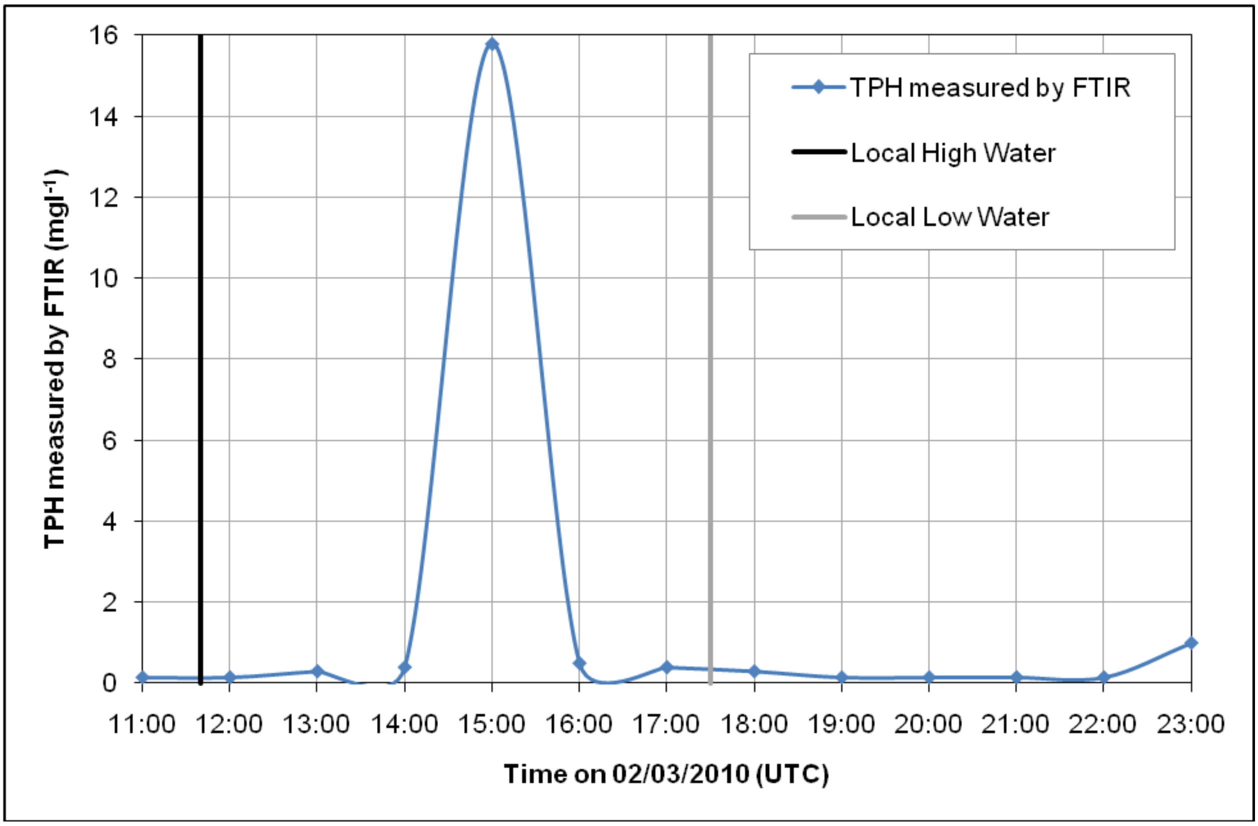

Figure 8 Total petroleum hydrocarbon concentration (TPH) measured by Fourier transform infrared spectroscopy (FTIR) and obtained during the tidal cycle survey conducted at Station 5 (the cooling water outfall).

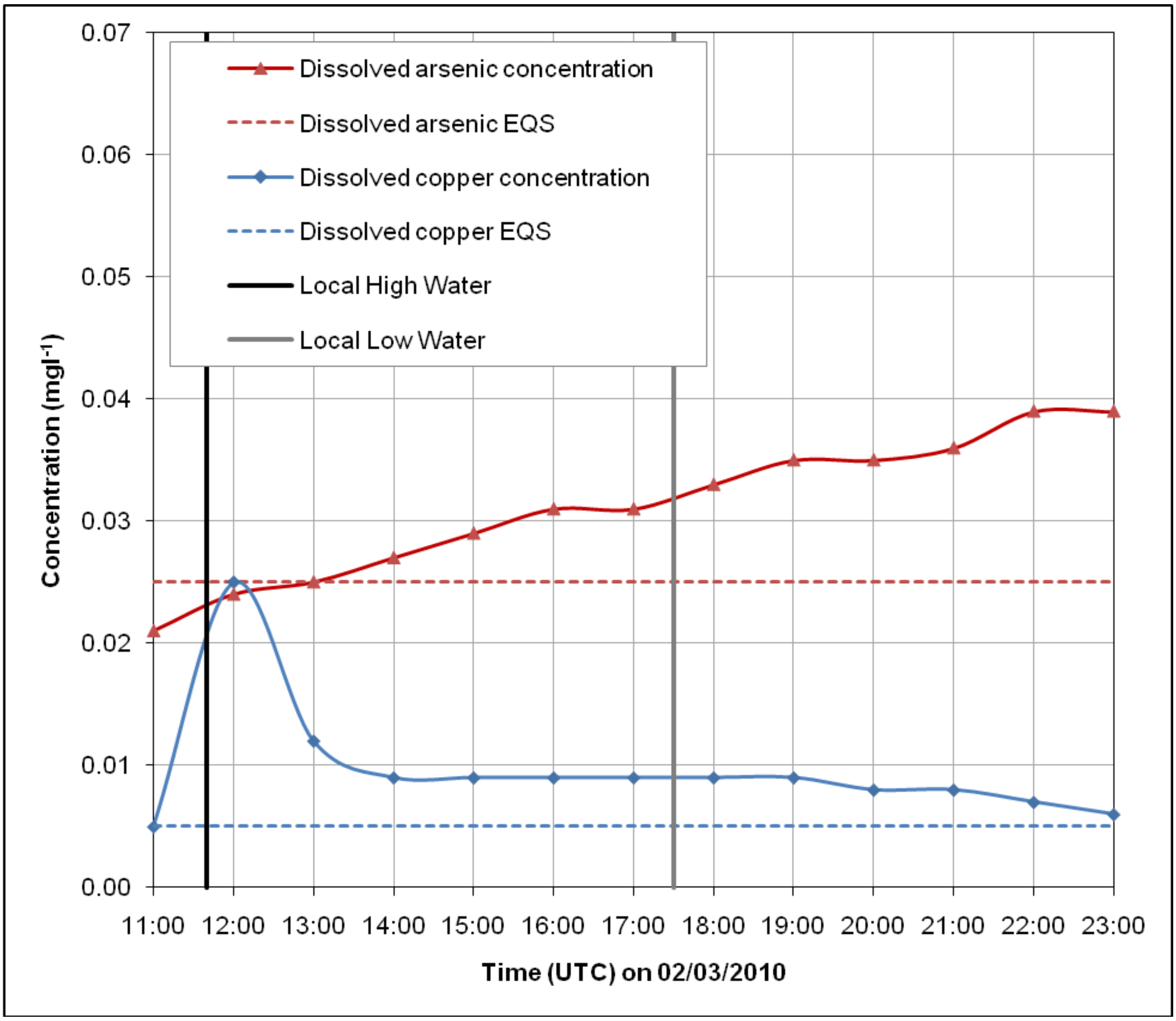

Figure 9 Dissolved arsenic and copper concentrations obtained during the tidal cycle survey conducted at Station 5 (the cooling water outfall).

3.2.3 Total Residual Oxidant (TRO)

TRO measurements (see Table 9) ranged from 0.01 mg.l^{-1} to 0.16 mg.l^{-1}. Each TRO value in Table 9 was obtained by taking the mean of triplicate readings from three separate sub-samples. The limit of detection for the TRO analysis was 0.02 mg.l^{-1} and negative (zero) analysis results were taken to be 0.01 mg.l^{-1} (half of the limit of detection) when calculating the mean values for each station and their standard deviations. The mean values for each station are presented in **Figure 10** and also Table 24 where the numbers of individual readings and the standard deviations are also given. All of the stations showed mean concentrations within one standard deviation of the limit of detection. The mean of all individual readings (n = 725) taken was 0.04 mg.l^{-1} (standard deviation 0.045).

TRO appears to be elevated at Station 5 compared with nearby stations along the coast (Stations 2, 3 and 4 to the north of the outfall and 6, 7 and 8 to the south). The TRO elevation reduces to limit of detection within 500 m to the north and 2.4 km to the south (at Stations 6 and 2 respectively). The highest mean TRO concentration was observed at Station 12, over 11 km south of the cooling water outfall, and the second highest at Station 9, 12 km south of the outfall. Stations 9 and 12 were sampled on two occasions during the survey programme on 08/04/2010 and 17/01/2011. The TRO measurements taken at other Stations on those days are presented in

Table 25. Some of the TRO measurements at stations other than 9 and 12 were average or lower than average for those stations (for instance at Stations 5 and 7), indicating that the measurements at Stations 9

and 12 were not the result of systematically elevated analyses on those days. This is reinforced by the observation that the TRO elevation observed at Stations 9 and 12 on the 08/04/2010 occurred in the surface samples only and not in the samples taken from near the seabed. These results do not suggest that TRO was regionally elevated because samples taken at other stations on the same day were unremarkable. The high TRO values therefore appear to be the result of localised TRO levels in the south of the survey area, or an unidentified factor causing spurious elevated readings. Manganese or chromium are known to have the potential to cause spurious elevated TRO readings (HACH, 2006) but no elevated levels of these substances were observed in the water samples from Stations 9 and 12. No spatial pattern exists to suggest that the elevated TRO at the southerly stations is linked to the Sizewell cooling water outfall.

Figure 11 shows that no clear temporal pattern of TRO was evident during a flood ebb cycle. The maximum mean TRO value occurred at 15:00 on the peak flow of the ebb tide, indicating increased TRO levels to the south of Sizewell. No similar maximum was observed during the peak flow of the flood tide. Peak concentrations of TRO might be expected to occur during slack water when water from the outfall can form a buoyant pool around the outfall structure rather than being advected away by the tidal flow. No such peaks are observed and so there is no evidence from this survey that TRO levels are driven by out-flowing cooling water beyond the localised increase observed in **Figure 10**.

Figure 12 shows the individual TRO measurements plotted against water temperature. Water temperature varies seasonally, but higher water temperatures also indicate samples containing a higher proportion of warm water from the outfall. No link between temperature and TRO is apparent: some high TRO measurements were acquired from cold water samples and some warm water samples gave low TRO readings.

Table 24 TRO measurements for each station

Station	Distance from outfall (km)	Mean TRO (mg.l^{-1})	Standard deviation	Number of readings
1	10	0.04	0.044	27
2	2.4	0.02	0.015	18
3	1.1	0.03	0.025	27
4	0.6	0.03	0.033	18
5	0.0	0.04	0.042	304
6	0.5	0.02	0.023	18
7	1.1	0.02	0.029	27
8	2.4	0.02	0.032	18
9	12.0	0.06	0.052	26
10	10.8	0.02	0.029	36
11	3.5	0.04	0.034	171
12	11.6	0.09	0.071	35
All stations	**n/a**	**0.04**	**0.042**	**725**

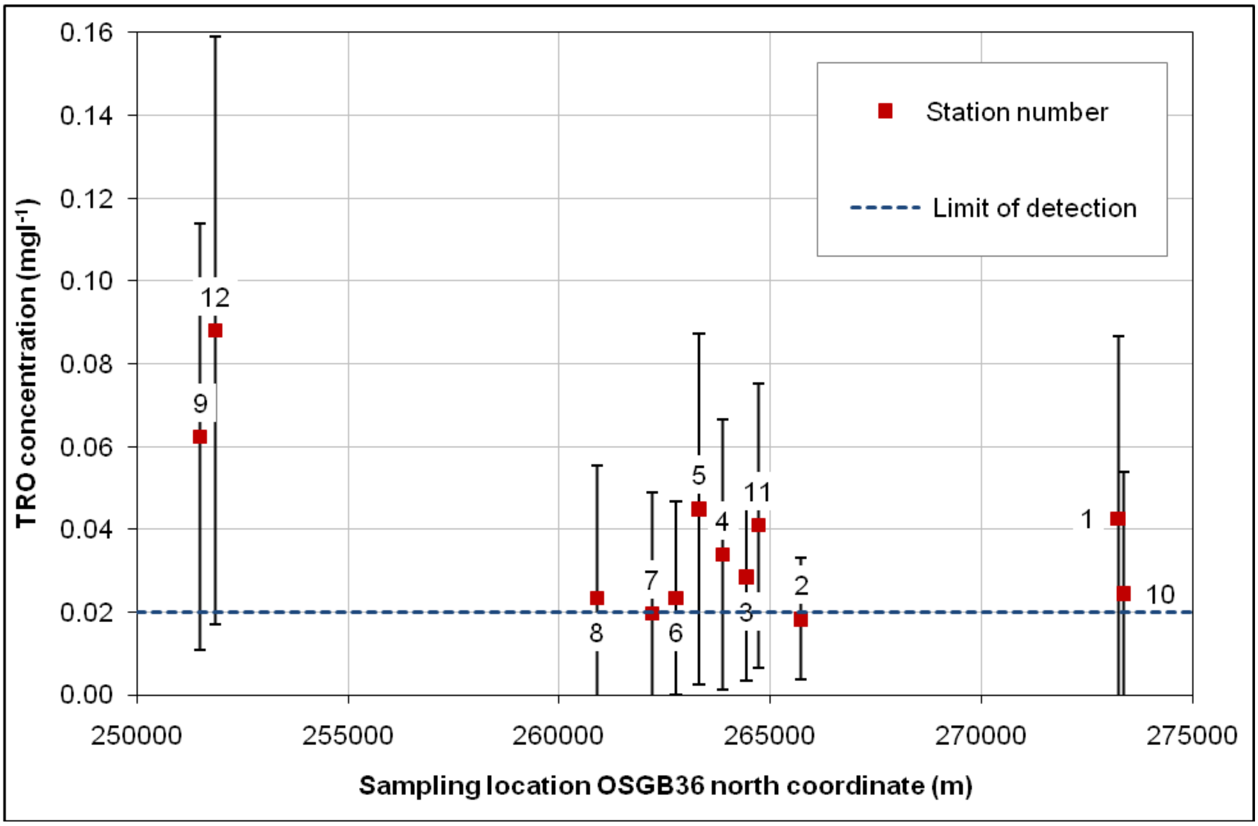

Figure 10 TRO values for each station plotted against the sample locations' north coordinates. Error bars show ± 1 standard deviation of the TRO measurements for that station.

Table 25 TRO analyses conducted on the days during which Stations 9 and 12 were sampled. Results from Stations 9 and 12 are highlighted in bold.

Sampling date	Station	Sample depth (m)	Mean TRO (mg.l^{-1})	Standard deviation	Number of TRO analyses carried out
08/04/2010	5	0	0.02	0.017	9
08/04/2010	7	0	0.01	0.000	9
08/04/2010	7	7	0.04	0.047	9
08/04/2010	8	0	0.03	0.041	9
08/04/2010	**9**	**0**	**0.10**	**0.046**	**8**
08/04/2010	**9**	**5**	**0.02**	**0.031**	**9**
08/04/2010	**12**	**0**	**0.16**	**0.097**	**9**
08/04/2010	**12**	**17**	**0.02**	**0.016**	**9**
17/01/2011	5	0	0.02	0.026	7
17/01/2011	**9**	**0**	**0.06**	**0.048**	**9**
17/01/2011	11	0	0.04	0.044	9
17/01/2011	**12**	**0**	**0.09**	**0.016**	**9**
17/01/2011	**12**	**17**	**0.09**	**0.034**	**8**

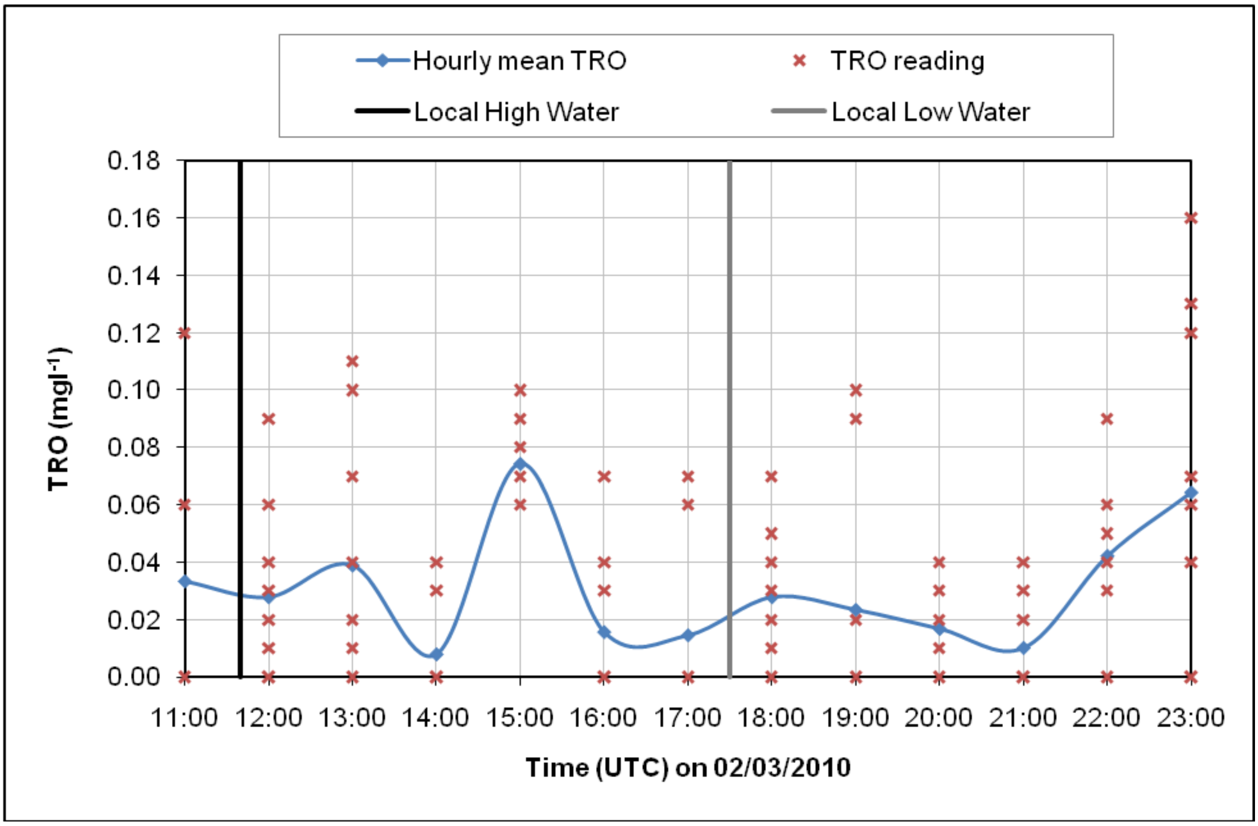

Figure 11 TRO values measured over a tidal cycle during spring tide conditions at Station 5

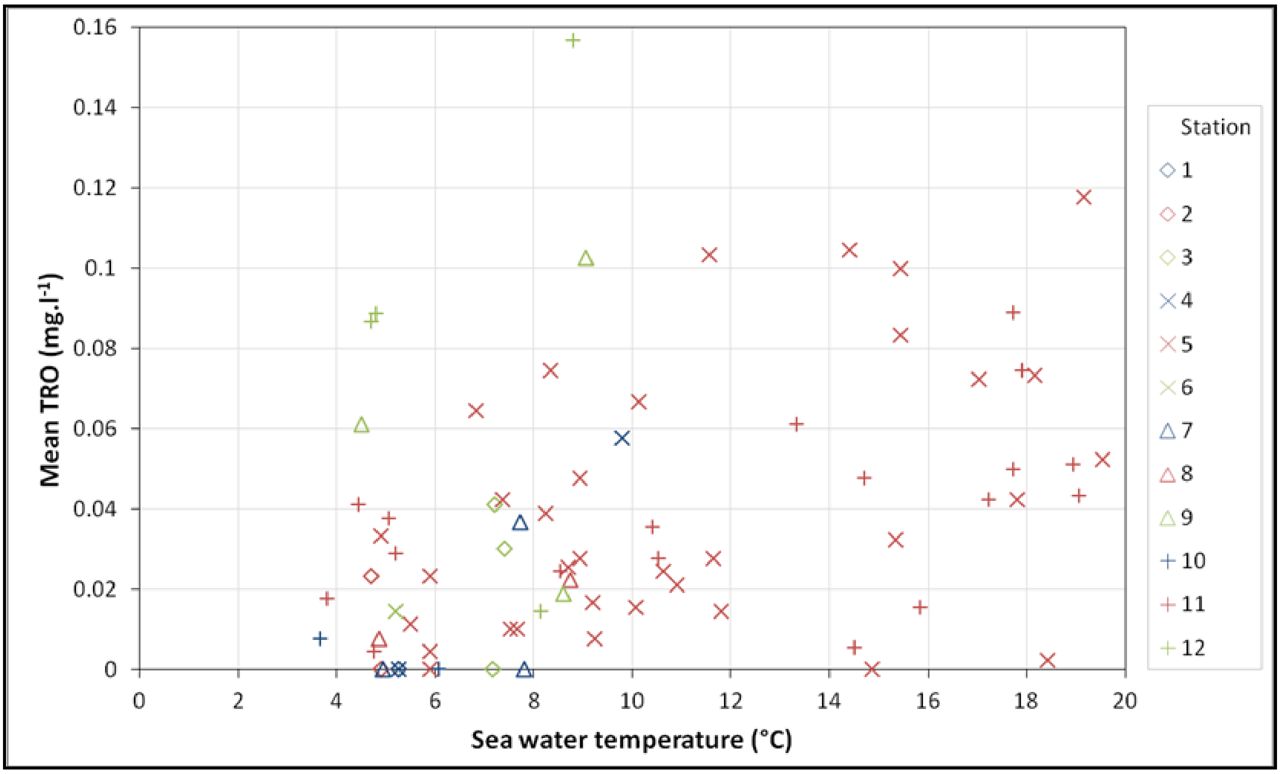

Figure 12 Individual TRO readings taken during the survey period plotted against water temperature.

3.2.4 Hydrazine

At the outset of the programme, the hydrazine analysis offered by Scientifics Ltd appeared to be the most suitable analysis for the proposed monitoring. Following the analysis of hydrazine results presented in BEEMS Technical Report TR130, Cefas were concerned about the validity of the relatively high concentrations of hydrazine apparently being detected. From August 2010 triplicate hydrazine samples (instead of a single sample) were acquired and analysed for each station visited. Surface water samples were also acquired from locations more distant from Sizewell. The results of these analyses are shown in **Table 26**. It can be seen that high hydrazine concentrations (up to 7 µg.l^{-1}) were recorded, even in Lowestoft, over 27 km to the north of the cooling water outfall. Following a request from Cefas, Scientifics Ltd and Mountainheath Ltd (who conducted the hydrazine analyses on Scientifics Ltd's behalf) examined their analytical methods and calculated the limit of quantification for the hydrazine analysis for natural sea water samples. The limit of quantification was estimated to be 10 µg.l^{-1} and they advised that any results below this level should be interpreted with caution.

Examination of the triplicate results of the hydrazine analyses revealed considerable variation in the results from samples taken from the same sampling bucket. Triplicate samples acquired on 31/01/2011 at Station 5, for example, returned analysis results of < 1, 21.7 and 2.4 µg.l^{-1} (see **Table 27**). Concerns regarding the elevated concentrations being measured by Scientifics Ltd, exacerbated by the wide variation in the analysis results obtained from triplicate samples and the analysing laboratory's comments regarding the limit of quantification, led Cefas to seek an alternative, more sensitive analysis. DVGW-Technologiezentrum Wasser (TZW) were contacted on EDF's recommendation. TZW had considerable experience analysing hydrazine in fresh water samples using liquid-liquid-extraction and subsequent GC-MS detection after derivatization. TZW agreed to carry out validation experiments to assess the applicability of their technique to seawater sample analysis. TZW found that their technique was suitable for analysing seawater samples, and began analysing samples for Cefas during November 2010. Analysing spiked samples showed that TZW could achieve the same limit of detection for both seawater and fresh water samples: 0.01µg.l^{-1}. During sampling operations a 1 litre sample was acquired for analysis by TZW alongside the triplicate samples acquired for Scientifics Ltd. All of the hydrazine samples acquired were acidified (using 10 ml of 1 M hydrochloric acid per litre of seawater) in order to stabilise the sample and prevent degradation of the hydrazine. Further work conducted by Cefas involving hydrazine analysis by TZW (BEEMS Technical Reports TR146 and TR145) indicated that the sample were stable once acidified.

Table 26 Hydrazine results from Scientifics Ltd for analyses of samples acquired from outside the spatial survey area.

Date	Time	Location (WGS84)			Hydrazine concentration (µg.l^{-1})			
		Latitude (N)	Longitude (E)	Description	Replicate 1	Replicate 2	Replicate 3	Mean
07/06/2010	08:26	52º 25.0'	001º 48.0'	S13	3.7	-	-	3.7
20/07/2010	16:00	52º 28.3'	001º 45.3'	Lowestoft Trawl Dock	0.5	-	-	0.5
11/08/2010	12:05	52º 18.8'	001º 40.9'	Southwold Harbour entrance	4.8	-	-	4.8
18/08/2010	15:45	52º 28.4'	001º 44.4'	Lowestoft North Quay	6.8	6.2	7.9	7.0
14/10/2010	08:10	52º 28.3'	001º 45.3'	Lowestoft Trawl Dock	4.0	10	4.0	6.0

The hydrazine concentrations measured by TZW are shown in **Table 27**, together with the concentrations measured by Scientifics from the same samples. All of the TZW results were negative (i.e. < 0.01 µg.l^{-1}) except for the concentration measured in the sample from Station 11 acquired on 15/12/2010, which was

0.01 µg.l^{-1}. The TZW mass spectrometry method was a far more sensitive than the Scientifics Ltd technique, with a limit of detection able to detect hydrazine at concentrations two orders of magnitude lower than that of Scientifics Ltd. Cefas therefore considers that the hydrazine results provided by Scientifics Ltd to be unreliable. One possible explanation for this is that the spectrophotometric technique used by Scientifics Ltd, although capable of resolving concentrations of 1 µg.l^{-1} in artificial seawater samples, appear to have been confounded by some sort of interference related to the suspended sediment present in the analysed samples or another unknown cause. This monitoring programme has therefore gathered approximately three months of reliable hydrazine data (November 2010 to February 2011) during which period the concentration of hydrazine measured has been less than or equal to 0.01 µg.l^{-1}. The TZW and Scientifics Ltd results are shown plotted by latitude in **Figure 13**, showing how the higher levels of hydrazine recorded by Scientifics Ltd are not detected by the more sensitive GC-MS technique applied by TZW.

Table 27 A comparison of hydrazine concentrations measured by different analytical techniques. Scientifics Ltd used an ultraviolet-visible spectrophotometry technique. TZW used a liquid-liquid extraction followed by gas chromatography mass spectrometry.

Station	Sampling date	Surface (s) or near-bed (b) sample	Scientifics results (µg.l^{-1})				TZW result (µg.l^{-1})
			Sample A	Sample B	Sample C	Mean	
1	06/12/2010	s	< 1	< 1	2.6	1.2	< 0.01
2	15/12/2010	s	2.4	3.9	3.7	3.3	< 0.01
3	06/12/2010	s	< 1	< 1	< 1	0.5	< 0.01
4	15/12/2010	s	4.5	4.1	5.2	4.6	< 0.01
5	15/11/2010	s	1.1	4.1		2.6	< 0.01
5	06/12/2010	s	< 1	< 1	< 1	0.5	< 0.01
5	15/12/2010	s	12.2	14.0	8.4	11.5	< 0.01
5	17/01/2011	s	< 1	< 1	< 1	0.5	< 0.01
5	31/01/2011	s	< 1	21.7	2.4	8.2	< 0.01
5	14/02/2011	s	1.7	< 1	< 1	0.9	< 0.01
6	15/12/2010	s	2.1	3.7	2.8	2.9	< 0.01
7	31/01/2011	s	2.5	1.4	< 1	1.5	< 0.01
8	31/01/2011	s	1.0	7.8	4.6	4.5	< 0.01
9	17/01/2011	s	4.0	6.0	40.0	16.7	< 0.01
10	31/01/2011	s	4.2	2.0	1.9	2.7	< 0.01
10	14/02/2011	b	1.1	1.5	1.6	1.4	< 0.01
11	15/11/2010	s	2.6	< 1	1.9	1.7	< 0.01
11	06/12/2010	s	< 1	< 1	5.7	2.2	< 0.01
11	15/12/2010	s	7.2	4.1	6.2	5.8	< 0.01
11	17/01/2011	s	1.0	4.0	< 1	1.8	< 0.01
11	31/01/2011	s	2.5	1.9	< 1	1.6	< 0.01
11	14/02/2011	s	3.1	4.5	3.1	3.6	< 0.01
12	17/01/2011	s	4.0	2.0	< 1	2.2	< 0.01
12	17/01/2011	b	40.0	7.0	1.0	16.0	< 0.01

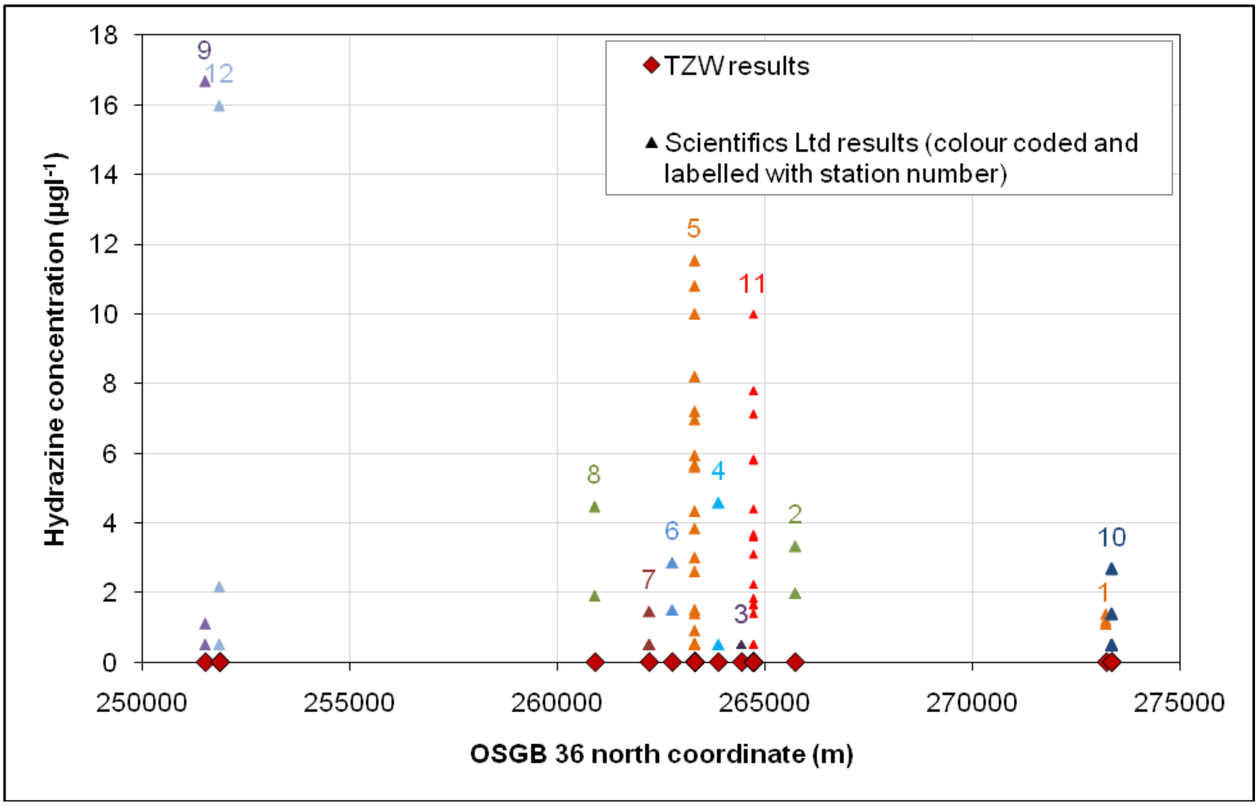

Figure 13 Hydrazine concentrations measured across the survey area including results from both analysing laboratories. Station 5 was located at the cooling water outfall.

3.2.5 Morpholine

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) are summarised in **Table 28**. For all of the spatial survey results (taking negative results as 1 mg.l^{-1}, half of the detection limit) the mean concentration of morpholine measured was 2.0 mg.l^{-1}. 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 cryptic. Analytical problems or some form of interference are possible explanations, as is an external, unknown source of morpholine.

Table 28 A summary of positive morpholine results

Station	Date	Time	Morpholine concentration (mg.l^{-1})
5	21/04/2010	09:45	14.8
5	22/06/2010	09:30	34.5
11	22/06/2010	10:00	31.8

3.2.6 Analysis results exceeding EQS values

Only a small proportion of the analyses conducted gave results in excess of the EQS values. These analyses are summarised in **Table 29** (metals and metalloids) and **Table 30** (organic compounds).

Table 29 Metal and metalloid analysis results exceeding EQS values

Station	Sample depth (m)	Date acquired	Time acquired (UTC)	Analysis	Result (mg.l^{-1})	EQS (mg.l^{-1})
1	5	07/04/2010	11:50	Copper (dissolved)	0.006	0.005
1	5	07/04/2010	11:50	Zinc (dissolved)	0.046	0.04
1	0	06/12/2010	11:30	Arsenic (dissolved)	0.031	0.025
1	0	06/12/2010	11:30	Mercury (dissolved)	0.0001	0.00005
3	0	25/02//2010	10:38	Mercury (dissolved)	0.0001	0.00005
3	4	25/02//2010	11:25	Mercury (dissolved)	0.0001	0.00005
3	0	06/12/2010	10:40	Mercury (dissolved)	0.0001	0.00005
3	0	06/12/2010	10:40	Arsenic (dissolved)	0.031	0.025
4	0	25/02//2010	12:20	Mercury (dissolved)	0.0002	0.00005
5	5	25/02//2010	13:25	Mercury (dissolved)	0.0002	0.00005
5	0	25/02//2010	13:05	Mercury (dissolved)	0.0002	0.00005
5	0	06/07/2010	12:30	Mercury (dissolved)	0.0001	0.00005
5	0	06/12/2010	10:02	Mercury (dissolved)	0.0001	0.00005
5	0	17/01/2010	15:25	Mercury (dissolved)	0.0001	0.00005
5	0	31/01/2011	14:00	Mercury (dissolved)	0.0001	0.00005
5	0	02/03/2010	12:00	Copper (dissolved)	0.025	0.005
5	0	02/03/2010	13:00	Copper (dissolved)	0.012	0.005
5	0	02/03/2010	14:00	Copper (dissolved)	0.009	0.005
5	0	02/03/2010	15:00	Copper (dissolved)	0.009	0.005
5	0	02/03/2010	16:00	Copper (dissolved)	0.009	0.005
5	0	02/03/2010	17:00	Copper (dissolved)	0.009	0.005
5	0	02/03/2010	18:00	Copper (dissolved)	0.009	0.005
5	0	02/03/2010	19:00	Copper (dissolved)	0.009	0.005
5	0	02/03/2010	20:00	Copper (dissolved)	0.008	0.005
5	0	02/03/2010	21:00	Copper (dissolved)	0.008	0.005
5	0	02/03/2010	22:00	Copper (dissolved)	0.007	0.005
5	0	02/03/2010	23:00	Copper (dissolved)	0.006	0.005
5	0	18/08/2010	12:05	Copper (dissolved)	0.008	0.005
5	0	09/09/2010	09:45	Copper (dissolved)	0.007	0.005
5	0	14/09/2010	10:45	Copper (dissolved)	0.006	0.005
5	0	02/03/2010	14:00	Arsenic (dissolved)	0.027	0.025
5	0	02/03/2010	15:00	Arsenic (dissolved)	0.029	0.025
5	0	02/03/2010	16:00	Arsenic (dissolved)	0.031	0.025

Station	Sample depth (m)	Date acquired	Time acquired (UTC)	Analysis	Result (mg.l^{-1})	EQS (mg.l^{-1})
5	0	02/03/2010	17:00	Arsenic (dissolved)	0.031	0.025
5	0	02/03/2010	18:00	Arsenic (dissolved)	0.033	0.025
5	0	02/03/2010	19:00	Arsenic (dissolved)	0.035	0.025
5	0	02/03/2010	20:00	Arsenic (dissolved)	0.035	0.025
5	0	02/03/2010	21:00	Arsenic (dissolved)	0.036	0.025
5	0	02/03/2010	22:00	Arsenic (dissolved)	0.039	0.025
5	0	02/03/2010	23:00	Arsenic (dissolved)	0.039	0.025
5	0	14/02/2010	13:30	Arsenic (dissolved)	0.027	0.025
5	0	25/02/2010	13:05	Cadmium (dissolved)	0.0003	0.0002
5	0	17/01/2011	15:25	Mercury (dissolved)	0.0001	0.00005
5	0	31/01/2011	14:00	Mercury (dissolved)	0.0001	0.00005
7	0	31/01/2011	11:20	Copper (dissolved)	0.006	0.005
7	0	31/01/2011	11:20	Mercury (dissolved)	0.0001	0.00005
8	0	31/01/2011	10:50	Copper (dissolved)	0.006	0.005
8	0	31/01/2011	10:50	Mercury (dissolved)	0.0001	0.00005
9	5	08/04/2010	14:30	Zinc (dissolved)	0.054	0.04
9	0	17/01/2011	14:35	Arsenic (dissolved)	0.028	0.025
9	0	17/01/2011	14:35	Mercury (dissolved)	0.0001	0.00005
10	11	07/04/2010	10:20	Zinc (dissolved)	0.043	0.04
10	12	14/02/2011	11:00	Zinc (dissolved)	0.516	0.04
10	0	09/09/2010	11:00	Copper (dissolved)	0.007	0.005
10	12	14/02/2011	11:00	Copper (dissolved)	0.007	0.005
10	12	14/02/2011	11:00	Arsenic (dissolved)	0.029	0.025
11	0	09/09/2010	10:40	Copper (dissolved)	0.007	0.005
11	0	14/09/2010	10:15	Copper (dissolved)	0.016	0.005
11	0	15/11/2010	11:00	Copper (dissolved)	0.010	0.005
11	0	15/12/2010	10:38	Copper (dissolved)	0.007	0.005
11	0	31/01/2011	10:10	Copper (dissolved)	0.010	0.005
11	0	06/07/2010	10:15	Mercury (dissolved)	0.00010	0.00005
11	0	17/01/2011	15:55	Mercury (dissolved)	0.00010	0.00005
11	0	06/12/2010	09:30	Arsenic (dissolved)	0.031	0.025
11	0	17/01/2011	15:55	Zinc (dissolved)	0.041	0.04
12	0	08/04/2010	11:30	Zinc (dissolved)	0.08	0.04
12	0	17/01/2011	12:20	Zinc (dissolved)	0.158	0.04
12	17	17/01/2011	12:20	Zinc (dissolved)	0.182	0.04
12	0	17/01/2011	12:20	Copper (dissolved)	0.007	0.005
12	17	17/01/2011	12:20	Copper (dissolved)	0.007	0.005
12	0	17/01/2011	12:20	Arsenic (dissolved)	0.027	0.025

Station	Sample depth (m)	Date acquired	Time acquired (UTC)	Analysis	Result (mg.l^{-1})	EQS (mg.l^{-1})
12	17	17/01/2011	12:20	Arsenic (dissolved)	0.028	0.025
12	0	17/01/2011	12:20	Mercury (dissolved)	0.00010	0.00005
12	17	17/01/2011	12:20	Mercury (dissolved)	0.00010	0.00005

Table 30 Organic analysis results exceeding EQS values

Station	Sample depth (m)	Date acquired	Time acquired (UTC)	Analysis	Result (mg.l^{-1})	EQS (mg.l^{-1})
1	0	07/04/2010	11:40	Benzo[k]fluoranthene	0.002	0.00003
1	0	07/04/2010	11:40	Benzo[a]pyrene	0.002	0.0005
1	0	07/04/2010	11:40	Indeno[1,2,3-cd]pyrene	0.003	0.00002 (sum of concns)
1	0	07/04/2010	11:40	Benzo[g,h,i]perylene	0.003	
5	0	19/05/2010	08:45	Biphenyl	0.026	0.025
9	0	08/04/2010	14:00	Indeno[1,2,3-cd]pyrene	0.004	0.00002 (sum of concns)
9	0	08/04/2010	14:00	Benzo[g,h,i]perylene	0.004	
12	0	08/04/2010	11:30	Bis (2-ethylhexyl) phthalate (DEHP)	0.009	0.0013

Metal and metalloid analysis results exceeding EQSs

EQS values were exceeded in some analyses for copper, arsenic, cadmium, zinc and mercury. The spatial distribution of these results is shown in **Figure 14** (zinc), **Figure 15** (copper and arsenic) and **Figure 16** (mercury and cadmium).

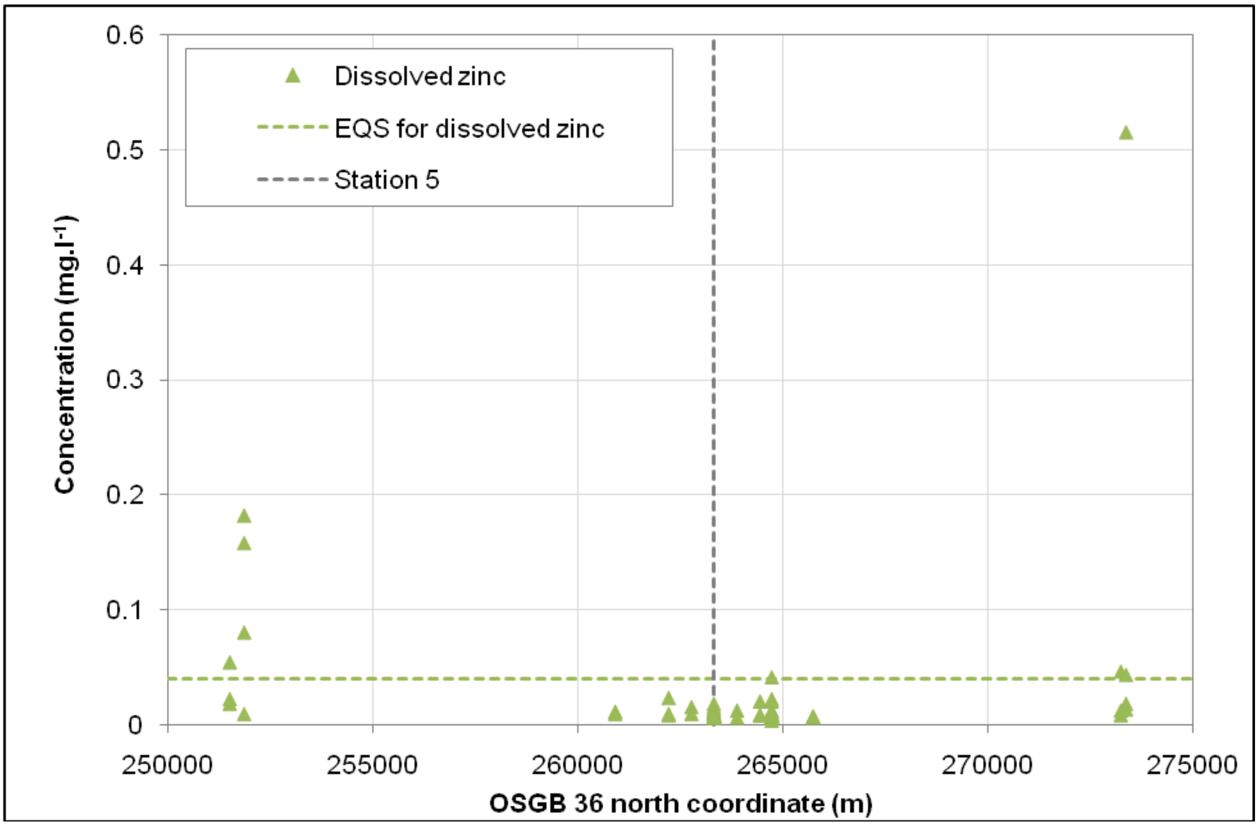

Figure 14 Dissolved zinc concentrations plotted against north coordinate. Station 5 was located at the cooling water outfall.

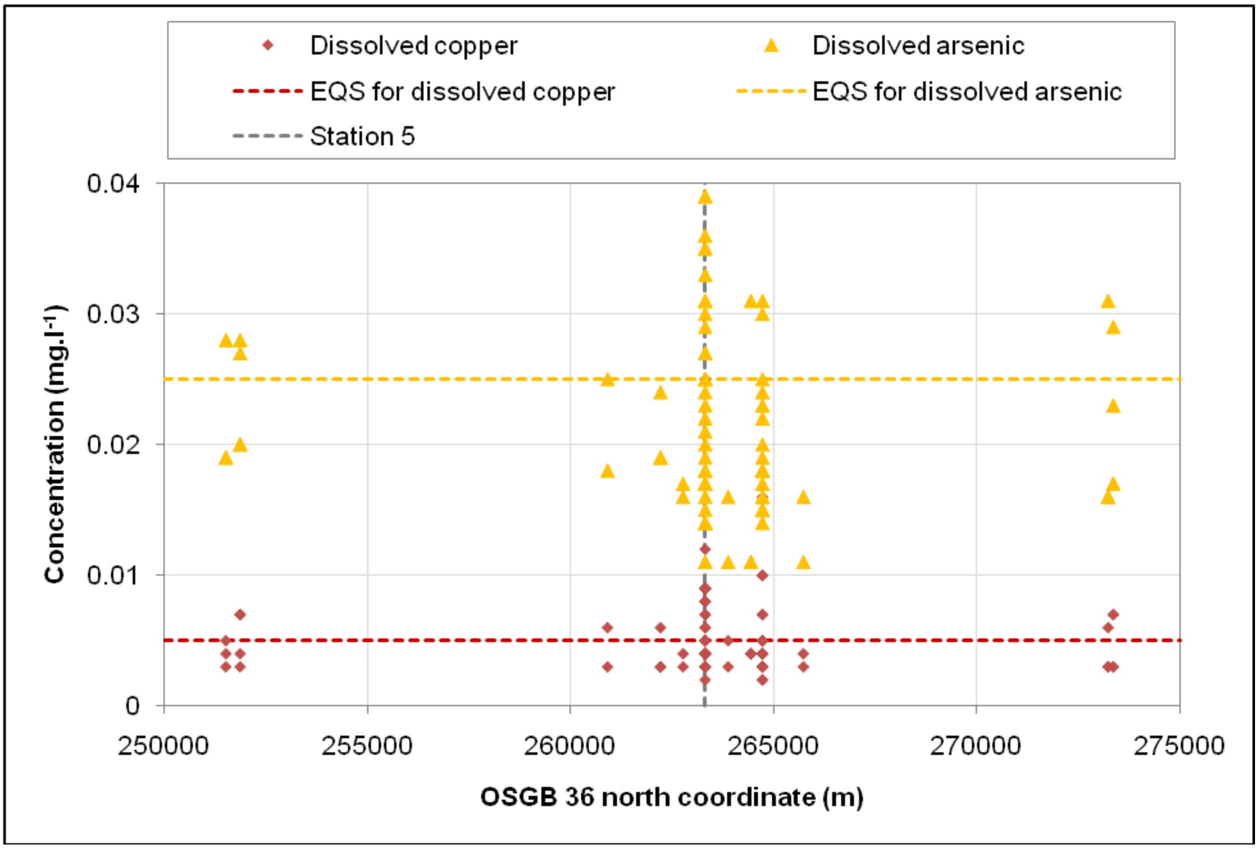

Figure 15 Dissolved copper and arsenic concentrations plotted against north coordinate. Station 5 was located at the cooling water outfall.

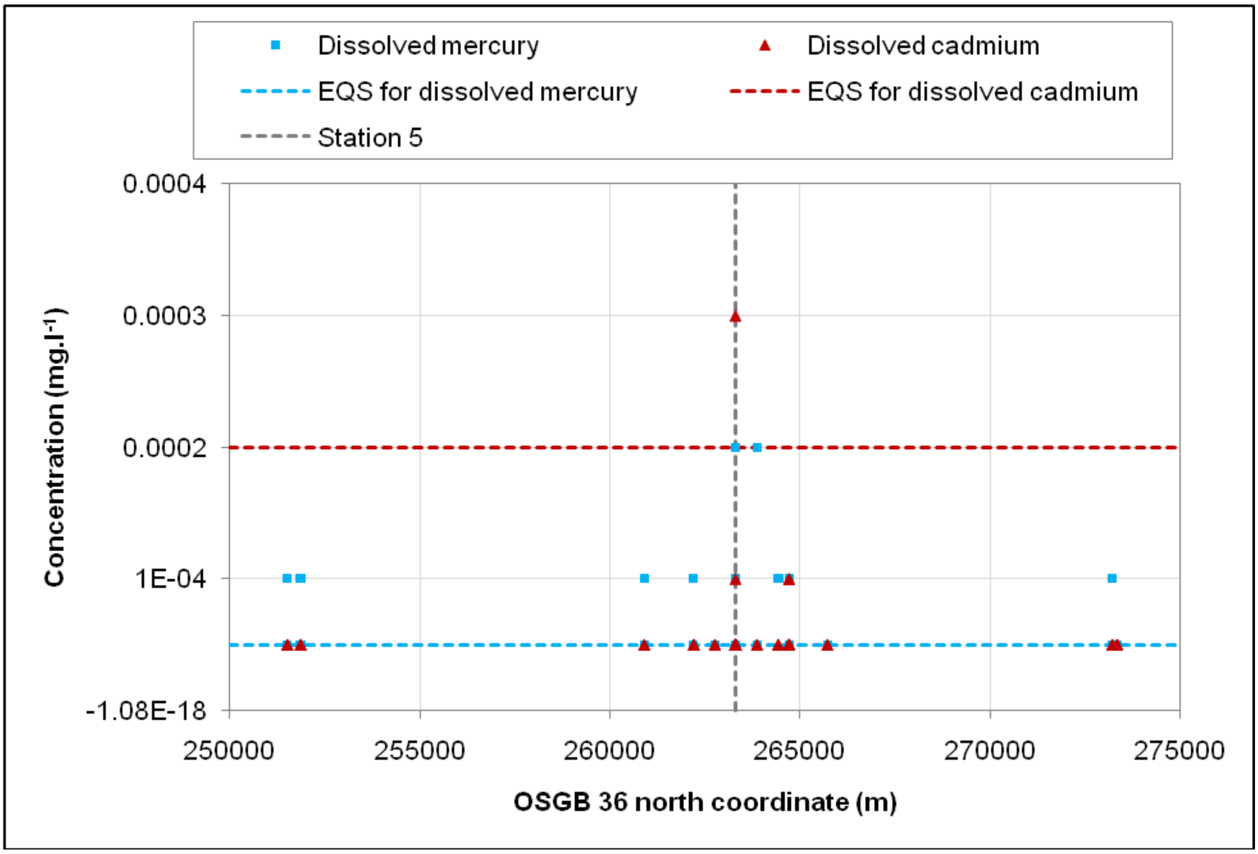

Figure 16 Dissolved mercury and cadmium concentrations plotted against north coordinate. Station 5 was located at the cooling water outfall.

Figure 14 shows that zinc concentrations are generally well below the EQS. The exceptions to this occur at Stations 9, 12 and 10 all distant from the cooling water outfall by over 10 km. High zinc concentrations were often observed in near-bed water samples and may be the result of zinc-laden suspended sediment. This may also explain the extremely high (> 0.5 mg.l^{-1}) result observed at Station 10.

Figure 15 shows the concentrations of copper and arsenic. Both substances were measured at concentrations exceeding the EQS and in both cases exceedance of the EQS is more common close to the cooling water outfall at Station 5.

Figure 16 shows the concentrations of mercury and cadmium. Cadmium concentrations were generally well below the EQS. Of 81 analyses, 77 gave negative results (< 0.0001 mg.l^{-1}) and only one of the remaining analyses exceeded the EQS. For mercury, 63 out of 81 analyses gave negative results. These 63 results are represented in **Figure 16** as concentrations of 0.0001 mg.l^{-1} (half of the limit of detection). These 63 results may not, therefore, represent actual environmental conditions where the EQS has been exceeded.

Certain dissolved metal concentrations measured were greater than the total metal concentrations measured from the same sub-sample (e.g. copper analyses for the sample from Station 5 acquired at 15:25 on the 17 January 2011 gave results of 0.004 mg.l^{-1} (total concentration) and 0.005 mg.l^{-1} (dissolved concentration). This occurs due to the sometimes heterogeneous nature of the sample and the variability inherent in making measurements very close to limit of detection.

Organic compound analysis results exceeding EQSs

Eight organic compound analyses produced results exceeding EQS levels (see **Table 30**). These included four different polycyclic aromatic hydrocarbons (PAHs) (Benzo[k]fluoranthene, Benzo[a]pyrene, Indeno[1,2,3-cd]pyrene and Benzo[g,h,i]perylene) detected at Stations 1 and 9. There were a total of six positive analyses for these compounds. The remaining 318 analyses conducted failed to detect any traces of these four PAHs during the remainder of the year's monitoring.

Biphenyl was detected at Station 5 on the 19/05/2010 at a concentration of 0.026 mg.l^{-1}, exceeding the EQS by 0.001 mg.l^{-1}. A further 80 analyses conducted during the monitoring programme failed to detect biphenyl.

Bis (2-ethylhexyl) phthalate (DEHP), a common plasticizer, was detected on four occasions during the monitoring programme. Only one of these occasions (Station 12 on the 08/04/2010) exceeded the EQS of 0.0013 mg.l^{-1}. The remaining 77 DEHP analyses were negative.

3.2.7 Sediment analysis results

Many of the analyses employed for sediment samples gave no positive results. These analyses are shown in **Table 31**. Sediment analyses giving positive results are shown in **Table 32**.

Table 31 Sediment sample analyses with no positive results; the analyte was either not present or present at undetectable levels

Analysis	Limit of detection (mg.kg^{-1} unless otherwise stated)
Selenium	0.5
Nitrite as N	0.1
2,4,6-tribromophenol	0.2
Dibromoacetic Acid	0.1
Dibromoacetonitrile	0.1
Dichloroacetonitrile	0.1
Ethanolamine	20
Hydrazine	1
Morpholine	10
Phenol	2
bis(2-Chloroethyl)ether	0.5
2-Chlorophenol	2
1,3-Dichlorobenzene	0.5
1,4-Dichlorobenzene	0.5
Benzyl alcohol	0.5
1,2-Dichlorobenzene	0.5
2-Methylphenol	0.5
bis(2-Chloroisopropyl)ether	0.5
Hexachloroethane	0.5
N-Nitroso-di-n-propylamine	0.5
3- & 4-Methylphenol	2.0
Nitrobenzene	0.5
Isophorone	0.5
2-Nitrophenol	2
2,4-Dimethylphenol	2
Benzoic Acid	< 10
bis(2-Chloroethoxy) methane	0.5
2,4-Dichlorophenol	2.0
1,2,4-Trichlorobenzene	0.5
Naphthalene	0.2
4-Chlorophenol	2
4-Chloroaniline	0.5
Hexachlorobutadiene	0.5
4-Chloro-3-methylphenol	0.5
N-Nitrosodiphenylamine	0.5
4-Bromophenyl-phenylether	0.5
Hexachlorobenzene	0.5
Pentachlorophenol	5
Phenanthrene	0.2
Anthracene	0.2
Di-n-butylphthalate	0.5
Fluoranthene	0.2
Pyrene	0.2
Butylbenzylphthalate	0.5
Benzo[a]anthracene	0.2
Chrysene	0.2
3,3'-Dichlorobenzidine	2
bis(2-Ethylhexyl)phthalate	0.5
Di-n-octylphthalate	0.2
Benzo[b]fluoranthene	0.2
Benzo[k]fluoranthene	0.2
Benzo[a]pyrene	0.2
Indeno[1,2,3-cd]pyrene	0.2
Dibenzo[a,h]anthracene	0.2
Benzo[g,h,i]perylene	0.2
Dichlorodifluoromethane	5 µg.l^{-1}
Chloromethane	5 µg.l^{-1}
Vinyl Chloride	5 µg.l^{-1}
Bromomethane	25 µg.l^{-1}
Chloroethane	25 µg.l^{-1}
Trichlorofluoromethane	5 µg.l^{-1}
1,1-Dichloroethene	5 µg.l^{-1}
trans 1,2-Dichloroethene	5 µg.l^{-1}
1,1-Dichloroethane	5 µg.l^{-1}
2,2-Dichloropropane	5 µg.l^{-1}
cis 1,2-Dichloroethene	5 µg.l^{-1}
Bromochloromethane	5 µg.l^{-1}
Chloroform	5 µg.l^{-1}

Analysis	Limit of detection (mg.kg^{-1} unless otherwise stated)
2-Methylnaphthalene	0.2
1-Methylnaphthalene	0.2
Hexachlorocyclopentadiene	0.5
2,4,6-Trichlorophenol	2
2,4,5-Trichlorophenol	2
2-Chloronaphthalene	0.2
Biphenyl	0.2
Diphenyl ether	0.2
2-Nitroaniline	0.5
Acenaphthylene	0.2
Dimethylphthalate	0.5
2,6-Dinitrotoluene	0.5
Acenaphthene	0.2
3-Nitroaniline	0.5
2,4-Dinitrophenol	1
Dibenzofuran	0.5
4-Nitrophenol	5
2,4-Dinitrotoluene	0.5
Fluorene	0.2
Diethylphthalate	0.5
4-Chlorophenyl-phenylether	0.5
4,6-Dinitro-2-methylphenol	5
4-Nitroaniline	0.5

Analysis	Limit of detection (mg.kg^{-1} unless otherwise stated)
1,1,1-Trichloroethane	5 μg.l^{-1}
Carbon Tetrachloride	5 μg.l^{-1}
1,1-Dichloropropene	5 μg.l^{-1}
Benzene	5 μg.l^{-1}
1,2-Dichloroethane	5 μg.l^{-1}
Trichloroethene	5 μg.l^{-1}
1,2-Dichloropropane	5 μg.l^{-1}
Dibromomethane	5 μg.l^{-1}
Bromodichloromethane	5 μg.l^{-1}
cis 1,3-Dichloropropene	5 μg.l^{-1}
Toluene	5 μg.l^{-1}
trans 1,3-Dichloropropene	5 μg.l^{-1}
1,1,2-Trichloroethane	5 μg.l^{-1}
Tetrachloroethene	25 μg.l^{-1}
1,3-Dichloropropane	5 μg.l^{-1}
Dibromochloromethane	5 μg.l^{-1}
1,2-Dibromoethane	5 μg.l^{-1}
Chlorobenzene	5 μg.l^{-1}
Ethylbenzene	5 μg.l^{-1}
1,1,1,2-Tetrachloroethane	5 μg.l^{-1}
m and p-Xylene	5 μg.l^{-1}
o-Xylene	5 μg.l^{-1}

Table 32 Sediment sample analyses with positive results. Negative results are presented as less than the limit of detection or “ND” (none detected) for tentatively identified compounds, for which the limits of detection vary.

Analysis	Units	Station 5 (sampled 18/06/2010)			Station 11 (sampled 17/06/2010)		
		Replicate 1	Replicate 2	Replicate 3	Replicate 1	Replicate 2	Replicate 3
Boron (H$_2$0 Soluble)	mg.kg^{-1}	7.5	4.5	3.2	6.7	5.3	5.7
Fluoride	mg.kg^{-1}	4.3	1.4	1.2	< 2.0	< 2.0	< 2.0
pH	pH Units	8	8.3	8.3	8	8	8.1
TPH (by GCFID)	mg.kg^{-1}	27	< 12.0	< 11.9	45	36	39
Exchange.Ammonium	mg.kg^{-1}	< 0.6	< 0.6	< 0.6	61.3	69.6	41.7
TPH (by FTIRPER)	mg.kg^{-1}	< 60	< 60	128	< 50	< 50	< 50
Arsenic	mg.kg^{-1}	3	3.2	2.9	13.4	12.4	13.2
Cadmium	mg.kg^{-1}	0.42	0.61	0.45	0.5	0.5	0.5
Chromium	mg.kg^{-1}	5.1	7.5	6.6	41.1	35.4	39.5
Cobalt	mg.kg^{-1}	0.9	1	0.9	7.8	6.7	7
Copper	mg.kg^{-1}	5.8	3.9	3.7	19.2	16.4	26.2
Lead	mg.kg^{-1}	8.9	8.7	7.4	28.7	24.4	28.2
Manganese	mg.kg^{-1}	57	90.3	67.6	303.9	292.2	261.5
Molybdenum	mg.kg^{-1}	< 1.0	< 1.0	< 1.0	1	0.8	0.9
Nickel	mg.kg^{-1}	2	1.8	1.7	18.3	15.5	16.2

Zinc	$mg.kg^{-1}$	8.2	8.6	5.8	96.3	88.7	79
Chloride:(2:1)	$mg.l^{-1}$	1600	1580	1520	5590	4530	5200
Nitrate (2:1)	$mg.l^{-1}$	0.4	< 0.4	< 0.4	< 0.2	< 0.2	< 0.2
Mercury	$mg.kg^{-1}$	0.02	0.02	0.2	< 0.1	< 0.1	< 0.1
Aluminium	$mg.kg^{-1}$	6950	6050	1130	34800	29100	31200
Bariu	$mg.kg^{-1}$	160	150	24	230	205	218
Calcium	$mg.kg^{-1}$	3860	5200	4330	33400	27500	30800
Iron	$mg.kg^{-1}$	6130	8570	1370	22700	18400	20200
Lithium	$mg.kg^{-1}$	< 10	< 10	< 10	29.2	23.8	26.7
Magnesium	$mg.kg^{-1}$	765	671	507	64900	5240	5900
Phosphorous	$mg.kg^{-1}$	108	205	< 99	536	15.4	492
Potassium	$mg.kg^{-1}$	4840	4530	4450	13900	11900	12700
Strontium	$mg.kg^{-1}$	46	43	7	141	115	125
Total Sulphur.	%	0.057	0.049	0.068	0.176	0.161	0.199
Total Organic Carbon	% M/M	0.09	0.08	0.1	0.82	0.58	0.67
Tentatively-identified semi-volatile organic compounds							
(Z)-9-Octadecenamide	$mg.kg^{-1}$	0.8	0.4	ND	ND	ND	ND
2-methyl-2-Hexanol	$mg.kg^{-1}$	ND	ND	ND	ND	ND	0.5
17-Pentatriacontene	$mg.kg^{-1}$	ND	ND	ND	ND	0.5	ND

Sediment analysis results were compared with Cefas Action Levels (**Table 33**) to determine if any of the results represented contamination levels of concern based on those values used to guide dredging and disposal activities. Concentrations below Cefas Action Level 1 are considered to be of no concern. Concentrations above Cefas Action Level 2 may raise concern for operations that require sediment removal and disposal. Dredged material containing contaminant concentrations above Action Level 2 would not be permitted to be disposed of at sea, for example.

Only two of the analytes detected exceeded Cefas Action level 1. Chromium was detected at a concentration exceeding Action Level 1 by 3 % in one of the samples from Station 11, though the mean concentration at Station 11 was just below Action Level 1. At Station 5 chromium concentrations were well below Action Level 1. Cadmium was detected at both Station 5 and 11 at concentrations slightly in excess of Action Level 1. Therefore neither chromium nor cadmium is present at concentrations that are of major concern as both are only slightly in excess of action level 1.

Table 33 A summary of positive sediment chemical analysis results for which a Cefas Action level exists.

Compound	Cefas Action level 1 (mg.kg^{-1})	Cefas Action level 2 (mg.kg^{-1})	Station 5		Station 11	
			Mean concentration (mg.kg^{-1})	Maximum concentration (mg.kg^{-1})	Mean concentration (mg.kg^{-1})	Maximum concentration (mg.kg^{-1})
Arsenic	20	100	3.0	3.2	13.0	13.4
Cadmium	0.4	5	0.49	0.61	0.50	0.50
Chromium	40	400	6.4	7.5	38.67	41.1
Copper	40	400	4.5	5.8	20.6	26.2
Mercury	0.3	3	0.08	0.20	< 0.1	< 0.1
Nickel	20	200	1.8	2.0	16.7	18.3
Lead	50	500	8.3	8.9	27.1	28.7
Zinc	130	800	7.5	8.6	88.0	96.3

3.2.8 Radionuclide analysis results

The results of the radionuclide analyses are shown in **Table 34**. Full results of radionuclide analyses are shown in **Appendix C**. The radionuclide results indicate that radionuclide concentrations in seawater are low and consistent with routine local radionuclide monitoring (Environment Agency et al., 2010).

Table 34 Radionuclide sample analysis results.

Analysis	Analysis results (Bq.l^{-1})				
	19/05/2010	19/05/2010	17/01/2011	17/01/2011	14/02/2011
	Station 5	Station 11	Station 5	Station 11	Station 5
Gross Alpha	< 3.80	< 3.80	< 3.80	< 3.80	< 3.80
Gross Beta	< 5.30	< 5.30	< 5.30	11.13	< 5.30
Tritium	4.44	< 3.19	1.77	2.23	44.90
Cs-134	< 0.107	< 0.109	< 0.119	< 0.105	< 0.095
Cs-137	< 0.105	< 0.107	< 0.119	< 0.105	< 0.095
K-40	10.215	11.229	11.696	14.009	13.130
Artificial C-14	< 2.045	< 0.056	< 1960	< 1960	< 1960
Natural C-14	3.570	3.330	3.84	3.63	3.27

4 Conclusions

Conclusions needed addressing main aims (or purpose) of this monitoring study, which was ‘to establish the environmental concentrations of certain chemical additives and their derivatives that are discharged from the existing cooling water outfall at Sizewell B, as well as establishing the local baseline environmental concentrations of numerous substances’.

What are the implications and/or recommendations which follow from these various baseline studies, with respect to ‘future engineering projects associated with the power station infrastructure at Sizewell’? e.g.

- Radionuclide levels are consistent with routine monitoring, hence any anomalies should be detectable
- Future monitoring of hydrazine should only use GC-MS methods...
- Etc....or something along those lines for all chemical analyses.

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Appendix A Water analysis results from Scientifics Ltd: spatial and seasonal surveys

Table 35 Station 1 spatial survey water sample analysis results. Negative results are presented as less than the limit of detection or "ND" (none detected) for tentatively identified compounds, for which the limits of detection vary. Station 1 was located 10 km from the cooling water outfall.

Analysis – Station 1	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**		
			7/4/10 Surface	**7/4/10 Near-bed**	**6/12/10 Surface**
pH	pH units		7.5	7.6	7.9
Suspended Solids	$mg.l^{-1}$		26	73	56
Total Alkalinity as $CaCO_3$	$mg.l^{-1}$		135	141	137
Bicarbonate Alkalinity as $CaCO_3$	$mg.l^{-1}$		135	141	137
Carbonate Alkalinity as $CaCO_3$	$mg.l^{-1}$		0	0	0
Chloride as Cl	$mg.l^{-1}$		12900	12700	13600
Fluoride as F	$mg.l^{-1}$		1.3	1.2	1.3
Total Sulphur as SO_4 (Dissolved)	$mg.l^{-1}$		3110	3240	2830
Calcium as Ca (Total)	$mg.l^{-1}$		265	214	267
Calcium as Ca (Dissolved)	$mg.l^{-1}$		255	259	251
Magnesium as Mg (Total)	$mg.l^{-1}$		1290	1070	1200
Magnesium as Mg (Dissolved)	$mg.l^{-1}$		1390	1430	1260
Strontium as Sr (Total)	$mg.l^{-1}$		4.9	3.86	4.89
Strontium as Sr (Dissolved)	$mg.l^{-1}$		4.82	4.78	4.67
Sodium as Na (Dissolved)	$mg.l^{-1}$		11600	8900	10600
Potassium as K (Total)	$mg.l^{-1}$		589	496	564
Potassium as K (Dissolved)	$mg.l^{-1}$		640	656	586
Nickel as Ni (Total)	$mg.l^{-1}$		0.003	0.004	0.004
Nickel as Ni (Dissolved)	$mg.l^{-1}$	0.02	0.004	0.004	0.004
Chromium as Cr (Total)	$mg.l^{-1}$		< 0.001	< 0.001	< 0.001
Chromium as Cr (Dissolved)	$mg.l^{-1}$	0.015	< 0.001	< 0.001	< 0.001
Cadmium as Cd (Total)	$mg.l^{-1}$		< 0.0001	< 0.0001	< 0.0001
Cadmium as Cd (Dissolved)	$mg.l^{-1}$	0.0002	< 0.0001	< 0.0001	< 0.0001
Copper as Cu (Total)	$mg.l^{-1}$		0.004	0.005	0.003
Copper as Cu (Dissolved)	$mg.l^{-1}$	0.005	0.003	0.006	0.003
Lead as Pb (Total)	$mg.l^{-1}$		< 0.001	< 0.001	< 0.001

Analysis – Station 1	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**		
			7/4/10 Surface	**7/4/10 Near-bed**	**6/12/10 Surface**
Zinc as Zn (Total)	$mg.l^{-1}$		0.013	0.046	0.018
Zinc as Zn (Dissolved)	$mg.l^{-1}$	0.04	0.012	0.046	0.008
Manganese as Mn (Dissolved)	$mg.l^{-1}$		< 0.002	< 0.002	< 0.002
Iron as Fe (Total)	$mg.l^{-1}$		0.02	< 0.01	0.11
Iron as Fe (Dissolved)	$mg.l^{-1}$	1	< 0.01	< 0.01	< 0.01
Aluminium as Al (Dissolved)	$mg.l^{-1}$		0.01	0.01	0.01
Arsenic as As (Total)	$mg.l^{-1}$		0.011	0.016	0.024
Arsenic as As (Dissolved)	$mg.l^{-1}$	0.025	0.016	0.016	0.031
Boron as B (Total)	$mg.l^{-1}$		4.68	3.9	4.09
Boron as B (Dissolved)	$mg.l^{-1}$		5.01	5.03	4.33
Mercury as Hg (Total)	$mg.l^{-1}$		< 0.0001	< 0.0001	0.0001
Mercury as Hg (Dissolved)	$mg.l^{-1}$	0.00005	< 0.0001	< 0.0001	0.0001
Selenium as Se (Dissolved)	$mg.l^{-1}$		0.033	0.002	0.058
Selenium as Se (Total)	$mg.l^{-1}$		0.01	0.008	0.039
Molybdenum as Mo (Total)	$mg.l^{-1}$		0.009	0.011	0.01
Molybdenum as Mo (Dissolved)	$mg.l^{-1}$		0.011	0.011	0.012
Cobalt as Co (Total)	$mg.l^{-1}$		< 0.001	< 0.001	< 0.001
Cobalt as Co (Dissolved)	$mg.l^{-1}$		< 0.001	< 0.001	< 0.001
Ammoniacal Nitrogen as N	$mg.l^{-1}$		0.45	0.3	0.41
Nitrite as N	$mg.l^{-1}$		< 0.01	< 0.01	< 0.01
Nitrate as N	$mg.l^{-1}$		< 0.2	< 0.2	< 0.2
Phosphate as P	$mg.l^{-1}$		< 0.01	< 0.01	< 0.01
Chemical Oxygen Demand (Settled)	$mg.l^{-1}$		210	205	230
Total Organic Carbon	$mg.l^{-1}$		0.57	0.54	0.63
Salinity	ppt		38.3	38.3	35.8
Turbidity N.T.U	NTU		13	43	18
Bromide as Br	$mg.l^{-1}$		105	120	236
Iodide as I	$mg.l^{-1}$		< 2	< 2	< 2
Barium as Ba (Total)	$mg.l^{-1}$		< 0.01	< 0.01	< 0.01
Lithium as Li (DIssolved)	$mg.l^{-1}$		0.08	0.08	0.07
Silicon as Si (Total)	$mg.l^{-1}$		0.5	0.4	0.6
MBAS as Lauryl Sulphate	$\mu g.l^{-1}$		< 20	40	< 20
Chlorophyll A	$\mu g.l^{-1}$		< 10	< 10	< 10
Biochemical Oxygen Demand	$mg.l^{-1}$		< 2	< 2	< 2

Analysis – Station 1	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)		
			7/4/10 Surface	7/4/10 Near-bed	6/12/10 Surface
Dissolved Organic Carbon	$mg.l^{-1}$		0.45	0.42	0.47
Total petroleum hydrocarbons (FTIRPER)	$mg.l^{-1}$		< 0.3	< 1.2	< 0.3
Total Viable Count @ 22°C	$Counts.ml^{-1}$		76	160	268
Total petroleum hydrocarbons (GC)	$mg.l^{-1}$		< 0.01	0.03	< 0.01
2,4,6-tribromophenol	$\mu g.l^{-1}$		< 0.20	< 0.20	< 0.20
Cationic Detergents	$mg.l^{-1}$		1.2	1.9	< 1.0
Dibromoacetic acid	$\mu g.l^{-1}$		< 1.00	15.5	< 1.00
Dibromoacetonitrile	$\mu g.l^{-1}$		< 10	< 10	< 0.10
Hydrazine (measurement not reliable)	$\mu g.l^{-1}$		1.4	1.1	1.2
Hydrazine (TZW)	$\mu g.l^{-1}$		-	-	< 0.01
Morpholine	$mg.l^{-1}$		< 10	< 10	< 10
bis(2-Chloroisopropyl)ether	$mg.l^{-1}$		< 0.005	< 0.005	< 0.005
2-Methylnaphthalene	$mg.l^{-1}$		< 0.002	< 0.002	< 0.002
1-Methylnaphthalene	$mg.l^{-1}$		< 0.002	< 0.002	< 0.002
Biphenyl	$mg.l^{-1}$	0.025	< 0.002	< 0.002	< 0.002
Acenaphthene	$mg.l^{-1}$		< 0.002	0.003	< 0.002
Dibenzofuran	$mg.l^{-1}$		< 0.005	< 0.005	< 0.005
Fluorene	$mg.l^{-1}$		< 0.002	< 0.002	< 0.002
Phenanthrene	$mg.l^{-1}$		< 0.002	< 0.002	< 0.002
Anthracene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002	< 0.002
Fluoranthene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002	< 0.002
Pyrene	$mg.l^{-1}$		< 0.002	< 0.002	< 0.002
bis(2-ethylhexyl)phthalate	$mg.l^{-1}$	0.0013	< 0.005	< 0.005	< 0.005
Benzo[k]fluoranthene	$mg.l^{-1}$	0.000003	0.002	< 0.002	< 0.002
Benzo[a]pyrene	$mg.l^{-1}$	0.000005	0.002	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	$mg.l^{-1}$	0.000002 (sum of concns)	0.003	< 0.002	< 0.002
Benzo[g,h,i]perylene	$mg.l^{-1}$		0.003	< 0.002	< 0.002
Dibenzo[a,h]anthracene	$mg.l^{-1}$		0.003	< 0.002	< 0.002
Toluene	$\mu g.l^{-1}$	10	< 1	< 1	< 1
Ethylbenzene	$\mu g.l^{-1}$		< 1	< 1	< 1
m and p-Xylene	$\mu g.l^{-1}$	30	< 1	< 1	< 1
o-Xylene	$\mu g.l^{-1}$	30	< 1	< 1	< 1
Bromoform	$\mu g.l^{-1}$		< 1	< 1	< 1

Analysis – Station 1	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**		
			7/4/10 Surface	**7/4/10 Near-bed**	**6/12/10 Surface**
iso-Propylbenzene	$\mu g.l^{-1}$		< 1	< 1	< 1
Propylbenzene	$\mu g.l^{-1}$		< 1	< 1	< 1
1,3,5-Trimethylbenzene	$\mu g.l^{-1}$		< 1	< 1	< 1
1,2,4-Trimethylbenzene	$\mu g.l^{-1}$		< 1	< 1	< 1
sec-Butylbenzene	$\mu g.l^{-1}$		< 1	< 1	< 1
p-Isopropyltoluene	$\mu g.l^{-1}$		< 1	< 1	< 1
Tentatively identified semi-volatile organic compounds:					
Tribromophenol	$mg.l^{-1}$		0.022	ND	ND
2,2'-azobis 2-methyl-propanenitrile	$mg.l^{-1}$		ND	0.012	ND
2,4-Dibromophenol	$mg.l^{-1}$		≤ 0.002	≤ 0.002	≤ 0.002
2,6-Dibromophenol	$mg.l^{-1}$		≤ 0.002	≤ 0.002	≤ 0.002
Tentatively identified volatile organic compounds:					
	$\mu g.l^{-1}$		ND	ND	ND

Table 36 Station 2 spatial survey water sample analysis results. Negative results are presented as less than the limit of detection or “ND” (none detected) for tentatively identified compounds, for which the limits of detection vary. Station 2 was located 2.4 km from the cooling water outfall.

Analysis – Station 2	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**	
			25/2/10 Surface	**15/12/10 Surface**
pH	pH units		7.7	7.9
Suspended Solids	$mg.l^{-1}$		102	48
Total Alkalinity as $CaCO_3$	$mg.l^{-1}$		137	135
Bicarbonate Alkalinity as $CaCO_3$	$mg.l^{-1}$		137	135
Carbonate Alkalinity as $CaCO_3$	$mg.l^{-1}$		0	0
Chloride as Cl	$mg.l^{-1}$		10200	16300
Fluoride as F	$mg.l^{-1}$		1.3	1.3
Total Sulphur as SO_4 (Dissolved)	$mg.l^{-1}$		2610	2670
Calcium as Ca (Total)	$mg.l^{-1}$		239	264
Calcium as Ca (Dissolved)	$mg.l^{-1}$		241	259
Magnesium as Mg (Total)	$mg.l^{-1}$		1120	1380
Magnesium as Mg (Dissolved)	$mg.l^{-1}$		1150	1210
Strontium as Sr (Total)	$mg.l^{-1}$		4.43	4.96
Strontium as Sr (Dissolved)	$mg.l^{-1}$		4.47	4.54
Sodium as Na (Dissolved)	$mg.l^{-1}$		10200	11200
Potassium as K (Total)	$mg.l^{-1}$		532	686
Potassium as K (Dissolved)	$mg.l^{-1}$		537	582
Nickel as Ni (Total)	$mg.l^{-1}$		0.009	0.003
Nickel as Ni (Dissolved)	$mg.l^{-1}$	0.02	0.012	0.004
Chromium as Cr (Total)	$mg.l^{-1}$		0.001	< 0.001
Chromium as Cr (Dissolved)	$mg.l^{-1}$	0.015	0.002	< 0.001
Cadmium as Cd (Total)	$mg.l^{-1}$		0.0002	< 0.0001
Cadmium as Cd (Dissolved)	$mg.l^{-1}$	0.0002	< 0.0001	< 0.0001
Copper as Cu (Total)	$mg.l^{-1}$		0.005	0.004
Copper as Cu (Dissolved)	$mg.l^{-1}$	0.005	0.003	0.004
Lead as Pb (Total)	$mg.l^{-1}$		0.001	< 0.001
Zinc as Zn (Total)	$mg.l^{-1}$		0.007	0.007
Zinc as Zn (Dissolved)	$mg.l^{-1}$	0.04	0.006	0.007
Manganese as Mn (Dissolved)	$mg.l^{-1}$		< 0.002	< 0.002

Analysis – Station 2	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**	
			25/2/10 Surface	**15/12/10 Surface**
Iron as Fe (Total)	mg.l^{-1}		0.16	< 0.01

Analysis – Station 2	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**	
			25/2/10 Surface	**15/12/10 Surface**
Iron as Fe (Dissolved)	$mg.l^{-1}$	1	< 0.01	< 0.01
Aluminium as Al (Dissolved)	$mg.l^{-1}$		< 0.01	< 0.01
Arsenic as As (Total)	$mg.l^{-1}$		0.006	0.015
Arsenic as As (Dissolved)	$mg.l^{-1}$	0.025	0.011	0.016
Boron as B (Total)	$mg.l^{-1}$		4.06	4.63
Boron as B (Dissolved)	$mg.l^{-1}$		4.01	4.01
Mercury as Hg (Total)	$mg.l^{-1}$		0.0002	< 0.0001
Mercury as Hg (Dissolved)	$mg.l^{-1}$	0.00005	< 0.0001	< 0.0001
Selenium as Se (Dissolved)	$mg.l^{-1}$		< 0.001	0.045
Selenium as Se (Total)	$mg.l^{-1}$		0.012	0.021
Molybdenum as Mo (Total)	$mg.l^{-1}$		0.008	0.009
Molybdenum as Mo (Dissolved)	$mg.l^{-1}$		0.012	0.01
Cobalt as Co (Total)	$mg.l^{-1}$		< 0.001	< 0.001
Cobalt as Co (Dissolved)	$mg.l^{-1}$		< 0.001	< 0.001
Ammoniacal Nitrogen as N	$mg.l^{-1}$		0.42	0.39
Nitrite as N	$mg.l^{-1}$		< 0.01	< 0.01
Nitrate as N	$mg.l^{-1}$		0.2	< 0.2
Phosphate as P	$mg.l^{-1}$		0.01	< 0.01
Chemical Oxygen Demand (Settled)	$mg.l^{-1}$		200	200
Total Organic Carbon	$mg.l^{-1}$		0.42	0.64
Salinity	ppt		34.5	35.5
Turbidity N.T.U	NTU		30	10
Bromide as Br	$mg.l^{-1}$		160	238
Iodide as I	$mg.l^{-1}$		< 2	< 2
Barium as Ba (Total)	$mg.l^{-1}$		< 0.01	< 0.01
Lithium as Li (DIssolved)	$mg.l^{-1}$		0.05	0.09
Silicon as Si (Total)	$mg.l^{-1}$		0.6	0.4
MBAS as Lauryl Sulphate	$\mu g.l^{-1}$		< 20	40
Chlorophyll A	$\mu g.l^{-1}$		< 10	< 10
Biochemical Oxygen Demand	$mg.l^{-1}$		< 2	< 2
Dissolved Organic Carbon	$mg.l^{-1}$		0.39	0.44
Total petroleum hydrocarbons (FTIRPER)	$mg.l^{-1}$		0.6	< 0.3
Total Viable Count @ 22°C	$Counts.ml^{-1}$		> 1000	75

Analysis – Station 2	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**	
			25/2/10 Surface	**15/12/10 Surface**
Total petroleum hydrocarbons (GC)	$mg.l^{-1}$		< 0.01	< 0.01
2,4,6-tribromophenol	$\mu g.l^{-1}$		< 0.2	< 0.2
Cationic Detergents	$mg.l^{-1}$		< 1.0	< 1.0
Dibromoacetic acid	$\mu g.l^{-1}$		< 1.00	< 1.00
Dibromoacetonitrile	$\mu g.l^{-1}$		< 10	< 0.1
Hydrazine (measurement not reliable)	$\mu g.l^{-1}$		2	3.3
Hydrazine (TZW)	$\mu g.l^{-1}$		-	< 0.01
Morpholine	$mg.l^{-1}$		< 10	< 10
bis(2-Chloroisopropyl)ether	$mg.l^{-1}$		< 0.005	< 0.005
2-Methylnaphthalene	$mg.l^{-1}$		< 0.002	< 0.002
1-Methylnaphthalene	$mg.l^{-1}$		< 0.002	< 0.002
Biphenyl	$mg.l^{-1}$	0.025	< 0.002	< 0.002
Acenaphthene	$mg.l^{-1}$		< 0.002	< 0.002
Dibenzofuran	$mg.l^{-1}$		< 0.005	< 0.005
Fluorene	$mg.l^{-1}$		< 0.002	< 0.002
Phenanthrene	$mg.l^{-1}$		< 0.002	< 0.002
Anthracene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002
Fluoranthene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002
Pyrene	$mg.l^{-1}$		< 0.002	< 0.002
bis(2-Ethylhexyl)phthalate	$mg.l^{-1}$	0.0013	< 0.005	< 0.005
Benzo[k]fluoranthene	$mg.l^{-1}$	0.000003	< 0.002	< 0.002
Benzo[a]pyrene	$mg.l^{-1}$	0.000005	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	$mg.l^{-1}$	0.000002 (sum of concns)	< 0.002	< 0.002
Benzo[g,h,i]perylene	$mg.l^{-1}$		< 0.002	< 0.002
Dibenzo[a,h]anthracene	$mg.l^{-1}$		< 0.002	< 0.002
Toluene	$\mu g.l^{-1}$	10	< 1	< 1
Ethylbenzene	$\mu g.l^{-1}$		< 1	< 1
m and p-Xylene	$\mu g.l^{-1}$	30	< 1	< 1
o-Xylene	$\mu g.l^{-1}$	30	< 1	< 1
Bromoform	$\mu g.l^{-1}$		< 1	< 1
iso-Propylbenzene	$\mu g.l^{-1}$		< 1	< 1
Propylbenzene	$\mu g.l^{-1}$		< 1	< 1
1,3,5-Trimethylbenzene	$\mu g.l^{-1}$		< 1	< 1
1,2,4-Trimethylbenzene	$\mu g.l^{-1}$		< 1	< 1

Analysis – Station 2	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)	
			25/2/10 Surface	15/12/10 Surface
sec-Butylbenzene	µg.l^{-1}		< 1	< 1
p-Isopropyltoluene	µg.l^{-1}		< 1	< 1
Tentatively identified semi-volatile organic compounds:				
2,4-Dibromophenol	mg.l^{-1}		ND	< 0.002
2,6-Dibromophenol	mg.l^{-1}		ND	< 0.002
Tentatively identified volatile organic compounds:				
	µg.l^{-1}		ND	ND

Table 37 Station 3 spatial survey water sample analysis results. Negative results are presented as less than the limit of detection or “ND” (none detected) for tentatively identified compounds, for which the limits of detection vary. Station 3 was located 1.1 km from the cooling water outfall.

Analysis – Station 3	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**		
			25/2/10 Surface	**25/2/10 Near-bed**	**6/12/10 Surface**
pH	pH units		7.7	7.7	7.8
Suspended Solids	$mg.l^{-1}$		187	167	53
Total Alkalinity as $CaCO_3$	$mg.l^{-1}$		134	145	136
Bicarbonate Alkalinity as $CaCO_3$	$mg.l^{-1}$		134	145	136
Carbonate Alkalinity as $CaCO_3$	$mg.l^{-1}$		0	0	0
Chloride as Cl	$mg.l^{-1}$		11500	12900	14900
Fluoride as F	$mg.l^{-1}$		1.3	1.3	1.3
Total Sulphur as SO_4 (Dissolved)	$mg.l^{-1}$		2600	2630	2780
Calcium as Ca (Total)	$mg.l^{-1}$		240	243	262
Calcium as Ca (Dissolved)	$mg.l^{-1}$		243	239	254
Magnesium as Mg (Total)	$mg.l^{-1}$		1140	1170	1220
Magnesium as Mg (Dissolved)	$mg.l^{-1}$		1150	1150	1230
Strontium as Sr (Total)	$mg.l^{-1}$		4.46	4.47	4.82
Strontium as Sr (Dissolved)	$mg.l^{-1}$		4.42	4.42	4.66
Sodium as Na (Dissolved)	$mg.l^{-1}$		10200	10400	10800
Potassium as K (Total)	$mg.l^{-1}$		542	549	568
Potassium as K (Dissolved)	$mg.l^{-1}$		535	541	566
Nickel as Ni (Total)	$mg.l^{-1}$		0.011	0.01	0.012
Nickel as Ni (Dissolved)	$mg.l^{-1}$	0.02	0.012	0.013	0.005
Chromium as Cr (Total)	$mg.l^{-1}$		0.001	0.001	0.013
Chromium as Cr (Dissolved)	$mg.l^{-1}$	0.015	0.002	0.002	< 0.001
Cadmium as Cd (Total)	$mg.l^{-1}$		< 0.0001	< 0.0001	< 0.0001
Cadmium as Cd (Dissolved)	$mg.l^{-1}$	0.0002	< 0.0001	< 0.0001	< 0.0001
Copper as Cu (Total)	$mg.l^{-1}$		0.003	0.004	0.004
Copper as Cu (Dissolved)	$mg.l^{-1}$	0.005	0.004	0.004	0.004
Lead as Pb (Total)	$mg.l^{-1}$		< 0.001	< 0.001	< 0.001
Zinc as Zn (Total)	$mg.l^{-1}$		0.007	0.035	0.017
Zinc as Zn (Dissolved)	$mg.l^{-1}$	0.04	0.008	0.02	0.008
Manganese as Mn (Dissolved)	$mg.l^{-1}$		< 0.002	< 0.002	< 0.002

Analysis – Station 3	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**		
			25/2/10 Surface	**25/2/10 Near-bed**	**6/12/10 Surface**
Iron as Fe (Total)	mg.l^{-1}		0.07	0.2	0.28

Analysis – Station 3	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**		
			25/2/10 Surface	**25/2/10 Near-bed**	**6/12/10 Surface**
Iron as Fe (Dissolved)	$mg.l^{-1}$	1	< 0.01	< 0.01	< 0.01
Aluminium as Al (Dissolved)	$mg.l^{-1}$		< 0.01	< 0.01	0.01
Arsenic as As (Total)	$mg.l^{-1}$		0.008	0.007	0.028
Arsenic as As (Dissolved)	$mg.l^{-1}$	0.025	0.011	0.011	0.031
Boron as B (Total)	$mg.l^{-1}$		4.14	4.14	4.16
Boron as B (Dissolved)	$mg.l^{-1}$		4.01	3.99	4.19
Mercury as Hg (Total)	$mg.l^{-1}$		0.0001	0.0001	0.0001
Mercury as Hg (Dissolved)	$mg.l^{-1}$	0.00005	0.0001	0.0001	0.0001
Selenium as Se (Dissolved)	$mg.l^{-1}$		0.008	0.008	0.032
Selenium as Se (Total)	$mg.l^{-1}$		< 0.001	0.002	0.045
Molybdenum as Mo (Total)	$mg.l^{-1}$		0.01	0.009	0.012
Molybdenum as Mo (Dissolved)	$mg.l^{-1}$		0.012	0.012	0.012
Cobalt as Co (Total)	$mg.l^{-1}$		< 0.001	0.001	0.001
Cobalt as Co (Dissolved)	$mg.l^{-1}$		< 0.001	< 0.001	< 0.001
Ammoniacal Nitrogen as N	$mg.l^{-1}$		0.42	0.2	0.41
Nitrite as N	$mg.l^{-1}$		< 0.01	< 0.01	< 0.01
Nitrate as N	$mg.l^{-1}$		< 0.2	< 0.2	< 0.2
Phosphate as P	$mg.l^{-1}$		< 0.01	< 0.01	< 0.01
Chemical Oxygen Demand (Settled)	$mg.l^{-1}$		190	240	220
Total Organic Carbon	$mg.l^{-1}$		0.4	0.38	0.67
Salinity	ppt		34.9	35.3	35.6
Turbidity N.T.U	NTU		72	< 1	20
Bromide as Br	$mg.l^{-1}$		142	170	236
Iodide as I	$mg.l^{-1}$		< 2	< 2	< 2
Barium as Ba (Total)	$mg.l^{-1}$		< 0.01	< 0.01	< 0.01
Lithium as Li (DIssolved)	$mg.l^{-1}$		0.05	0.05	0.07
Silicon as Si (Total)	$mg.l^{-1}$		0.5	0.6	0.8
MBAS as Lauryl Sulphate	$\mu g.l^{-1}$		< 20	< 20	< 20
Chlorophyll A	$\mu g.l^{-1}$		< 10	< 10	< 10
Biochemical Oxygen Demand	$mg.l^{-1}$		< 2	2	< 2
Dissolved Organic Carbon	$mg.l^{-1}$		0.39	0.37	0.4
Total petroleum hydrocarbons (FTIRPER)	$mg.l^{-1}$		0.3	< 0.3	< 0.3
Total Viable Count @ 22°C	$Counts.ml^{-1}$		584	160	91

Analysis – Station 3	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**		
			25/2/10 Surface	**25/2/10 Near-bed**	**6/12/10 Surface**
Total petroleum hydrocarbons (GC)	mg.l^{-1}		0.94	0.02	0.02
2,4,6-tribromophenol	µg.l^{-1}		< 0.20	< 0.20	< 0.20
Cationic Detergents	mg.l^{-1}		< 1	< 1	< 1
Dibromoacetic acid	µg.l^{-1}		< 1	< 1	2.2
Dibromoacetonitrile	µg.l^{-1}		< 10	< 10	< 0.10
Hydrazine (measurement not reliable)	µg.l^{-1}		0.5	0.5	0.5
Hydrazine (TZW)	µg.l^{-1}		-	-	< 0.01
Morpholine	mg.l^{-1}		< 10	< 10	< 10
bis(2-Chloroisopropyl)ether	mg.l^{-1}		< 0.005	< 0.005	< 0.005
2-Methylnaphthalene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
1-Methylnaphthalene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
Biphenyl	mg.l^{-1}	0.025	< 0.002	< 0.002	< 0.002
Acenaphthene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
Dibenzofuran	mg.l^{-1}		< 0.005	< 0.005	< 0.005
Fluorene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
Phenanthrene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
Anthracene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002
Fluoranthene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002
Pyrene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
bis(2-Ethylhexyl)phthalate	mg.l^{-1}	0.0013	< 0.005	< 0.005	< 0.005
Benzo[k]fluoranthene	mg.l^{-1}	0.000003	< 0.002	< 0.002	< 0.002
Benzo[a]pyrene	mg.l^{-1}	0.000005	< 0.002	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	mg.l^{-1}	0.000002 (sum of concns)	< 0.002	< 0.002	< 0.002
Benzo[g,h,i]perylene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
Dibenzo[a,h]anthracene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
Toluene	µg.l^{-1}	10	< 1	< 1	< 1
Ethylbenzene	µg.l^{-1}		< 1	< 1	< 1
m and p-Xylene	µg.l^{-1}	30	< 1	< 1	< 1
o-Xylene	µg.l^{-1}	30	< 1	< 1	< 1
Bromoform	µg.l^{-1}		< 1	< 1	< 1
iso-Propylbenzene	µg.l^{-1}		< 1	< 1	< 1
Propylbenzene	µg.l^{-1}		< 1	< 1	< 1
1,3,5-Trimethylbenzene	µg.l^{-1}		< 1	< 1	< 1
1,2,4-Trimethylbenzene	µg.l^{-1}		< 1	< 1	< 1

Analysis – Station 3	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**		
			25/2/10 Surface	**25/2/10 Near-bed**	**6/12/10 Surface**
sec-Butylbenzene	µg.l^{-1}		< 1	< 1	< 1
p-Isopropyltoluene	µg.l^{-1}		< 1	< 1	< 1
Tentatively identified semi-volatile organic compounds:					
2,4-Dibromophenol	mg.l^{-1}		ND	ND	≤0.002
2,6-Dibromophenol	mg.l^{-1}		ND	ND	≤0.002
Tentatively identified volatile organic compounds:					
	µg.l^{-1}		ND	ND	ND

Table 38 Station 4 spatial survey water sample analysis results. Negative results are presented as less than the limit of detection or “ND” (none detected) for tentatively identified compounds, for which the limits of detection vary. Station 4 was located 0.6 km from the cooling water outfall.

Analysis – Station 4	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)	
			25/2/10 Surface	15/12/10 Surface
pH	pH units		7.7	7.9
Suspended Solids	mg.l^{-1}		131	53
Total Alkalinity as $CaCO_3$	mg.l^{-1}		138	110
Bicarbonate Alkalinity as $CaCO_3$	mg.l^{-1}		138	110
Carbonate Alkalinity as $CaCO_3$	mg.l^{-1}		0	0
Chloride as Cl	mg.l^{-1}		13600	16400
Fluoride as F	mg.l^{-1}		1.5	1.3
Total Sulphur as SO_4 (Dissolved)	mg.l^{-1}		2600	2730
Calcium as Ca (Total)	mg.l^{-1}		243	259
Calcium as Ca (Dissolved)	mg.l^{-1}		238	253
Magnesium as Mg (Total)	mg.l^{-1}		1170	1380
Magnesium as Mg (Dissolved)	mg.l^{-1}		1150	1220
Strontium as Sr (Total)	mg.l^{-1}		4.43	4.89
Strontium as Sr (Dissolved)	mg.l^{-1}		4.41	4.51
Sodium as Na (Dissolved)	mg.l^{-1}		10200	11100
Potassium as K (Total)	mg.l^{-1}		547	691
Potassium as K (Dissolved)	mg.l^{-1}		534	593
Nickel as Ni (Total)	mg.l^{-1}		0.01	0.004
Nickel as Ni (Dissolved)	mg.l^{-1}	0.02	0.012	0.004
Chromium as Cr (Total)	mg.l^{-1}		0.001	< 0.001
Chromium as Cr (Dissolved)	mg.l^{-1}	0.015	0.001	< 0.001
Cadmium as Cd (Total)	mg.l^{-1}		0.0002	< 0.0001
Cadmium as Cd (Dissolved)	mg.l^{-1}	0.0002	< 0.0001	< 0.0001
Copper as Cu (Total)	mg.l^{-1}		0.003	0.004
Copper as Cu (Dissolved)	mg.l^{-1}	0.005	0.003	0.005
Lead as Pb (Total)	mg.l^{-1}		< 0.001	< 0.001
Zinc as Zn (Total)	mg.l^{-1}		0.01	0.008
Zinc as Zn (Dissolved)	mg.l^{-1}	0.04	0.012	0.006
Manganese as Mn (Dissolved)	mg.l^{-1}		< 0.002	< 0.002

Analysis – Station 4	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**	
			25/2/10 Surface	**15/12/10 Surface**
Iron as Fe (Total)	mg.l^{-1}		0.2	< 0.01

Analysis – Station 4	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**	
			25/2/10 Surface	**15/12/10 Surface**
Iron as Fe (Dissolved)	$mg.l^{-1}$	1	< 0.01	< 0.01
Aluminium as Al (Dissolved)	$mg.l^{-1}$		< 0.01	< 0.01
Arsenic as As (Total)	$mg.l^{-1}$		0.007	0.014
Arsenic as As (Dissolved)	$mg.l^{-1}$	0.025	0.011	0.016
Boron as B (Total)	$mg.l^{-1}$		4.24	4.66
Boron as B (Dissolved)	$mg.l^{-1}$		4.01	4.08
Mercury as Hg (Total)	$mg.l^{-1}$		0.0001	< 0.0001
Mercury as Hg (Dissolved)	$mg.l^{-1}$	0.00005	0.0002	< 0.0001
Selenium as Se (Dissolved)	$mg.l^{-1}$		0.019	< 0.001
Selenium as Se (Total)	$mg.l^{-1}$		< 0.001	0.016
Molybdenum as Mo (Total)	$mg.l^{-1}$		0.009	0.009
Molybdenum as Mo (Dissolved)	$mg.l^{-1}$		0.012	0.01
Cobalt as Co (Total)	$mg.l^{-1}$		< 0.001	< 0.001
Cobalt as Co (Dissolved)	$mg.l^{-1}$		< 0.001	< 0.001
Ammoniacal Nitrogen as N	$mg.l^{-1}$		0.42	0.39
Nitrite as N	$mg.l^{-1}$		< 0.01	< 0.01
Nitrate as N	$mg.l^{-1}$		< 0.2	< 0.2
Phosphate as P	$mg.l^{-1}$		0.01	< 0.01
Chemical Oxygen Demand (Settled)	$mg.l^{-1}$		230	230
Total Organic Carbon	$mg.l^{-1}$		0.38	0.59
Salinity	ppt		35.4	35.5
Turbidity N.T.U	NTU		45	4
Bromide as Br	$mg.l^{-1}$		179	302
Iodide as I	$mg.l^{-1}$		< 2	< 2
Barium as Ba (Total)	$mg.l^{-1}$		< 0.01	< 0.01
Lithium as Li (DIssolved)	$mg.l^{-1}$		0.05	0.09
Silicon as Si (Total)	$mg.l^{-1}$		0.6	0.3
MBAS as Lauryl Sulphate	$\mu g.l^{-1}$		< 20	50
Chlorophyll A	$\mu g.l^{-1}$		< 10	< 10
Biochemical Oxygen Demand	$mg.l^{-1}$		2	< 2
Dissolved Organic Carbon	$mg.l^{-1}$		0.36	0.43
Total petroleum hydrocarbons (FTIRPER)	$mg.l^{-1}$		< 0.3	< 0.3
Total Viable Count @ 22°C	$Counts.ml^{-1}$		164	95

Analysis – Station 4	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**	
			25/2/10 Surface	**15/12/10 Surface**
Total petroleum hydrocarbons (GC)	$mg.l^{-1}$		0.03	< 0.01
2,4,6-tribromophenol	$\mu g.l^{-1}$		< 0.2	< 0.2
Cationic Detergents	$mg.l^{-1}$		< 1	< 1
Dibromoacetic acid	$\mu g.l^{-1}$		< 1	< 1
Dibromoacetonitrile	$\mu g.l^{-1}$		< 10	< 0.1
Hydrazine (measurement not reliable)	$\mu g.l^{-1}$		0.5	4.6
Hydrazine (TZW)	$\mu g.l^{-1}$		-	< 0.01
Morpholine	$mg.l^{-1}$		< 10	< 10
bis(2-Chloroisopropyl)ether	$mg.l^{-1}$		< 0.005	< 0.005
2-Methylnaphthalene	$mg.l^{-1}$		< 0.002	< 0.002
1-Methylnaphthalene	$mg.l^{-1}$		< 0.002	< 0.002
Biphenyl	$mg.l^{-1}$	0.025	< 0.002	< 0.002
Acenaphthene	$mg.l^{-1}$		< 0.002	< 0.002
Dibenzofuran	$mg.l^{-1}$		< 0.005	< 0.005
Fluorene	$mg.l^{-1}$		< 0.002	< 0.002
Phenanthrene	$mg.l^{-1}$		< 0.002	< 0.002
Anthracene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002
Fluoranthene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002
Pyrene	$mg.l^{-1}$		< 0.002	< 0.002
bis(2-ethylhexyl)phthalate	$mg.l^{-1}$	0.0013	< 0.005	< 0.005
Benzo[k]fluoranthene	$mg.l^{-1}$	0.000003	< 0.002	< 0.002
Benzo[a]pyrene	$mg.l^{-1}$	0.000005	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	$mg.l^{-1}$	0.000002 (sum of concns)	< 0.002	< 0.002
Benzo[g,h,i]perylene	$mg.l^{-1}$		< 0.002	< 0.002
Dibenzo[a,h]anthracene	$mg.l^{-1}$		< 0.002	< 0.002
Toluene	$\mu g.l^{-1}$	10	< 1	< 1
Ethylbenzene	$\mu g.l^{-1}$		< 1	< 1
m and p-Xylene	$\mu g.l^{-1}$	30	< 1	< 1
o-Xylene	$\mu g.l^{-1}$	30	< 1	< 1
Bromoform	$\mu g.l^{-1}$		< 1	< 1
iso-Propylbenzene	$\mu g.l^{-1}$		< 1	< 1
Propylbenzene	$\mu g.l^{-1}$		< 1	< 1
1,3,5-Trimethylbenzene	$\mu g.l^{-1}$		< 1	< 1
1,2,4-Trimethylbenzene	$\mu g.l^{-1}$		< 1	< 1

Analysis – Station 4	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)	
			25/2/10 Surface	15/12/10 Surface
sec-Butylbenzene	$\mu g.l^{-1}$		< 1	< 1
p-Isopropyltoluene	$\mu g.l^{-1}$		< 1	< 1
Tentatively identified semi-volatile organic compounds:				
2,4-Dibromophenol	$mg.l^{-1}$		ND	< 0.002
2,6-Dibromophenol	$mg.l^{-1}$		ND	< 0.002
Tentatively identified volatile organic compounds:				
	$\mu g.l^{-1}$		ND	ND

Table 39 Station 5 spatial survey water sample analysis results. Negative results are presented as less than the limit of detection or “ND” (none detected) for tentatively identified compounds, for which the limits of detection vary. Station 5 was located at the cooling water outfall.

Analysis – Station 5	**Units**	**EQS (annual average concn)**	**Concentration/value (ND = none detected)**																				
			25/2/10 surface	**25/2/10 near-bed**	**8/4/10 surface**	**21/4/10 surface**	**19/5/10 surface**	**07/06/10 surface**	**22/06/10 surface**	**06/07/10 surface**	**20/07/10 surface**	**11/08/10 surface**	**18/08/10 surface**	**09/09/10 surface**	**14/09/10 surface**	**28/09/10 surface**	**14/10/10 surface**	**15/11/10 surface**	**06/12/10 surface**	**15/12/10 surface**	**17/01/11 surface**	**31/01/11 surface**	**14/02/11 surface**
pH	pH units		7.7	7.7	7.8	7.9	7.7	8.1	7.8	7.9	7.9	8	7.9	7.6	7.7	7.9	7.9	7.8	7.7	7.9	7.7	7.8	7.4
Suspended Solids	mg.l^{-1}		135	203	58	142	144	14	15	49	74	95	34	109	9	48	110	302	76	89	31	124	426
Total Alkalinity as $CaCO_3$	mg.l^{-1}		136	138	139	135	132	126	111	125	129	134	136	131	125	129	131	133	137	140	135	139	132
Bicarbonate Alkalinity as $CaCO_3$	mg.l^{-1}		136	138	139	135	92	126	111	125	129	134	136	131	125	129	131	133	137	140	135	139	132
Carbonate Alkalinity as $CaCO_3$	mg.l^{-1}		0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chloride as Cl	mg.l^{-1}		14200	14200	14800	15400	10100	14800	17200	17000	15600	13200	16400	16200	15000	14800	12500	15100	16400	16000	12400	11000	13400
Fluoride as F	mg.l^{-1}		1.3	1.3	1.3	1.3	1.3	1.3	8.1	1.3	1.9	2.6	1.3	1.3	1.3	1.3	1.2	1.3	1.3	1.4	1.3	1.3	1.4
Total Sulphur as SO_4 (Dissolved)	mg.l^{-1}		2570	2620	2860	3060	2720	2610	2500	2810	2590	2670	2620	2630	2460	2810	2700	3900	1730	2730	2890	2750	2630
Calcium as Ca (Total)	mg.l^{-1}		250	246	308	259	228	257	197	225	259	267	260	252	280	264	264	269	256	262	281	250	258
Calcium as Ca (Dissolved)	mg.l^{-1}		245	241	253	260	255	250	245	247	251	254	242	255	276	262	252	278	251	260	273	263	249
Magnesium as Mg (Total)	mg.l^{-1}		1170	1150	1470	1180	1030	1150	807	1010	1200	1230	1200	1190	1140	1230	1220	1560	1190	1280	1330	1080	1260
Magnesium as Mg (Dissolved)	mg.l^{-1}		1150	1160	1240	1280	1150	1140	1110	1210	1100	1170	1120	1120	1110	1370	1240	1420	252	1220	1420	1260	1170
Strontium as Sr (Total)	mg.l^{-1}		4.59	4.49	5.61	4.66	4.16	4.64	3.58	4.13	4.72	4.91	4.75	4.63	5.07	4.81	4.85	4.87	4.72	4.94	5.14	4.38	4.8
Strontium as Sr (Dissolved)	mg.l^{-1}		4.5	4.49	4.78	4.69	4.61	4.48	4.45	4.54	4.63	4.67	4.44	4.63	4.94	4.8	4.72	4.99	4.59	4.53	4.96	4.76	4.66
Sodium as Na (Dissolved)	mg.l^{-1}		10200	10300	9880	11000	10700	10400	10200	11500	9740	11000	9790	9970	9460	11000	10500	11500	288	11300	11400	11600	11100
Potassium as K (Total)	mg.l^{-1}		551	534	677	567	480	533	388	482	575	604	588	566	540	548	559	750	558	634	628	513	611
Potassium as K (Dissolved)	mg.l^{-1}		534	542	571	615	530	521	540	576	521	569	546	521	520	362	570	687	18	589	437	593	565
Nickel as Ni (Total)	mg.l^{-1}		0.013	0.011	0.003	0.003	0.003	0.003	0.004	0.003	0.007	0.002	0.004	0.005	0.005	0.003	0.005	0.006	0.005	0.003	0.004	0.006	0.005
Nickel as Ni (Dissolved)	mg.l^{-1}	0.02	0.012	0.012	0.003	0.004	0.003	0.005	0.004	0.003	0.005	0.003	0.004	0.004	0.004	0.004	0.004	0.006	0.006	0.004	0.004	0.005	0.004
Chromium as Cr (Total)	mg.l^{-1}		0.001	0.005	< 0.001	< 0.001	0.001	0.001	0.001	0.001	0.003	< 0.001	0.001	0.001	0.001	0.001	0.013	0.001	< 0.001	< 0.001	< 0.001	0.002	0.001
Chromium as Cr (Dissolved)	mg.l^{-1}	0.015	0.001	0.001	< 0.001	< 0.001	0.002	0.002	< 0.001	0.001	0.001	0.002	0.002	0.001	0.002	0.001	< 0.001	0.001	< 0.001	< 0.001	< 0.001	0.001	0.001
Cadmium as Cd (Total)	mg.l^{-1}		<0.0001	0.0004	< 0.001	<0.0001	<0.0001	0.0002	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0002	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Analysis – Station 5	**Units**	**EQS (annual average concn)**	**Concentration/value (ND = none detected)**																				
			25/2/10 surface	**25/2/10 near-bed**	**8/4/10 surface**	**21/4/10 surface**	**19/5/10 surface**	**07/06/10 surface**	**22/06/10 surface**	**06/07/10 surface**	**20/07/10 surface**	**11/08/10 surface**	**18/08/10 surface**	**09/09/10 surface**	**14/09/10 surface**	**28/09/10 surface**	**14/10/10 surface**	**15/11/10 surface**	**06/12/10 surface**	**15/12/10 surface**	**17/01/11 surface**	**31/01/11 surface**	**14/02/11 surface**
Cadmium as Cd (Dissolved)	mg.l^{-1}	0.0002	0.0003	<0.0001	<0.0001	<0.0001	< .0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Copper as Cu (Total)	mg.l^{-1}		0.004	0.004	0.002	0.002	0.004	0.003	0.004	0.002	0.004	0.002	0.006	0.005	0.013	0.004	0.007	0.007	0.004	0.003	0.004	0.008	0.004
Copper as Cu (Dissolved)	mg.l^{-1}	0.005	0.004	0.004	0.003	0.003	0.004	0.003	0.004	0.002	0.004	0.003	0.008	0.007	0.006	0.004	0.005	0.004	0.003	0.004	0.005	0.005	0.004
Lead as Pb (Total)	mg.l^{-1}		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.016	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Zinc as Zn (Total)	mg.l^{-1}		0.008	0.016	0.009	0.016	0.014	0.007	0.008	0.006	0.008	0.005	0.015	0.006	0.01	0.01	0.013	0.008	0.018	0.011	0.016	0.013	0.009
Zinc as Zn (Dissolved)	mg.l^{-1}	0.04	0.008	0.015	0.008	0.01	0.007	0.007	0.007	0.006	0.01	0.006	0.008	0.006	0.008	0.009	0.008	0.008	0.007	0.013	0.018	0.011	0.007
Manganese as Mn (Dissolved)	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.005	< 0.002	< 0.002	0.002	0.003	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.025
Iron as Fe (Total)	mg.l^{-1}		0.22	0.08	0.03	0.26	0.04	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.06	0.09	0.09	< 0.01	< 0.01	< 0.01	< 0.01	2.98	< 0.01
Iron as Fe (Dissolved)	mg.l^{-1}	1	< 0.01	< 0.01	< 0.01	0.18	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Aluminium as Al (Dissolved)	mg.l^{-1}		< 0.01	< 0.01	0.01	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.01	0.01	0.01	0.01	0.02	0.01	0.06	0.01	< 0.01	0.01	< 0.01	< 0.01
Arsenic as As (Total)	mg.l^{-1}		0.009	0.008	0.012	0.013	0.016	0.01	0.019	0.014	0.018	0.012	0.013	0.011	0.014	0.013	0.02	0.016	0.025	0.013	0.02	0.024	0.023
Arsenic as As (Dissolved)	mg.l^{-1}	0.025	0.011	0.011	0.018	0.017	0.018	0.014	0.022	0.014	0.023	0.017	0.016	0.014	0.015	0.017	0.02	0.019	0.03	0.017	0.025	0.025	0.027
Boron as B (Total)	mg.l^{-1}		4.17	4.02	5.26	4.19	3.85	4.15	2.83	3.41	4.4	4.56	4.23	4.41	4.27	4.19	4.16	5.22	4.05	4.33	4.34	3.64	4.25
Boron as B (Dissolved)	mg.l^{-1}		3.98	4.08	4.36	4.46	4.49	4.1	3.86	4.07	4	4.35	4.04	4.3	4.12	4.96	4.21	4.8	0.3	4.04	3.49	4.11	3.88
Mercury as Hg (Total)	mg.l^{-1}		0.0002	0.0002	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0003	< 0.0001	0.0001	< 0.0001	0.0001	0.0007	< 0.0001
Mercury as Hg (Dissolved)	mg.l^{-1}	0.00005	0.0002	0.0002	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001	< 0.0001	0.0001	0.0001	< 0.0001
Selenium as Se (Dissolved)	mg.l^{-1}		< 0.001	0.01	0.055	0.063	0.04	0.012	0.04	0.03	0.054	0.032	< 0.001	< 0.001	0.01	0.021	< 0.001	0.042	< 0.001	0.024	0.08	< 0.001	0.096
Selenium as Se (Total)	mg.l^{-1}		0.01	< 0.001	0.033	0.033	0.01	0.014	0.033	0.027	0.046	0.025	< 0.001	< 0.001	0.02	0.008	< 0.001	< 0.001	0.039	0.026	0.052	0.008	0.078
Molybdenum as Mo (Total)	mg.l^{-1}		0.01	0.01	0.009	0.008	0.011	0.008	0.01	0.012	0.01	0.009	0.012	0.009	0.011	0.01	0.011	0.011	0.011	0.008	0.01	0.01	0.011
Molybdenum as Mo (Dissolved)	mg.l^{-1}		0.012	0.011	0.011	0.011	0.01	0.011	0.01	0.012	0.011	0.011	0.013	0.011	0.011	0.011	0.01	0.011	0.012	0.01	0.011	0.011	0.012
Cobalt as Co (Total)	mg.l^{-1}		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< 0.001	< 0.001	< 0.001	0.001	0.001
Cobalt as Co (Dissolved)	mg.l^{-1}		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	0.001
Ammoniacal Nitrogen as N	mg.l^{-1}		0.45	0.45	0.44	0.3	0.2	0.2	0.42	0.4	0.45	0.46	0.45	0.46	0.4	0.41	0.44	0.36	0.45	0.52	0.2	0.41	0.41
Nitrite as N	mg.l^{-1}		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Nitrate as N	mg.l^{-1}		< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2

Analysis – Station 5	**Units**	**EQS (annual average concn)**	**Concentration/value (ND = none detected)**																				
			25/2/10 surface	**25/2/10 near-bed**	**8/4/10 surface**	**21/4/10 surface**	**19/5/10 surface**	**07/06/10 surface**	**22/06/10 surface**	**06/07/10 surface**	**20/07/10 surface**	**11/08/10 surface**	**18/08/10 surface**	**09/09/10 surface**	**14/09/10 surface**	**28/09/10 surface**	**14/10/10 surface**	**15/11/10 surface**	**06/12/10 surface**	**15/12/10 surface**	**17/01/11 surface**	**31/01/11 surface**	**14/02/11 surface**
Phosphate as P	mg.l^{-1}		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.31	< 0.01	0.02	< 0.01	0.03	0.03	0.21	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01
Chemical Oxygen Demand (Settled)	mg.l^{-1}		230	200	185	240	< 5	< 5	1100	240	230	180	280	280	270	370	270	280	320	250	125	320	120
Total Organic Carbon	mg.l^{-1}		0.39	0.42	0.55	0.56	0.62	0.53	0.54	0.51	0.87	0.64	0.58	0.63	0.72	0.59	0.67	0.63	0.59	0.65	0.59	0.6	0.76
Salinity	ppt		35.4	35.4	37.4	35.2	33.8	28	31.9	29.9	3502	36.1	37	37.2	35.5	36.3	35.5	40.4	35.5	35.6	36	32.6	33.2
Turbidity N.T.U	NTU		38	96	4	17	16	< 1	14	32	3	2	6	22	2	16	32	7	26	11	5	31	< 1
Bromide as Br	mg.l^{-1}		174	191	242	160	99.5	194	162	197	552	380	226	218	196	180	212	250	254	266	770	61.5	65.3
Iodide as I	mg.l^{-1}		< 2	< 2	< 2	2.1	0.4	< 2	< 2	2.2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Barium as Ba (Total)	mg.l^{-1}		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.03	< 0.01
Lithium as Li (DIssolved)	mg.l^{-1}		0.05	0.05	0.07	0.03	0.06	0.06	0.06	0.05	0.07	0.05	0.05	0.06	0.07	0.07	0.07	0.06	0.07	0.09	0.07	0.06	0.09
Silicon as Si (Total)	mg.l^{-1}		0.6	0.5	0.6	0.4	0.4	0.1	0.4	0.3	0.2	< 0.1	0.3	0.4	0.5	0.6	0.4	0.2	0.4	0.3	0.3	2.5	0.2
MBAS as Lauryl Sulphate	µg.l^{-1}		< 20	< 20	20	< 20	< 20	26	28	109	< 20	< 20	70	< 20	< 20	51	< 20	45	25	30	20	30	136
Chlorophyll A	µg.l^{-1}		< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	1.4	1.4	< 10	< 10	12.5	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Biochemical Oxygen Demand	mg.l^{-1}		< 2	2	< 2	< 2	< 2	< 2	7.5	< 2	< 2	8.5	< 2	< 2	3.5	< 2	< 2	5.5	< 2	< 2	< 2	< 2	< 2
Dissolved Organic Carbon	mg.l^{-1}		0.37	0.38	0.33	0.52	0.5	0.43	0.34	0.18	0.14	0.66	0.38	0.25	< 0.1	0.43	0.36	0.27	0.38	0.53	0.31	0.44	0.35
Total petroleum hydrocarbons (FTIRPER)	mg.l^{-1}		0.4	0.5	0.6	< 0.3	14.7	< 0.3	2	4.3	< 0.3	< 0.3	1.3	< 0.3	0.0231	< 0.3	0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
Total Viable Count @ 22°C	Counts. ml^{-1}		488	76	624	>1000	6	88	5	1	1008	28	>1000	200	608	25	408	348	114	145	51	109	232
Total petroleum hydrocarbons (GC)	mg.l^{-1}		0.01	0.02	< 0.01	< 0.01	< 0.01	0.02	0.01	0.02	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01	0.02	< 0.01	0.15
2,4,6-tribromophenol	µg.l^{-1}		< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.2	0.39	< 0.20	< 0.2	< 0.20	< 0.20	< 0.20
Cationic Detergents	mg.l^{-1}		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	1.2	< 1	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	1.4	1	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Dibromoacetic acid	µg.l^{-1}		< 1.00	< 1.00	< 1.00	2.4	< 1.0	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	1.2	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00
Dibromo-acetonitrile	µg.l^{-1}		< 10	< 10	< 10	< 10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.1	0.26	< 0.10	< 0.1	< 0.10	< 0.10	< 0.10
Hydrazine (measurement not reliable)	µg.l^{-1}		3.0	0.5	0.5	1.5	1.4	10.8	7.2	0.5	0.5	5.9	7.0	5.7	5.6	3.8	4.3	2.6	0.5	11.5	0.5	8.2	0.9
Hydrazine (TZW)	µg.l^{-1}		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Morpholine	mg.l^{-1}		< 10	< 10	< 10	14.8	< 2	< 10	34.5	< 10	< 10	< 10	< 10	< 10	< 20	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
bis(2-Chloroisopropyl)	mg.l^{-1}		< 0.005	< 0.005	< 0.005	< 0.005	0.008	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005

Analysis – Station 5	Units	EQS (annual average concn)	Concentration/value (ND = none detected)																				
			25/2/10 surface	25/2/10 near-bed	8/4/10 surface	21/4/10 surface	19/5/10 surface	07/06/10 surface	22/06/10 surface	06/07/10 surface	20/07/10 surface	11/08/10 surface	18/08/10 surface	09/09/10 surface	14/09/10 surface	28/09/10 surface	14/10/10 surface	15/11/10 surface	06/12/10 surface	15/12/10 surface	17/01/11 surface	31/01/11 surface	14/02/11 surface
ether																							
2-Methylnaphthalene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002	0.05	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
1-Methylnaphthalene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002	0.036	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Biphenyl	mg.l^{-1}	0.025	< 0.002	< 0.002	< 0.002	< 0.002	0.026	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Acenaphthene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002	0.011	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Dibenzofuran	mg.l^{-1}		< 0.005	< 0.005	< 0.005	< 0.005	0.007	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Fluorene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002	0.028	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Phenanthrene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002	0.048	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Anthracene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002	< 0.002	0.007	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Fluoranthene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002	< 0.002	0.004	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Pyrene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002	0.026	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
bis(2-ethylhexyl) phthalate	mg.l^{-1}	0.0013	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.007	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Benzo[k]fluoranthene	mg.l^{-1}	0.000003	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Benzo[a]pyrene	mg.l^{-1}	0.000005	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Indeno[1,2,3-cd] pyrene	mg.l^{-1}	0.000002 (sum of concen-trations)	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Benzo[g,h,i] perylene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Dibenzo[a,h] anthracene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Toluene	µg.l^{-1}	10	< 1	< 1	< 1	< 1	9	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Ethylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1	13	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
m and p-Xylene	µg.l^{-1}	30	< 1	< 1	< 1	< 1	58	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	1	< 1	< 1	< 1	< 1	< 1	< 1	3
o-Xylene	µg.l^{-1}	30	< 1	< 1	< 1	< 1	38	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	2
Bromoform	µg.l^{-1}		< 1	< 1	< 1	2	< 1	< 1	< 1	< 1	8	8	6	< 1	< 1	7	< 1	10	< 1	2	< 1	< 1	< 1
iso-Propylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1	4	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Propylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1	15	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,3,5-Trimethylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1	45	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	3
1,2,4-Trimethylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1	188	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	9
sec-Butylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1	6	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
p-Isopropyltoluene	µg.l^{-1}		< 1	< 1	< 1	< 1	6	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1

Analysis – Station 5	Units	EQS (annual average concn)	Concentration/value (ND = none detected)																				
			25/2/10 surface	25/2/10 near-bed	8/4/10 surface	21/4/10 surface	19/5/10 surface	07/06/10 surface	22/06/10 surface	06/07/10 surface	20/07/10 surface	11/08/10 surface	18/08/10 surface	09/09/10 surface	14/09/10 surface	28/09/10 surface	14/10/10 surface	15/11/10 surface	06/12/10 surface	15/12/10 surface	17/01/11 surface	31/01/11 surface	14/02/11 surface
Tentatively identified semi-volatile organic compounds:																							
2,4 Dibromophenol	mg.l^{-1}		ND	ND	< 0.002	< 0.002	ND	< 0.002	< 0.05	< 0.05	< 0.002	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	ND	< 0.002	ND	< 0.002	< 0.02	ND	< 0.02
2,6-Dibromophenol	mg.l^{-1}		ND	ND	< 0.02	< 0.02	ND	< 0.002	< 0.05	< 0.05	< 0.002	< 0.02	< 0.02	< 0.02	< 0.02	< 0.002	ND	< 0.002	ND	< 0.002	< 0.02	ND	< 0.02
Tetrachloro-ethylene	mg.l^{-1}		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.016	ND	ND	ND	ND	ND
2-Oxazolidone	mg.l^{-1}		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.018	ND	ND
butyl cyclohexyl ester 1,2-Benzene dicarboxylic acid	mg.l^{-1}		ND	ND	ND	ND	ND	ND	ND	ND	0.011	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,3,5-trimethyl-Phenanthrene	mg.l^{-1}		ND	ND	ND	ND	0.125	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Eicosane	mg.l^{-1}		ND	ND	ND	ND	0.114	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bacchotricuneatin c	mg.l^{-1}		ND	ND	ND	ND	0.081	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,6,10,14-tetramethyl-Hexadecane	mg.l^{-1}		ND	ND	ND	ND	0.079	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Bromo dodecane	mg.l^{-1}		ND	ND	ND	ND	0.072	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dodecane	mg.l^{-1}		ND	ND	ND	ND	0.064	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-methyl-Pyrene	mg.l^{-1}		ND	ND	ND	ND	0.061	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-methyl-Phenanthrene	mg.l^{-1}		ND	ND	ND	ND	0.057	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9-methyl-9H-Fluorene	mg.l^{-1}		ND	ND	ND	ND	0.054	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,6,10,15-tetramethyl-Heptadecane	mg.l^{-1}		ND	ND	ND	ND	0.053	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,7-dimethyl-Phenanthrene	mg.l^{-1}		ND	ND	ND	ND	0.051	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetradecane	mg.l^{-1}		ND	ND	ND	ND	0.050	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-methyl-Octadecane	mg.l^{-1}		ND	ND	ND	ND	0.049	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-methyl-6-propyl-Dodecane	mg.l^{-1}		ND	ND	ND	ND	0.045	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Heptacosane	mg.l^{-1}		ND	ND	ND	ND	0.044	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Octadecane	mg.l^{-1}		ND	ND	ND	ND	0.041	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetradecane	mg.l^{-1}		ND	ND	ND	ND	0.039	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pentadecane	mg.l^{-1}		ND	ND	ND	ND	0.037	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,3,4-tetrahydro-Phenanthrene	mg.l^{-1}		ND	ND	ND	ND	0.034	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Analysis – Station 5	Units	EQS (annual average concn)	Concentration/value (ND = none detected)																				
			25/2/10 surface	25/2/10 near-bed	8/4/10 surface	21/4/10 surface	19/5/10 surface	07/06/10 surface	22/06/10 surface	06/07/10 surface	20/07/10 surface	11/08/10 surface	18/08/10 surface	09/09/10 surface	14/09/10 surface	28/09/10 surface	14/10/10 surface	15/11/10 surface	06/12/10 surface	15/12/10 surface	17/01/11 surface	31/01/11 surface	14/02/11 surface
Tentatively identified volatile organic compounds:																							
Dodecane	µg.l^{-1}		ND	ND	ND	ND	183	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-methyl-Naphthalene	µg.l^{-1}		ND	ND	ND	ND	132	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3-methyl-Undecane	µg.l^{-1}		ND	ND	ND	ND	132	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetradecane	µg.l^{-1}		ND	ND	ND	ND	126	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-methyl-1-propenyl-Benzene	µg.l^{-1}		ND	ND	ND	ND	117	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,3,4-tetrahydro-5-methyl-Naphthalene	µg.l^{-1}		ND	ND	ND	ND	107	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-ethenyl-2-methyl-Benzene	µg.l^{-1}		ND	ND	ND	ND	106	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-ethyl-2,3-dimethyl-Benzene	µg.l^{-1}		ND	ND	ND	ND	76	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,3,4-tetrahydro-Naphthalene	µg.l^{-1}		ND	ND	ND	ND	74	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
alpha, beta, beta.-Trimethylstyrene	µg.l^{-1}		ND	ND	ND	ND	74	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-methyl-2-(2-propenyl)-Benzene	µg.l^{-1}		ND	ND	ND	ND	64	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-methyl-4-(1-methylethyl)-Benzene	µg.l^{-1}		ND	ND	ND	ND	64	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,3,4,5,6,7-Hexahydro-1H-cyclopenta[a] pentalene	µg.l^{-1}		ND	ND	ND	ND	63	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-methyl-4-propyl-Benzene	µg.l^{-1}		ND	ND	ND	ND	58	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
(2-methyl-1-butenyl)-Benzene	µg.l^{-1}		ND	ND	ND	ND	52	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-methyl-4-(2-propenyl)-Benzene	µg.l^{-1}		ND	ND	ND	ND	43	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-butyl-Benzene-sulfonamide	µg.l^{-1}		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6	ND	ND

Table 40 Station 6 spatial survey water sample analysis results. Negative results are presented as less than the limit of detection or "ND" (none detected) for tentatively identified compounds, for which the limits of detection vary. Station 6 was located 0.5 km from the cooling water outfall.

Analysis – Station 6	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**	
			07/04/10 Surface	**15/12/10 Surface**
pH	pH units		7.7	7.9
Suspended Solids	mg.l^{-1}		58	84
Total Alkalinity as $CaCO_3$	mg.l^{-1}		135	100
Bicarbonate Alkalinity as $CaCO_3$	mg.l^{-1}		135	100
Carbonate Alkalinity as $CaCO_3$	mg.l^{-1}		0	0
Chloride as Cl	mg.l^{-1}		13400	15800
Fluoride as F	mg.l^{-1}		1.3	1.2
Total Sulphur as SO_4 (Dissolved)	mg.l^{-1}		2780	2710
Calcium as Ca (Total)	mg.l^{-1}		268	257
Calcium as Ca (Dissolved)	mg.l^{-1}		260	264
Magnesium as Mg (Total)	mg.l^{-1}		1400	1300
Magnesium as Mg (Dissolved)	mg.l^{-1}		1230	1210
Strontium as Sr (Total)	mg.l^{-1}		5	4.86
Strontium as Sr (Dissolved)	mg.l^{-1}		4.75	4.54
Sodium as Na (Dissolved)	mg.l^{-1}		9570	11400
Potassium as K (Total)	mg.l^{-1}		640	637
Potassium as K (Dissolved)	mg.l^{-1}		564	589
Nickel as Ni (Total)	mg.l^{-1}		0.002	0.004
Nickel as Ni (Dissolved)	mg.l^{-1}	0.02	0.003	0.004
Chromium as Cr (Total)	mg.l^{-1}		< 0.001	< 0.001
Chromium as Cr (Dissolved)	mg.l^{-1}	0.015	< 0.001	< 0.001
Cadmium as Cd (Total)	mg.l^{-1}		< 0.0001	< 0.0001
Cadmium as Cd (Dissolved)	mg.l^{-1}	0.0002	< 0.0001	< 0.0001
Copper as Cu (Total)	mg.l^{-1}		0.002	0.004
Copper as Cu (Dissolved)	mg.l^{-1}	0.005	0.003	0.004
Lead as Pb (Total)	mg.l^{-1}		< 0.001	< 0.001
Zinc as Zn (Total)	mg.l^{-1}		0.015	0.011
Zinc as Zn (Dissolved)	mg.l^{-1}	0.04	0.015	0.009
Manganese as Mn (Dissolved)	mg.l^{-1}		< 0.002	< 0.002

Analysis – Station 6	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**	
			07/04/10 Surface	**15/12/10 Surface**
Iron as Fe (Total)	$mg.l^{-1}$		0.01	< 0.01

Analysis – Station 6	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**	
			07/04/10 Surface	**15/12/10 Surface**
Iron as Fe (Dissolved)	mg.l^{-1}	1	< 0.01	< 0.01
Aluminium as Al (Dissolved)	mg.l^{-1}		0.01	< 0.01
Arsenic as As (Total)	mg.l^{-1}		0.008	0.015
Arsenic as As (Dissolved)	mg.l^{-1}	0.025	0.017	0.016
Boron as B (Total)	mg.l^{-1}		4.99	4.37
Boron as B (Dissolved)	mg.l^{-1}		4.37	4.07
Mercury as Hg (Total)	mg.l^{-1}		< 0.0001	0.0002
Mercury as Hg (Dissolved)	mg.l^{-1}	0.00005	< 0.0001	< 0.0001
Selenium as Se (Dissolved)	mg.l^{-1}		0.025	0.024
Selenium as Se (Total)	mg.l^{-1}		0.015	0.015
Molybdenum as Mo (Total)	mg.l^{-1}		0.007	0.01
Molybdenum as Mo (Dissolved)	mg.l^{-1}		0.01	0.01
Cobalt as Co (Total)	mg.l^{-1}		< 0.001	< 0.001
Cobalt as Co (Dissolved)	mg.l^{-1}		< 0.001	< 0.001
Ammoniacal Nitrogen as N	mg.l^{-1}		0.43	0.4
Nitrite as N	mg.l^{-1}		< 0.01	< 0.01
Nitrate as N	mg.l^{-1}		< 0.2	< 0.2
Phosphate as P	mg.l^{-1}		< 0.01	< 0.01
Chemical Oxygen Demand (Settled)	mg.l^{-1}		220	240
Total Organic Carbon	mg.l^{-1}		0.48	0.55
Salinity	ppt		38	35.6
Turbidity N.T.U	NTU		37	11
Bromide as Br	mg.l^{-1}		125	253
Iodide as I	mg.l^{-1}		< 2	< 2
Barium as Ba (Total)	mg.l^{-1}		< 0.01	< 0.01
Lithium as Li (DIssolved)	mg.l^{-1}		0.08	0.09
Silicon as Si (Total)	mg.l^{-1}		0.5	0.4
MBAS as Lauryl Sulphate	µg.l^{-1}		60	< 20
Chlorophyll A	µg.l^{-1}		< 10	< 10
Biochemical Oxygen Demand	mg.l^{-1}		< 2	< 2
Dissolved Organic Carbon	mg.l^{-1}		0.4	0.46
Total petroleum hydrocarbons (FTIRPER)	mg.l^{-1}		< 0.3	< 0.3
Total Viable Count @ 22°C	Counts.ml^{-1}		800	256

Analysis – Station 6	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)	
			07/04/10 Surface	15/12/10 Surface
Total petroleum hydrocarbons (GC)	$mg.l^{-1}$		< 0.01	< 0.01
2,4,6-tribromophenol	$µg.l^{-1}$		< 0.20	< 0.2
Cationic Detergents	$mg.l^{-1}$		< 1	< 1
Dibromoacetic acid	$µg.l^{-1}$		< 1	< 1
Dibromoacetonitrile	$µg.l^{-1}$		< 10	< 0.1
Hydrazine (measurement not reliable)	$µg.l^{-1}$		1.5	2.9
Hydrazine (TZW)	$µg.l^{-1}$		-	< 0.01
Morpholine	$mg.l^{-1}$		< 10	< 10
bis(2-Chloroisopropyl)ether	$mg.l^{-1}$		< 0.005	< 0.005
2-Methylnaphthalene	$mg.l^{-1}$		< 0.002	< 0.002
1-Methylnaphthalene	$mg.l^{-1}$		< 0.002	< 0.002
Biphenyl	$mg.l^{-1}$	0.025	< 0.002	< 0.002
Acenaphthene	$mg.l^{-1}$		< 0.002	< 0.002
Dibenzofuran	$mg.l^{-1}$		< 0.005	< 0.005
Fluorene	$mg.l^{-1}$		< 0.002	< 0.002
Phenanthrene	$mg.l^{-1}$		< 0.002	< 0.002
Anthracene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002
Fluoranthene	$mg.l^{-1}$	0.0001	< 0.002	< 0.002
Pyrene	$mg.l^{-1}$		< 0.002	< 0.002
bis(2-ethylhexyl)phthalate	$mg.l^{-1}$	0.0013	< 0.005	< 0.005
Benzo[k]fluoranthene	$mg.l^{-1}$	0.000003	< 0.002	< 0.002
Benzo[a]pyrene	$mg.l^{-1}$	0.000005	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	$mg.l^{-1}$	0.000002 (sum of concns.)	< 0.002	< 0.002
Benzo[g,h,i]perylene	$mg.l^{-1}$		< 0.002	< 0.002
Dibenzo[a,h]anthracene	$mg.l^{-1}$		< 0.002	< 0.002
Toluene	$µg.l^{-1}$	10	< 1	< 1
Ethylbenzene	$µg.l^{-1}$		< 1	< 1
m and p-Xylene	$µg.l^{-1}$	30	< 1	< 1
o-Xylene	$µg.l^{-1}$	30	< 1	< 1
Bromoform	$µg.l^{-1}$		< 1	< 1
iso-Propylbenzene	$µg.l^{-1}$		< 1	< 1
Propylbenzene	$µg.l^{-1}$		< 1	< 1
1,3,5-Trimethylbenzene	$µg.l^{-1}$		< 1	< 1
1,2,4-Trimethylbenzene	$µg.l^{-1}$		< 1	< 1

Analysis – Station 6	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**	
			07/04/10 Surface	**15/12/10 Surface**
sec-Butylbenzene	µg.l^{-1}		< 1	< 1
p-Isopropyltoluene	µg.l^{-1}		< 1	< 1
Tentatively identified semi-volatile organic compounds:				
2,4-Dibromophenol	mg.l^{-1}		ND	< 0.002
2,6-Dibromophenol	mg.l^{-1}		ND	< 0.002
Tentatively identified volatile organic compounds:				
	µg.l^{-1}		ND	ND

Table 41 Station 7 spatial survey water sample analysis results. Negative results are presented as less than the limit of detection or “ND” (none detected) for tentatively identified compounds, for which the limits of detection vary. Station 7 was located 1.1 km from the cooling water outfall.

Analysis – Station 7	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)		
			08/04/10 Surface	08/04/10 Near-bed	31/01/11 Surface
pH	pH units		7.9	7.9	7.8
Suspended Solids	$mg.l^{-1}$		100	95	57
Total Alkalinity as $CaCO_3$	$mg.l^{-1}$		139	126	142
Bicarbonate Alkalinity as $CaCO_3$	$mg.l^{-1}$		139	126	142
Carbonate Alkalinity as $CaCO_3$	$mg.l^{-1}$		0	0	0
Chloride as Cl	$mg.l^{-1}$		14300	11600	16600
Fluoride as F	$mg.l^{-1}$		1.3	1.3	1.2
Total Sulphur as SO_4 (Dissolved)	$mg.l^{-1}$		3080	2780	2760
Calcium as Ca (Total)	$mg.l^{-1}$		275	268	261
Calcium as Ca (Dissolved)	$mg.l^{-1}$		260	261	259
Magnesium as Mg (Total)	$mg.l^{-1}$		1370	1480	1200
Magnesium as Mg (Dissolved)	$mg.l^{-1}$		1340	1250	1240
Strontium as Sr (Total)	$mg.l^{-1}$		5.09	4.93	4.65
Strontium as Sr (Dissolved)	$mg.l^{-1}$		4.77	4.8	4.75
Sodium as Na (Dissolved)	$mg.l^{-1}$		9400	10100	11600
Potassium as K (Total)	$mg.l^{-1}$		629	673	578
Potassium as K (Dissolved)	$mg.l^{-1}$		615	567	585
Nickel as Ni (Total)	$mg.l^{-1}$		0.002	0.003	0.006
Nickel as Ni (Dissolved)	$mg.l^{-1}$	0.02	0.003	0.003	0.005
Chromium as Cr (Total)	$mg.l^{-1}$		< 0.001	< 0.001	0.004
Chromium as Cr (Dissolved)	$mg.l^{-1}$	0.015	< 0.001	< 0.001	0.001
Cadmium as Cd (Total)	$mg.l^{-1}$		< 0.0001	< 0.0001	< 0.0001
Cadmium as Cd (Dissolved)	$mg.l^{-1}$	0.0002	< 0.0001	< 0.0001	< 0.0001
Copper as Cu (Total)	$mg.l^{-1}$		0.002	0.003	0.01
Copper as Cu (Dissolved)	$mg.l^{-1}$	0.005	0.003	0.003	0.006
Lead as Pb (Total)	$mg.l^{-1}$		< 0.001	< 0.001	0.002
Zinc as Zn (Total)	$mg.l^{-1}$		0.007	0.018	0.016
Zinc as Zn (Dissolved)	$mg.l^{-1}$	0.04	0.008	0.023	0.009
Manganese as Mn (Dissolved)	$mg.l^{-1}$		< 0.002	< 0.002	< 0.002

Analysis – Station 7	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)		
			08/04/10 Surface	08/04/10 Near-bed	31/01/11 Surface
Iron as Fe (Total)	$mg.l^{-1}$		0.03	0.07	1.07

Analysis – Station 7	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**		
			08/04/10 Surface	**08/04/10 Near-bed**	**31/01/11 Surface**
Iron as Fe (Dissolved)	$mg.l^{-1}$	1	< 0.01	< 0.01	< 0.01
Aluminium as Al (Dissolved)	$mg.l^{-1}$		0.01	0.01	0.01
Arsenic as As (Total)	$mg.l^{-1}$		0.013	0.014	0.011
Arsenic as As (Dissolved)	$mg.l^{-1}$	0.025	0.019	0.019	0.024
Boron as B (Total)	$mg.l^{-1}$		4.89	5.26	4.05
Boron as B (Dissolved)	$mg.l^{-1}$		4.7	4.57	4.12
Mercury as Hg (Total)	$mg.l^{-1}$		< 0.0001	< 0.0001	0.0002
Mercury as Hg (Dissolved)	$mg.l^{-1}$	0.00005	< 0.0001	< 0.0001	0.0001
Selenium as Se (Dissolved)	$mg.l^{-1}$		0.043	0.054	< 0.001
Selenium as Se (Total)	$mg.l^{-1}$		0.038	0.036	< 0.001
Molybdenum as Mo (Total)	$mg.l^{-1}$		0.008	0.008	0.01
Molybdenum as Mo (Dissolved)	$mg.l^{-1}$		0.01	0.01	0.011
Cobalt as Co (Total)	$mg.l^{-1}$		< 0.001	< 0.001	0.002
Cobalt as Co (Dissolved)	$mg.l^{-1}$		< 0.001	< 0.001	0.001
Ammoniacal Nitrogen as N	$mg.l^{-1}$		0.4	0.47	0.44
Nitrite as N	$mg.l^{-1}$		< 0.01	< 0.01	< 0.01
Nitrate as N	$mg.l^{-1}$		< 0.2	< 0.2	< 0.2
Phosphate as P	$mg.l^{-1}$		< 0.01	< 0.01	< 0.01
Chemical Oxygen Demand (Settled)	$mg.l^{-1}$		225	190	280
Total Organic Carbon	$mg.l^{-1}$		0.49	0.48	0.61
Salinity	ppt		37.9	38.1	32.9
Turbidity N.T.U	NTU		12	16	121
Bromide as Br	$mg.l^{-1}$		219	254	60.9
Iodide as I	$mg.l^{-1}$		< 2	< 2	< 2
Barium as Ba (Total)	$mg.l^{-1}$		< 0.01	< 0.01	< 0.01
Lithium as Li (DIssolved)	$mg.l^{-1}$		0.07	0.07	0.05
Silicon as Si (Total)	$mg.l^{-1}$		0.5	0.5	1.6
MBAS as Lauryl Sulphate	$\mu g.l^{-1}$		< 20	60	< 20
Chlorophyll A	$\mu g.l^{-1}$		< 10	< 10	< 10
Biochemical Oxygen Demand	$mg.l^{-1}$		< 2	< 2	< 2
Dissolved Organic Carbon	$mg.l^{-1}$		0.34	0.29	0.45
Total petroleum hydrocarbons (FTIRPER)	$mg.l^{-1}$		0.6	1.1	< 0.3
Total Viable Count @ 22°C	$Counts.ml^{-1}$		32	160	29

Analysis – Station 7	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**		
			08/04/10 Surface	**08/04/10 Near-bed**	**31/01/11 Surface**
Total petroleum hydrocarbons (GC)	mg.l^{-1}		< 0.01	0.02	< 0.01
2,4,6-tribromophenol	µg.l^{-1}		< 0.20	< 0.20	< 0.20
Cationic Detergents	mg.l^{-1}		< 1	< 1	< 1
Dibromoacetic acid	µg.l^{-1}		< 1	< 1	< 1
Dibromoacetonitrile	µg.l^{-1}		< 10	< 10	< 0.10
Hydrazine (measurement not reliable)	µg.l^{-1}		0.5	0.5	1.5
Hydrazine (TZW)	µg.l^{-1}		-	-	< 0.01
Morpholine	mg.l^{-1}		< 10	< 10	< 10
bis(2-Chloroisopropyl)ether	mg.l^{-1}		< 0.005	< 0.005	< 0.005
2-Methylnaphthalene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
1-Methylnaphthalene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
Biphenyl	mg.l^{-1}	0.025	< 0.002	< 0.002	< 0.002
Acenaphthene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
Dibenzofuran	mg.l^{-1}		< 0.005	< 0.005	< 0.005
Fluorene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
Phenanthrene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
Anthracene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002
Fluoranthene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002
Pyrene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
bis(2-ethylhexyl)phthalate	mg.l^{-1}	0.0013	< 0.005	< 0.005	< 0.005
Benzo[k]fluoranthene	mg.l^{-1}	0.000003	< 0.002	< 0.002	< 0.002
Benzo[a]pyrene	mg.l^{-1}	0.000005	< 0.002	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	mg.l^{-1}	0.000002 (sum of concns)	< 0.002	< 0.002	< 0.002
Benzo[g,h,i]perylene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
Dibenzo[a,h]anthracene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
Toluene	µg.l^{-1}	10	< 1	< 1	< 1
Ethylbenzene	µg.l^{-1}		< 1	< 1	< 1
m and p-Xylene	µg.l^{-1}	30	< 1	< 1	< 1
o-Xylene	µg.l^{-1}	30	< 1	< 1	< 1
Bromoform	µg.l^{-1}		< 1	< 1	< 1
iso-Propylbenzene	µg.l^{-1}		< 1	< 1	< 1
Propylbenzene	µg.l^{-1}		< 1	< 1	< 1
1,3,5-Trimethylbenzene	µg.l^{-1}		< 1	< 1	< 1
1,2,4-Trimethylbenzene	µg.l^{-1}		< 1	< 1	< 1

Analysis – Station 7	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**		
			08/04/10 Surface	**08/04/10 Near-bed**	**31/01/11 Surface**
sec-Butylbenzene	µg.l^{-1}		< 1	< 1	< 1
p-Isopropyltoluene	µg.l^{-1}		< 1	< 1	< 1
Tentatively identified semi-volatile organic compounds:					
2,4-Dibromophenol	mg.l^{-1}		< 0.002	< 0.002	ND
2,6-Dibromophenol	mg.l^{-1}		< 0.002	< 0.002	ND
Tentatively identified volatile organic compounds:					
	µg.l^{-1}		ND	ND	ND

Table 42 Station 8 spatial survey water sample analysis results. Negative results are presented as less than the limit of detection or “ND” (none detected) for tentatively identified compounds, for which the limits of detection vary. Station 8 was located 2.4 km from the cooling water outfall.

Analysis – Station 8	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**	
			08/04/10 Surface	**31/01/11 Surface**
pH	pH units		7.9	7.8
Suspended Solids	$mg.l^{-1}$		96	69
Total Alkalinity as $CaCO_3$	$mg.l^{-1}$		137	129
Bicarbonate Alkalinity as $CaCO_3$	$mg.l^{-1}$		137	129
Carbonate Alkalinity as $CaCO_3$	$mg.l^{-1}$		0	0
Chloride as Cl	$mg.l^{-1}$		14200	12300
Fluoride as F	$mg.l^{-1}$		1.3	1.3
Total Sulphur as SO_4 (Dissolved)	$mg.l^{-1}$		2870	2630
Calcium as Ca (Total)	$mg.l^{-1}$		200	261
Calcium as Ca (Dissolved)	$mg.l^{-1}$		261	263
Magnesium as Mg (Total)	$mg.l^{-1}$		841	1310
Magnesium as Mg (Dissolved)	$mg.l^{-1}$		1250	1220
Strontium as Sr (Total)	$mg.l^{-1}$		3.58	4.7
Strontium as Sr (Dissolved)	$mg.l^{-1}$		4.77	4.74
Sodium as Na (Dissolved)	$mg.l^{-1}$		10000	11400
Potassium as K (Total)	$mg.l^{-1}$		380	616
Potassium as K (Dissolved)	$mg.l^{-1}$		573	582
Nickel as Ni (Total)	$mg.l^{-1}$		0.003	0.007
Nickel as Ni (Dissolved)	$mg.l^{-1}$	0.02	0.003	0.006
Chromium as Cr (Total)	$mg.l^{-1}$		< 0.001	0.004
Chromium as Cr (Dissolved)	$mg.l^{-1}$	0.015	< 0.001	0.001
Cadmium as Cd (Total)	$mg.l^{-1}$		< 0.0001	< 0.0001
Cadmium as Cd (Dissolved)	$mg.l^{-1}$	0.0002	< 0.0001	< 0.0001
Copper as Cu (Total)	$mg.l^{-1}$		0.003	0.01
Copper as Cu (Dissolved)	$mg.l^{-1}$	0.005	0.003	0.006
Lead as Pb (Total)	$mg.l^{-1}$		< 0.001	0.003
Zinc as Zn (Total)	$mg.l^{-1}$		0.011	0.02
Zinc as Zn (Dissolved)	$mg.l^{-1}$	0.04	0.011	0.009
Manganese as Mn (Dissolved)	$mg.l^{-1}$		< 0.002	< 0.002

Analysis – Station 8	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**	
			08/04/10 Surface	**31/01/11 Surface**
Iron as Fe (Total)	mg.l^{-1}		0.01	3.97

Analysis – Station 8	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**	
			08/04/10 Surface	**31/01/11 Surface**
Iron as Fe (Dissolved)	$mg.l^{-1}$	1	< 0.01	< 0.01
Aluminium as Al (Dissolved)	$mg.l^{-1}$		0.01	0.01
Arsenic as As (Total)	$mg.l^{-1}$		0.009	0.022
Arsenic as As (Dissolved)	$mg.l^{-1}$	0.025	0.018	0.025
Boron as B (Total)	$mg.l^{-1}$		3.03	4.31
Boron as B (Dissolved)	$mg.l^{-1}$		4.45	3.99
Mercury as Hg (Total)	$mg.l^{-1}$		< 0.0001	0.0002
Mercury as Hg (Dissolved)	$mg.l^{-1}$	0.00005	< 0.0001	0.0001
Selenium as Se (Dissolved)	$mg.l^{-1}$		0.057	< 0.001
Selenium as Se (Total)	$mg.l^{-1}$		0.017	< 0.001
Molybdenum as Mo (Total)	$mg.l^{-1}$		0.01	0.01
Molybdenum as Mo (Dissolved)	$mg.l^{-1}$		0.01	0.012
Cobalt as Co (Total)	$mg.l^{-1}$		< 0.001	0.002
Cobalt as Co (Dissolved)	$mg.l^{-1}$		< 0.001	0.001
Ammoniacal Nitrogen as N	$mg.l^{-1}$		0.45	0.44
Nitrite as N	$mg.l^{-1}$		< 0.01	< 0.01
Nitrate as N	$mg.l^{-1}$		< 0.2	< 0.2
Phosphate as P	$mg.l^{-1}$		< 0.01	< 0.01
Chemical Oxygen Demand (Settled)	$mg.l^{-1}$		200	300
Total Organic Carbon	$mg.l^{-1}$		0.51	0.68
Salinity	ppt		37.9	33.1
Turbidity N.T.U	NTU		9	12
Bromide as Br	$mg.l^{-1}$		189	61.1
Iodide as I	$mg.l^{-1}$		< 2	< 2
Barium as Ba (Total)	$mg.l^{-1}$		< 0.01	0.01
Lithium as Li (DIssolved)	$mg.l^{-1}$		0.07	0.05
Silicon as Si (Total)	$mg.l^{-1}$		0.3	4.6
MBAS as Lauryl Sulphate	$\mu g.l^{-1}$		20	< 20
Chlorophyll A	$\mu g.l^{-1}$		< 10	< 10
Biochemical Oxygen Demand	$mg.l^{-1}$		< 2	< 2
Dissolved Organic Carbon	$mg.l^{-1}$		0.28	0.61
Total petroleum hydrocarbons (FTIRPER)	$mg.l^{-1}$		0.7	< 0.3
Total Viable Count @ 22°C	$Counts.ml^{-1}$		180	118

Analysis – Station 8	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**	
			08/04/10 Surface	**31/01/11 Surface**
Total petroleum hydrocarbons (GC)	mg.l^{-1}		< 0.01	< 0.01
2,4,6-tribromophenol	µg.l^{-1}		< 0.20	< 0.20
Cationic Detergents	mg.l^{-1}		< 1	1.6
Dibromoacetic acid	µg.l^{-1}		< 1	< 1
Dibromoacetonitrile	µg.l^{-1}		< 10	< 0.10
Hydrazine (measurement not reliable)	µg.l^{-1}		1.9	4.5
Hydrazine (TZW)	µg.l^{-1}		-	< 0.01
Morpholine	mg.l^{-1}		< 10	< 10
bis(2-Chloroisopropyl)ether	mg.l^{-1}		< 0.005	< 0.005
2-Methylnaphthalene	mg.l^{-1}		< 0.002	< 0.002
1-Methylnaphthalene	mg.l^{-1}		< 0.002	< 0.002
Biphenyl	mg.l^{-1}	0.025	< 0.002	< 0.002
Acenaphthene	mg.l^{-1}		< 0.002	< 0.002
Dibenzofuran	mg.l^{-1}		< 0.005	< 0.005
Fluorene	mg.l^{-1}		< 0.002	< 0.002
Phenanthrene	mg.l^{-1}		< 0.002	< 0.002
Anthracene	mg.l^{-1}	0.0001	< 0.002	< 0.002
Fluoranthene	mg.l^{-1}	0.0001	< 0.002	< 0.002
Pyrene	mg.l^{-1}		< 0.002	< 0.002
bis(2-ethylhexyl)phthalate	mg.l^{-1}	0.0013	< 0.005	< 0.005
Benzo[k]fluoranthene	mg.l^{-1}	0.000003	< 0.002	< 0.002
Benzo[a]pyrene	mg.l^{-1}	0.000005	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	mg.l^{-1}	0.000002 (sum of concns)	< 0.002	< 0.002
Benzo[g,h,i]perylene	mg.l^{-1}		< 0.002	< 0.002
Dibenzo[a,h]anthracene	mg.l^{-1}		< 0.002	< 0.002
Toluene	µg.l^{-1}	10	< 1	< 1
Ethylbenzene	µg.l^{-1}		< 1	< 1
m and p-Xylene	µg.l^{-1}	30	< 1	< 1
o-Xylene	µg.l^{-1}	30	< 1	< 1
Bromoform	µg.l^{-1}		< 1	< 1
iso-Propylbenzene	µg.l^{-1}		< 1	< 1
Propylbenzene	µg.l^{-1}		< 1	< 1
1,3,5-Trimethylbenzene	µg.l^{-1}		< 1	< 1
1,2,4-Trimethylbenzene	µg.l^{-1}		< 1	< 1

Analysis – Station 8	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**	
			08/04/10 Surface	**31/01/11 Surface**
sec-Butylbenzene	µg.l^{-1}		< 1	< 1
p-Isopropyltoluene	µg.l^{-1}		< 1	< 1
Tentatively identified semi-volatile organic compounds:				
2,4-Dibromophenol	mg.l^{-1}		ND	< 0.002
2,6-Dibromophenol	mg.l^{-1}		ND	< 0.002
Tentatively identified volatile organic compounds:				
	µg.l^{-1}		ND	ND

Table 43 Station 9 spatial survey water sample analysis results. Negative results are presented as less than the limit of detection or “ND” (none detected) for tentatively identified compounds, for which the limits of detection vary. Station 9 was located 12 km from the cooling water outfall.

Analysis – Station 9	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)		
			08/04/10 Surface	08/04/10 Near-bed	17/01/11 Surface
pH	pH units		7.9	7.9	7.8
Suspended Solids	$mg.l^{-1}$		68	80	65
Total Alkalinity as $CaCO_3$	$mg.l^{-1}$		134	140	149
Bicarbonate Alkalinity as $CaCO_3$	$mg.l^{-1}$		134	140	149
Carbonate Alkalinity as $CaCO_3$	$mg.l^{-1}$		0	0	0
Chloride as Cl	$mg.l^{-1}$		14300	15500	13000
Fluoride as F	$mg.l^{-1}$		1.4	1.3	1.3
Total Sulphur as SO_4 (Dissolved)	$mg.l^{-1}$		2800	3200	2820
Calcium as Ca (Total)	$mg.l^{-1}$		258	266	262
Calcium as Ca (Dissolved)	$mg.l^{-1}$		256	262	272
Magnesium as Mg (Total)	$mg.l^{-1}$		1240	1420	1340
Magnesium as Mg (Dissolved)	$mg.l^{-1}$		1270	1430	1350
Strontium as Sr (Total)	$mg.l^{-1}$		4.73	5.01	4.78
Strontium as Sr (Dissolved)	$mg.l^{-1}$		4.81	4.79	4.95
Sodium as Na (Dissolved)	$mg.l^{-1}$		10100	9510	11000
Potassium as K (Total)	$mg.l^{-1}$		563	646	626
Potassium as K (Dissolved)	$mg.l^{-1}$		582	656	417
Nickel as Ni (Total)	$mg.l^{-1}$		0.003	0.004	0.005
Nickel as Ni (Dissolved)	$mg.l^{-1}$	0.02	0.003	0.003	0.004
Chromium as Cr (Total)	$mg.l^{-1}$		< 0.001	< 0.001	< 0.001
Chromium as Cr (Dissolved)	$mg.l^{-1}$	0.015	< 0.001	< 0.001	< 0.001
Cadmium as Cd (Total)	$mg.l^{-1}$		< 0.0001	< 0.0001	< 0.0001
Cadmium as Cd (Dissolved)	$mg.l^{-1}$	0.0002	< 0.0001	< 0.0001	< 0.0001
Copper as Cu (Total)	$mg.l^{-1}$		0.003	0.003	0.006
Copper as Cu (Dissolved)	$mg.l^{-1}$	0.005	0.003	0.004	0.005
Lead as Pb (Total)	$mg.l^{-1}$		< 0.001	< 0.001	< 0.001
Zinc as Zn (Total)	$mg.l^{-1}$		0.016	0.044	0.027
Zinc as Zn (Dissolved)	$mg.l^{-1}$	0.04	0.018	0.054	0.022
Manganese as Mn (Dissolved)	$mg.l^{-1}$		< 0.002	< 0.002	< 0.002

Analysis – Station 9	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**		
			08/04/10 Surface	**08/04/10 Near-bed**	**17/01/11 Surface**
Iron as Fe (Total)	$mg.l^{-1}$		0.03	0.06	< 0.01

Analysis – Station 9	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**		
			08/04/10 Surface	**08/04/10 Near-bed**	**17/01/11 Surface**
Iron as Fe (Dissolved)	mg.l^{-1}	1	< 0.01	< 0.01	< 0.01
Aluminium as Al (Dissolved)	mg.l^{-1}		0.01	0.02	0.01
Arsenic as As (Total)	mg.l^{-1}		0.014	0.014	0.026
Arsenic as As (Dissolved)	mg.l^{-1}	0.025	0.019	0.019	0.028
Boron as B (Total)	mg.l^{-1}		4.45	5.06	4.37
Boron as B (Dissolved)	mg.l^{-1}		4.51	5.05	3.25
Mercury as Hg (Total)	mg.l^{-1}		< 0.0001	< 0.0001	0.0001
Mercury as Hg (Dissolved)	mg.l^{-1}	0.00005	< 0.0001	< 0.0001	0.0001
Selenium as Se (Dissolved)	mg.l^{-1}		0.061	0.054	0.1
Selenium as Se (Total)	mg.l^{-1}		0.034	0.044	0.082
Molybdenum as Mo (Total)	mg.l^{-1}		0.008	0.008	0.012
Molybdenum as Mo (Dissolved)	mg.l^{-1}		0.011	0.01	0.012
Cobalt as Co (Total)	mg.l^{-1}		< 0.001	< 0.001	0.001
Cobalt as Co (Dissolved)	mg.l^{-1}		< 0.001	< 0.001	< 0.001
Ammoniacal Nitrogen as N	mg.l^{-1}		0.47	0.3	0.4
Nitrite as N	mg.l^{-1}		< 0.01	< 0.01	< 0.01
Nitrate as N	mg.l^{-1}		< 0.2	< 0.2	< 0.2
Phosphate as P	mg.l^{-1}		0.02	< 0.01	< 0.01
Chemical Oxygen Demand (Settled)	mg.l^{-1}		250	240	300
Total Organic Carbon	mg.l^{-1}		0.45	0.52	0.52
Salinity	ppt		38.2	38	36.2
Turbidity N.T.U	NTU		8	21	< 1
Bromide as Br	mg.l^{-1}		229	215	786
Iodide as I	mg.l^{-1}		< 2	< 2	< 2
Barium as Ba (Total)	mg.l^{-1}		< 0.01	< 0.01	< 0.01
Lithium as Li (DIssolved)	mg.l^{-1}		0.07	0.07	0.06
Silicon as Si (Total)	mg.l^{-1}		0.4	0.5	0.5
MBAS as Lauryl Sulphate	µg.l^{-1}		< 20	20	30
Chlorophyll A	µg.l^{-1}		< 10	< 10	< 10
Biochemical Oxygen Demand	mg.l^{-1}		< 2	< 2	< 2
Dissolved Organic Carbon	mg.l^{-1}		0.42	0.24	0.36
Total petroleum hydrocarbons (FTIRPER)	mg.l^{-1}		0.3	0.9	< 0.3
Total Viable Count @ 22°C	Counts.ml^{-1}		456	184	72

Analysis – Station 9	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)		
			08/04/10 Surface	08/04/10 Near-bed	17/01/11 Surface
Total petroleum hydrocarbons (GC)	mg.l^{-1}		< 0.01	0.01	0.03
2,4,6-tribromophenol	µg.l^{-1}		< 0.20	< 0.20	< 0.20
Cationic Detergents	mg.l^{-1}		< 1	2	< 1
Dibromoacetic acid	µg.l^{-1}		< 1	< 1	< 1
Dibromoacetonitrile	µg.l^{-1}		< 10	< 10	< 0.10
Hydrazine (measurement not reliable)	µg.l^{-1}		1.1	0.5	16.7
Hydrazine (TZW)	µg.l^{-1}		-	-	< 0.01
Morpholine	mg.l^{-1}		< 0.0	< 10	< 10
bis(2-Chloroisopropyl)ether	mg.l^{-1}		< 0.005	< 0.005	< 0.005
2-Methylnaphthalene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
1-Methylnaphthalene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
Biphenyl	mg.l^{-1}	0.025	< 0.002	< 0.002	< 0.002
Acenaphthene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
Dibenzofuran	mg.l^{-1}		< 0.005	< 0.005	< 0.005
Fluorene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
Phenanthrene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
Anthracene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002
Fluoranthene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002
Pyrene	mg.l^{-1}		< 0.002	< 0.002	< 0.002
bis(2-ethylhexyl)phthalate	mg.l^{-1}	0.0013	< 0.005	< 0.005	< 0.005
Benzo[k]fluoranthene	mg.l^{-1}	0.000003	< 0.002	< 0.002	< 0.002
Benzo[a]pyrene	mg.l^{-1}	0.000005	< 0.002	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	mg.l^{-1}	0.000002 (sum of concns)	0.004	< 0.002	< 0.002
Benzo[g,h,i]perylene	mg.l^{-1}		0.004	< 0.002	< 0.002
Dibenzo[a,h]anthracene	mg.l^{-1}		0.004	< 0.002	< 0.002
Toluene	µg.l^{-1}	10	< 1	< 1	< 1
Ethylbenzene	µg.l^{-1}		< 1	< 1	< 1
m and p-Xylene	µg.l^{-1}	30	< 1	< 1	< 1
o-Xylene	µg.l^{-1}	30	< 1	< 1	< 1
Bromoform	µg.l^{-1}		< 1	< 1	< 1
iso-Propylbenzene	µg.l^{-1}		< 1	< 1	< 1
Propylbenzene	µg.l^{-1}		< 1	< 1	< 1
1,3,5-Trimethylbenzene	µg.l^{-1}		< 1	< 1	< 1
1,2,4-Trimethylbenzene	µg.l^{-1}		< 1	< 1	< 1

Analysis – Station 9	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**		
			08/04/10 Surface	**08/04/10 Near-bed**	**17/01/11 Surface**
sec-Butylbenzene	µg.l^{-1}		< 1	< 1	< 1
p-Isopropyltoluene	µg.l^{-1}		< 1	< 1	< 1
Tentatively identified semi-volatile organic compounds:					
2,4-Dibromophenol	mg.l^{-1}		< 0.002	< 0.002	< 0.02
2,6-Dibromophenol	mg.l^{-1}		< 0.002	< 0.002	< 0.02
Tentatively identified volatile organic compounds:					
	µg.l^{-1}		ND	ND	ND

Table 44 Station 10 spatial survey water sample analysis results. Negative results are presented as less than the limit of detection or "ND" (none detected) for tentatively identified compounds, for which the limits of detection vary. Station 10 was located 10.8 km from the cooling water outfall.

Analysis – Station 10	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)			
			07/04/10 Surface	07/04/10 Near-bed	31/01/11 Surface	14/02/11 Near-bed
pH	pH units		7.7	7.7	7.2	7.5
Suspended Solids	mg.l^{-1}		17	75	28	778
Total Alkalinity as $CaCO_3$	mg.l^{-1}		130	133	101	140
Bicarbonate Alkalinity as $CaCO_3$	mg.l^{-1}		130	133	101	140
Carbonate Alkalinity as $CaCO_3$	mg.l^{-1}		0	0	0	0
Chloride as Cl	mg.l^{-1}		15300	10600	10600	14500
Fluoride as F	mg.l^{-1}		1.3	1.3	1.2	1.2
Total Sulphur as SO_4 (Dissolved)	mg.l^{-1}		3130	2700	2620	2760
Calcium as Ca (Total)	mg.l^{-1}		258	269	256	262
Calcium as Ca (Dissolved)	mg.l^{-1}		258	254	261	251
Magnesium as Mg (Total)	mg.l^{-1}		1280	1390	1260	1240
Magnesium as Mg (Dissolved)	mg.l^{-1}		1380	1210	1210	1270
Strontium as Sr (Total)	mg.l^{-1}		4.82	4.93	4.62	4.82
Strontium as Sr (Dissolved)	mg.l^{-1}		4.75	4.81	4.73	4.66
Sodium as Na (Dissolved)	mg.l^{-1}		9430	9610	11800	10500
Potassium as K (Total)	mg.l^{-1}		582	635	594	599
Potassium as K (Dissolved)	mg.l^{-1}		626	562	574	616
Nickel as Ni (Total)	mg.l^{-1}		0.004	0.002	0.007	0.004
Nickel as Ni (Dissolved)	mg.l^{-1}	0.02	0.003	0.003	0.006	0.004
Chromium as Cr (Total)	mg.l^{-1}		< 0.001	< 0.001	0.002	0.002
Chromium as Cr (Dissolved)	mg.l^{-1}	0.015	< 0.001	< 0.001	0.001	0.001
Cadmium as Cd (Total)	mg.l^{-1}		< 0.0001	< 0.0001	< 0.0001	0.0001
Cadmium as Cd (Dissolved)	mg.l^{-1}	0.0002	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Copper as Cu (Total)	mg.l^{-1}		0.002	0.002	0.017	0.007
Copper as Cu (Dissolved)	mg.l^{-1}	0.005	0.003	0.003	0.007	0.007
Lead as Pb (Total)	mg.l^{-1}		< 0.001	< 0.001	< 0.001	0.001
Zinc as Zn (Total)	mg.l^{-1}		0.015	0.036	0.017	0.434
Zinc as Zn (Dissolved)	mg.l^{-1}	0.04	0.013	0.043	0.018	0.516
Manganese as Mn (Dissolved)	mg.l^{-1}		< 0.002	< 0.002	0.002	< 0.02
Iron as Fe (Total)	mg.l^{-1}		0.04	0.03	0.54	0.58

Analysis – Station 10	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)			
			07/04/10 Surface	07/04/10 Near-bed	31/01/11 Surface	14/02/11 Near-bed
Iron as Fe (Dissolved)	mg.l^{-1}	1	< 0.01	< 0.01	< 0.01	< 0.01
Aluminium as Al (Dissolved)	mg.l^{-1}		0.02	0.01	0.01	< 0.01
Arsenic as As (Total)	mg.l^{-1}		0.014	0.013	0.027	0.019
Arsenic as As (Dissolved)	mg.l^{-1}	0.025	0.017	0.017	0.023	0.029
Boron as B (Total)	mg.l^{-1}		4.6	4.89	4.31	4.2
Boron as B (Dissolved)	mg.l^{-1}		4.86	4.31	4.38	4.14
Mercury as Hg (Total)	mg.l^{-1}		< 0.0001	< 0.0001	0.0002	< 0.0001
Mercury as Hg (Dissolved)	mg.l^{-1}	0.00005	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Selenium as Se (Dissolved)	mg.l^{-1}		0.04	0.043	< 0.001	0.097
Selenium as Se (Total)	mg.l^{-1}		0.036	0.041	< 0.001	0.063
Molybdenum as Mo (Total)	mg.l^{-1}		0.009	0.008	0.01	0.011
Molybdenum as Mo (Dissolved)	mg.l^{-1}		0.01	0.01	0.011	0.012
Cobalt as Co (Total)	mg.l^{-1}		< 0.001	< 0.001	0.002	0.001
Cobalt as Co (Dissolved)	mg.l^{-1}		< 0.001	< 0.001	0.001	0.001
Ammoniacal Nitrogen as N	mg.l^{-1}		0.44	0.46	0.42	0.36
Nitrite as N	mg.l^{-1}		< 0.01	< 0.01	< 0.01	< 0.01
Nitrate as N	mg.l^{-1}		< 0.2	< 0.2	< 0.2	< 0.2
Phosphate as P	mg.l^{-1}		< 0.01	< 0.01	< 0.01	< 0.01
Chemical Oxygen Demand (Settled)	mg.l^{-1}		230	230	200	< 100
Total Organic Carbon	mg.l^{-1}		0.44	0.51	0.49	0.65
Salinity	ppt		38.3	38.6	33	33
Turbidity N.T.U	NTU		8	43	2	173
Bromide as Br	mg.l^{-1}		128	128	61	65.9
Iodide as I	mg.l^{-1}		< 2	< 2	< 2	< 2
Barium as Ba (Total)	mg.l^{-1}		< 0.01	< 0.01	< 0.01	< 0.01
Lithium as Li (DIssolved)	mg.l^{-1}		0.07	0.07	0.05	0.09
Silicon as Si (Total)	mg.l^{-1}		0.4	0.5	1.1	1.2
MBAS as Lauryl Sulphate	µg.l^{-1}		< 20	< 20	32	40
Chlorophyll A	µg.l^{-1}		< 10	< 10	< 10	< 10
Biochemical Oxygen Demand	mg.l^{-1}		< 2	< 2	< 2	< 2
Dissolved Organic Carbon	mg.l^{-1}		0.35	0.36	0.53	0.44
Total petroleum hydrocarbons (FTIRPER)	mg.l^{-1}		< 0.3	0.4	< 0.3	< 1.2
Total Viable Count @ 22°C	Counts.ml^{-1}		> 1000	> 1000	6	440

Analysis – Station 10	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**			
			07/04/10 Surface	**07/04/10 Near-bed**	**31/01/11 Surface**	**14/02/11 Near-bed**
Total petroleum hydrocarbons (GC)	mg.l^{-1}		0.01	0.12	0.04	0.02
2,4,6-tribromophenol	µg.l^{-1}		< 0.20	< 0.20	< 0.20	< 0.20
Cationic Detergents	mg.l^{-1}		< 1	1.3	< 1	1.1
Dibromoacetic acid	µg.l^{-1}		< 1	< 1	< 1	< 1
Dibromoacetonitrile	µg.l^{-1}		< 10	< 10	< 0.10	< 0.10
Hydrazine (measurement not reliable)	µg.l^{-1}		0.5	0.5	2.7	1.4
Hydrazine (TZW)	µg.l^{-1}		-	-	< 0.01	< 0.01
Morpholine	mg.l^{-1}		< 10	< 10	< 10	< 10
bis(2-Chloroisopropyl) ether	mg.l^{-1}		< 0.005	< 0.005	< 0.005	< 0.005
2-Methylnaphthalene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002
1-Methylnaphthalene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002
Biphenyl	mg.l^{-1}	0.025	< 0.002	< 0.002	< 0.002	< 0.002
Acenaphthene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002
Dibenzofuran	mg.l^{-1}		< 0.005	< 0.005	< 0.005	< 0.005
Fluorene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002
Phenanthrene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002
Anthracene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002	< 0.002
Fluoranthene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002	< 0.002
Pyrene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002
bis(2-ethylhexyl) phthalate	mg.l^{-1}	0.0013	< 0.005	< 0.005	< 0.005	< 0.005
Benzo[k]fluoranthene	mg.l^{-1}	0.000003	< 0.002	< 0.002	< 0.002	< 0.002
Benzo[a]pyrene	mg.l^{-1}	0.000005	< 0.002	< 0.002	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	mg.l^{-1}	0.000002 (sum of concns)	< 0.002	< 0.002	< 0.002	< 0.002
Benzo[g,h,i]perylene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002
Dibenzo[a,h]anthracene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002
Toluene	µg.l^{-1}	10	< 1	< 1	< 1	< 1
Ethylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1
m and p-Xylene	µg.l^{-1}	30	< 1	< 1	< 1	< 1
o-Xylene	µg.l^{-1}	30	< 1	< 1	< 1	< 1
Bromoform	µg.l^{-1}		< 1	< 1	< 1	< 1
iso-Propylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1
Propylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1
1,3,5-Trimethylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1
1,2,4-Trimethylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1

Analysis – Station 10	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**			
			07/04/10 Surface	**07/04/10 Near-bed**	**31/01/11 Surface**	**14/02/11 Near-bed**
sec-Butylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1
p-Isopropyltoluene	µg.l^{-1}		< 1	< 1	< 1	< 1
Tentatively identified semi-volatile organic compounds:						
2,4-Dibromophenol	mg.l^{-1}		< 0.002	< 0.002	ND	< 0.02
2,6-Dibromophenol	mg.l^{-1}		< 0.002	< 0.002	ND	< 0.02
Tentatively identified volatile organic compounds:						
	µg.l^{-1}		ND	ND	ND	ND

Table 45 Station 11 spatial survey water sample analysis results. Negative results are presented as less than the limit of detection or "ND" (none detected) for tentatively identified compounds, for which the limits of detection vary. Station 11 was located 3.5 km from the cooling water outfall.

Analysis – Station 11	Units	EQS (annual average concn)	Concentration/value (ND = none detected)																		
			07/04/10 surface	21/04/10 surface	19/05/10 surface	07/06/10 surface	22/06/10 surface	06/07/10 surface	20/07/10 surface	11/08/10 surface	18/08/10 surface	09/09/10 surface	14/09/10 surface	28/09/10 surface	14/10/10 surface	15/11/10 surface	06/12/10 surface	15/12/10 surface	17/01/11 surface	31/01/11 surface	14/02/11 surface
pH	pH units		7.7	7.9	7.7	8.2	7.9	7.9	8	7.8	8	7.9	7.9	8	7.9	7.9	7.8	7.8	7.7	7.7	7.6
Suspended Solids	mg.l^{-1}		28	122	244	43	52	49	58	95	44		89	49	113	81	90	155	59	31	246
Total Alkalinity as CaCO$_3$	mg.l^{-1}		136	132	128	130	136	125	132	136	136	132	127	130	130	131	136	123	120	142	161
Bicarbonate Alkalinity as CaCO$_3$	mg.l^{-1}		136	132	82	130	136	125	132	136	136	132	127	130	130	131	136	123	120	142	161
Carbonate Alkalinity as CaCO$_3$	mg.l^{-1}		0	0	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chloride as Cl	mg.l^{-1}		15100	11600	10400	14000	14200	17800	13000	11900	16900	15700	16400	14400	13800	13100	18000	14000	11300	17300	15200
Fluoride as F	mg.l^{-1}		1.3	1.2	0.2	1.3	1.5	1.4	2.5	1.3	1.3	1.4	1.3	1.3	1.2	1.3	1.3	1.3	1.4	1.2	1.3
Total Sulphur as SO$_4$ (Dissolved)	mg.l^{-1}		2930	2970	2760	2700	2530	2800	2610	2750	2610	2650	2500	2690	2530	3810	2870	2630	3150	2630	2780
Calcium as Ca (Total)	mg.l^{-1}		254	203	172	221	198	216	253	207	265	236	280	265	257	285	259	255	274	253	251
Calcium as Ca (Dissolved)	mg.l^{-1}		259	256	254	254	246	251	248	247	248	250	280	258	256	267	249	258	269	262	246
Magnesium as Mg (Total)	mg.l^{-1}		1110	928	653	941	857	958	1150	843	1210	1070	1160	1270	1230	1580	1230	1280	1270	1170	1210
Magnesium as Mg (Dissolved)	mg.l^{-1}		1300	1260	1180	1160	1140	1210	1150	1160	1130	1170	1120	1360	1190	1400	1280	1180	1440	1180	1280
Strontium as Sr (Total)	mg.l^{-1}		4.54	3.72	2.98	3.95	3.65	3.96	4.61	3.77	4.79	4.34	5.07	4.97	4.94	5.16	4.82	4.78	4.98	4.61	4.69
Strontium as Sr (Dissolved)	mg.l^{-1}		4.83	4.66	4.6	4.58	4.43	4.59	4.61	4.64	4.46	4.55	5.02	4.73	4.76	4.89	4.65	4.5	4.93	4.76	4.59
Sodium as Na (Dissolved)	mg.l^{-1}		9870	10100	11100	9580	10100	11600	10100	11300	9640	9950	9200	10900	10600	11400	10900	11200	11700	11500	10100
Potassium as K (Total)	mg.l^{-1}		517	438	276	440	420	455	550	417	591	503	548	561	563	771	568	636	608	560	584
Potassium as K (Dissolved)	mg.l^{-1}		587	616	535	528	553	579	547	554	555	557	525	363	538	672	596	571	444	560	620
Nickel as Ni (Total)	mg.l^{-1}		0.003	0.004	0.003	0.004	0.005	0.003	0.006	0.003	0.003	0.005	0.004	0.003	0.004	0.006	0.003	0.005	0.005	0.006	0.005
Nickel as Ni (Dissolved)	mg.l^{-1}	0.02	0.003	0.003	0.003	0.004	0.005	0.003	0.007	0.003	0.003	0.005	0.005	0.003	0.004	0.007	0.004	0.005	0.005	0.006	0.005
Chromium as Cr (Total)	mg.l^{-1}		< 0.001	< 0.001	0.001	0.001	0.003	0.001	0.001	< 0.001	< 0.001	0.001	0.002	0.002	0.006	0.001	0.001	0.001	0.002	0.001	0.001
Chromium as Cr (Dissolved)	mg.l^{-1}	0.015	< 0.001	< 0.001	0.002	0.001	< 0.001	0.001	0.001	0.002	0.002	0.001	0.002	0.002	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001	0.001
Cadmium as Cd (Total)	mg.l^{-1}		< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0002
Cadmium as Cd (Dissolved)	mg.l^{-1}	0.0002	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001	0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Copper as Cu (Total)	mg.l^{-1}		0.002	0.003	0.004	0.004	0.004	0.002	0.003	0.003	0.003	0.006	0.012	0.004	0.005	0.008	0.003	0.007	0.005	0.011	0.005
Copper as Cu (Dissolved)	mg.l^{-1}	0.005	0.002	0.003	0.003	0.004	0.004	0.002	0.004	0.003	0.005	0.007	0.016	0.004	0.005	0.01	0.003	0.007	0.005	0.01	0.004
Lead as Pb (Total)	mg.l^{-1}		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.002	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< 0.001	< 0.001
Zinc as Zn (Total)	mg.l^{-1}		0.014	0.014	0.012	0.008	0.009	0.005	0.007	0.019	0.007	0.01	0.01	0.01	0.013	0.007	0.012	0.022	0.016	0.02	0.03
Zinc as Zn (Dissolved)	mg.l^{-1}	0.04	0.012	0.009	0.007	0.008	0.006	0.003	0.006	0.008	0.006	0.009	0.009	0.009	0.007	0.007	0.008	0.02	0.041	0.011	0.022
Manganese as Mn (Dissolved)	mg.l^{-1}		< 0.002	< 0.002	< 0.002	0.009	< 0.002	< 0.002	0.003	0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.02
Iron as Fe (Total)	mg.l^{-1}		0.02	0.23	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.6	0.14	0.07	0.02	0.43	< 0.01	1.46	0.72	< 0.01

Analysis – Station 11	Units	EQS (annual average concn)	Concentration/value (ND = none detected)																		
			07/04/10 surface	21/04/10 surface	19/05/10 surface	07/06/10 surface	22/06/10 surface	06/07/10 surface	20/07/10 surface	11/08/10 surface	18/08/10 surface	09/09/10 surface	14/09/10 surface	28/09/10 surface	14/10/10 surface	15/11/10 surface	06/12/10 surface	15/12/10 surface	17/01/11 surface	31/01/11 surface	14/02/11 surface
Iron as Fe (Dissolved)	mg.l^{-1}	1	< 0.01	0.16	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.2	< 0.01	< 0.01	0.16	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Aluminium as Al (Dissolved)	mg.l^{-1}		0.01	< 0.01	< 0.01	0.04	< 0.01	< 0.01	< 0.01	0.01	0.17	< 0.01	0.01	0.02	0.01	0.01	0.01	< 0.01	0.01	0.01	0.02
Arsenic as As (Total)	mg.l^{-1}		0.018	0.014	0.013	0.015	0.021	0.015	0.016	0.014	0.014	0.013	0.012	0.013	0.019	0.015	0.024	0.015	0.021	0.024	0.029
Arsenic as As (Dissolved)	mg.l^{-1}	0.025	0.018	0.018	0.018	0.015	0.022	0.015	0.023	0.018	0.016	0.014	0.015	0.016	0.02	0.019	0.031	0.017	0.024	0.025	0.03
Boron as B (Total)	mg.l^{-1}		4.07	3.29	2.07	3.43	3	3.19	4.16	3.13	4.14	4.04	4.31	4.25	4.25	5.35	4.19	4.29	4.16	3.94	4.07
Boron as B (Dissolved)	mg.l^{-1}		4.56	4.4	4.37	4.14	3.9	4.04	4.11	4.29	3.91	4.35	4.15	4.81	4.03	4.69	4.42	3.98	3.74	4.01	4.19
Mercury as Hg (Total)	mg.l^{-1}		< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001	0.0001	< 0.0001	< 0.0001	0.0001	0.0002	< 0.0001
Mercury as Hg (Dissolved)	mg.l^{-1}	0.00005	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001	< 0.0001	< 0.0001
Selenium as Se (Dissolved)	mg.l^{-1}		0.036	0.062	0.051	0.023	0.013	0.036	0.05	0.033	< 0.001	< 0.001	< 0.001	0.02	0.008	< 0.001	0.073	< 0.001	0.08	< 0.001	0.1
Selenium as Se (Total)	mg.l^{-1}		0.04	0.025	0.029	0.028	0.032	0.029	0.023	0.012	0.027	< 0.001	0.011	0.019	< 0.001	< 0.001	0.067	< 0.001	0.054	< 0.001	0.096
Molybdenum as Mo (Total)	mg.l^{-1}		0.011	0.01	0.011	0.011	0.01	0.012	0.008	0.009	0.012	0.012	0.009	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.012
Molybdenum as Mo (Dissolved)	mg.l^{-1}		0.011	0.01	0.01	0.011	0.01	0.012	0.011	0.01	0.012	0.011	0.011	0.011	0.01	0.011	0.012	0.01	0.011	0.012	0.012
Cobalt as Co (Total)	mg.l^{-1}		< 0.001	< 0.001	< 0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< 0.001	0.001	0.001	0.001	0.001
Cobalt as Co (Dissolved)	mg.l^{-1}		< 0.001	< 0.001	< 0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< 0.001	0.001	< 0.001	0.002	0.001
Ammoniacal Nitrogen as N	mg.l^{-1}		0.2	0.3	0.46	0.3	0.42	0.43	0.59	0.2	0.48	0.46	0.44	0.42	0.42	0.35	0.42	0.43	0.39	0.42	0.36
Nitrite as N	mg.l^{-1}		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Nitrate as N	mg.l^{-1}		< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Phosphate as P	mg.l^{-1}		0.06	< 0.01	< 0.01	< 0.01	0.02	< 0.01	0.02	< 0.01	0.02	< 0.01	0.02	< 0.01	0.02	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01
Chemical Oxygen Demand (Settled)	mg.l^{-1}		210	235	< 5	< 5	975	250	210	200	200	260	240	210	280	270	220	280	150	200	< 100
Total Organic Carbon	mg.l^{-1}		0.54	0.54	0.64	0.38	0.7	0.46	0.66	0.7	0.59	0.6	0.66	0.57	0.59	0.52	0.52	0.75	0.57	0.56	0.55
Salinity	ppt		38.5	35.6	33.8	28.6	31.3	29.8	3507	40.3	37	37.4	36.1	35.7	37.5	40.2	36	36	36.7	32.8	32.7
Turbidity N.T.U	NTU		7	14	6	< 1	105	22	< 1	1	5	1	2	8	17	< 1	28	40	1	9	4
Bromide as Br	mg.l^{-1}		129	415	105	171	172	212	480	405	218	253	188	190	223	330	264	246	760	59.6	66.9
Iodide as I	mg.l^{-1}		< 2	2.1	2.4	< 2	< 2	2.2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Barium as Ba (Total)	mg.l^{-1}		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.03	< 0.01
Lithium as Li (DIssolved)	mg.l^{-1}		0.07	0.03	0.06	0.06	0.06	0.05	0.06	0.05	0.06	0.06	0.07	0.07	0.07	0.06	0.07	0.09	0.07	0.06	0.08
Silicon as Si (Total)	mg.l^{-1}		0.3	0.3	0.1	< 0.1	0.2	0.2	0.2	0.1	0.2	0.3	0.7	0.6	0.5	0.4	0.9	0.4	2.1	1	0.4
MBAS as Lauryl Sulphate	µg.l^{-1}		< 20	< 20	< 20	< 20	30	40	< 20	68	30	100	< 20	30	< 20	20	40	30	39	30	20
Chlorophyll A	µg.l^{-1}		< 10	< 10	< 10	< 10	< 10	< 10	< 10	1.1	1.2	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Biochemical Oxygen Demand	mg.l^{-1}		< 2	< 2	< 2	< 2	4.5	< 2	< 2	8.5	< 2	< 2	3	< 2	< 2	3	< 2	< 2	< 2	< 2	< 2
Dissolved Organic Carbon	mg.l^{-1}		0.43	0.48	0.54	0.43	0.36	0.17	0.12	0.58	0.23	0.33	< 0.1	0.43	0.29	0.34	0.66	0.62	0.33	0.42	0.37
Total petroleum hydrocarbons (FTIRPER)	mg.l^{-1}		0.4	0.5	0.9	< 0.3	1.4	3.8	< 0.3	< 0.3	1.4	< 0.3	0.0533	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
Total Viable Count @ 22°C	Counts.ml^{-1}		1152	1040	800	10	5	91	180	51	1	>1000	>1000	848	312	195	496	283	86	27	51

Analysis – Station 11	Units	EQS (annual average concn)	Concentration/value (ND = none detected)																		
			07/04/10 surface	21/04/10 surface	19/05/10 surface	07/06/10 surface	22/06/10 surface	06/07/10 surface	20/07/10 surface	11/08/10 surface	18/08/10 surface	09/09/10 surface	14/09/10 surface	28/09/10 surface	14/10/10 surface	15/11/10 surface	06/12/10 surface	15/12/10 surface	17/01/11 surface	31/01/11 surface	14/02/11 surface
Total petroleum hydrocarbons (GC)	mg.l^{-1}		1.05	0.01	0.11	< 0.01	< 0.01	< 0.01	< 0.01	0.04	0.01	< 0.01	< 0.01	0.01	0.03	0.01	0.02	< 0.01	0.02	0.01	0.09
2,4,6-tribromophenol	µg.l^{-1}		< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.2	< 0.20	< 0.20	< 0.20
Cationic Detergents	mg.l^{-1}		1.1	< 1.0	< 1.0	1.2	< 1.0	1.7	2	< 1.0	< 1.0	< 1.0	< 1.0	1.4	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	1.9
Dibromoacetic acid	µg.l^{-1}		< 1.00	< 1.00	< 1.0	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00
Dibromoacetonitrile	µg.l^{-1}		< 10	< 10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.1	< 0.10	< 0.10	< 0.10
Hydrazine (measurement not reliable)	µg.l^{-1}		0.5	0.5	0.5	7.8	7.8	1.4	0.5	4.4	5.8	10	7.1	3.1	3.7	1.7	2.2	5.8	1.8	1.6	3.6
Hydrazine (TZW)	µg.l^{-1}		-	-	-	-	-	-	-	-	-	-	-	-	-	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01
Morpholine	mg.l^{-1}		< 10	< 10	< 2	< 10	31.8	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
bis(2-Chloroisopropyl)ether	mg.l^{-1}		< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
2-Methylnaphthalene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
1-Methylnaphthalene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Biphenyl	mg.l^{-1}	0.025	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Acenaphthene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Dibenzofuran	mg.l^{-1}		< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Fluorene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Phenanthrene	mg.l^{-1}		< 0.002	< 0.002	0.006	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Anthracene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Fluoranthene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Pyrene	mg.l^{-1}		< 0.002	< 0.002	0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
bis(2-ethylhexyl)phthalate	mg.l^{-1}	0.0013	< 0.005	< 0.005	< 0.005	0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Benzo[k]fluoranthene	mg.l^{-1}	0.000003	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Benzo[a]pyrene	mg.l^{-1}	0.000005	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	mg.l^{-1}	0.000002 (sum of concen-trations)	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Benzo[g,h,i]perylene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Dibenzo[a,h]anthracene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Toluene	µg.l^{-1}	10	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Ethylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
m and p-Xylene	µg.l^{-1}	30	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
o-Xylene	µg.l^{-1}	30	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Bromoform	µg.l^{-1}		< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
iso-Propylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Propylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,3,5-Trimethylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,2,4-Trimethylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1

Analysis – Station 11	Units	EQS (annual average concn)	Concentration/value (ND = none detected)																		
			07/04/10 surface	21/04/10 surface	19/05/10 surface	07/06/10 surface	22/06/10 surface	06/07/10 surface	20/07/10 surface	11/08/10 surface	18/08/10 surface	09/09/10 surface	14/09/10 surface	28/09/10 surface	14/10/10 surface	15/11/10 surface	06/12/10 surface	15/12/10 surface	17/01/11 surface	31/01/11 surface	14/02/11 surface
sec-Butylbenzene	$\mu g.l^{-1}$		< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
p-Isopropyltoluene	$\mu g.l^{-1}$		< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Tentatively identified semi-volatile organic compounds:																					
2,4 Dibromophenol	$mg.l^{-1}$		< 0.002	< 0.02	< 0.002	< 0.002	< 0.05	< 0.05	< 0.002	< 0.02	< 0.02	< 0.02	< 0.02	< 0.002	< 0.02	ND	< 0.002	< 0.002	< 0.02	ND	< 0.02
2,6-Dibromophenol	$mg.l^{-1}$		< 0.002	< 0.02	< 0.002	< 0.002	< 0.05	< 0.05	< 0.002	< 0.02	< 0.02	< 0.02	< 0.02	< 0.002	< 0.02	ND	< 0.002	< 0.002	< 0.02	ND	< 0.02
Pentanamide	$mg.l^{-1}$		ND	0.036	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,5-dimethyl-Phenanthrene	$mg.l^{-1}$		ND	ND	0.019	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bacchotricuneatin c	$mg.l^{-1}$		ND	ND	0.018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-methyl- Phenanthrene	$mg.l^{-1}$		ND	ND	0.017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-methyl-9H-Fluorene	$mg.l^{-1}$		ND	ND	0.013	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,3-dimethyl-9H-Fluorene	$mg.l^{-1}$		ND	ND	0.012	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,3,4-tetrahydro-Phenanthrene	$mg.l^{-1}$		ND	ND	0.012	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexadecane	$mg.l^{-1}$		ND	ND	0.011	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
n-Nonylcyclohexane	$mg.l^{-1}$		ND	ND	0.011	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Docosane	$mg.l^{-1}$		ND	ND	0.011	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pentadecane	$mg.l^{-1}$		ND	ND	0.011	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetradecane	$mg.l^{-1}$		ND	ND	0.011	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-ethyl-4-methyl-1-Pentanol	$mg.l^{-1}$		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.107	ND	ND	ND	ND	ND	ND
1,3-dichloro-2-Propanol	$mg.l^{-1}$		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.015	ND	ND	ND	ND	ND	ND
2-ethyl-4-methyl-1,3-Dioxolane	$mg.l^{-1}$		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.013	ND	ND	ND	ND
Tentatively identified volatile organic compounds:																					
	$\mu g.l^{-1}$		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 46 Station 12 spatial survey water sample analysis results. Negative results are presented as less than the limit of detection or "ND" (none detected) for tentatively identified compounds, for which the limits of detection vary. Station 12 was located 11.6 km from the cooling water outfall.

Analysis – Station 12	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**			
			08/04/10 Surface	**08/04/10 Near-bed**	**17/01/11 Surface**	**17/01/11 Near-bed**
pH	pH units		7.9	7.9	7.7	7.7
Suspended Solids	$mg.l^{-1}$		52	53	86	115
Total Alkalinity as $CaCO_3$	$mg.l^{-1}$		135	137	151	127
Bicarbonate Alkalinity as $CaCO_3$	$mg.l^{-1}$		135	137	151	127
Carbonate Alkalinity as $CaCO_3$	$mg.l^{-1}$		0	0	0	0
Chloride as Cl	$mg.l^{-1}$		16600	13700	10700	12900
Fluoride as F	$mg.l^{-1}$		1.3	1.3	1.3	1.3
Total Sulphur as SO_4 (Dissolved)	$mg.l^{-1}$		2820	3240	2940	2690
Calcium as Ca (Total)	$mg.l^{-1}$		265	269	277	296
Calcium as Ca (Dissolved)	$mg.l^{-1}$		256	261	267	272
Magnesium as Mg (Total)	$mg.l^{-1}$		1340	1280	1310	902
Magnesium as Mg (Dissolved)	$mg.l^{-1}$		1260	1420	1430	1380
Strontium as Sr (Total)	$mg.l^{-1}$		4.92	4.94	5	5.4
Strontium as Sr (Dissolved)	$mg.l^{-1}$		4.79	4.81	4.91	4.95
Sodium as Na (Dissolved)	$mg.l^{-1}$		10300	9830	11600	11200
Potassium as K (Total)	$mg.l^{-1}$		616	584	627	383
Potassium as K (Dissolved)	$mg.l^{-1}$		576	645	444	424
Nickel as Ni (Total)	$mg.l^{-1}$		0.003	0.003	0.004	0.013
Nickel as Ni (Dissolved)	$mg.l^{-1}$	0.02	0.003	0.003	0.004	0.005
Chromium as Cr (Total)	$mg.l^{-1}$		< 0.001	< 0.001	< 0.001	< 0.001
Chromium as Cr (Dissolved)	$mg.l^{-1}$	0.015	< 0.001	< 0.001	< 0.001	< 0.001
Cadmium as Cd (Total)	$mg.l^{-1}$		< 0.0001	< 0.0001	< 0.0001	0.0005
Cadmium as Cd (Dissolved)	$mg.l^{-1}$	0.0002	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Copper as Cu (Total)	$mg.l^{-1}$		0.01	0.004	0.007	0.003
Copper as Cu (Dissolved)	$mg.l^{-1}$	0.005	0.003	0.004	0.007	0.007
Lead as Pb (Total)	$mg.l^{-1}$		< 0.001	< 0.001	< 0.001	0.001
Zinc as Zn (Total)	$mg.l^{-1}$		0.011	0.073	0.144	0.054
Zinc as Zn (Dissolved)	$mg.l^{-1}$	0.04	0.009	0.08	0.158	0.182
Manganese as Mn (Dissolved)	$mg.l^{-1}$		< 0.002	< 0.002	< 0.002	< 0.002

Analysis – Station 12	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**			
			08/04/10 Surface	**08/04/10 Near-bed**	**17/01/11 Surface**	**17/01/11 Near-bed**
Iron as Fe (Total)	mg.l^{-1}		0.02	0.04	< 0.01	0.36
Iron as Fe (Dissolved)	mg.l^{-1}	1	< 0.01	< 0.01	< 0.01	< 0.01
Aluminium as Al (Dissolved)	mg.l^{-1}		0.01	0.01	0.01	< 0.01
Arsenic as As (Total)	mg.l^{-1}		0.016	0.017	0.023	< 0.001
Arsenic as As (Dissolved)	mg.l^{-1}	0.025	0.02	0.02	0.027	0.028
Boron as B (Total)	mg.l^{-1}		4.76	4.68	4.37	3.04
Boron as B (Dissolved)	mg.l^{-1}		4.45	5.03	3.5	3.19
Mercury as Hg (Total)	mg.l^{-1}		< 0.0001	< 0.0001	0.0001	0.0001
Mercury as Hg (Dissolved)	mg.l^{-1}	0.00005	< 0.0001	< 0.0001	0.0001	0.0001
Selenium as Se (Dissolved)	mg.l^{-1}		0.064	0.069	0.071	0.08
Selenium as Se (Total)	mg.l^{-1}		0.044	0.054	0.062	0.002
Molybdenum as Mo (Total)	mg.l^{-1}		0.009	0.009	0.011	< 0.001
Molybdenum as Mo (Dissolved)	mg.l^{-1}		0.011	0.011	0.012	0.012
Cobalt as Co (Total)	mg.l^{-1}		< 0.001	< 0.001	< 0.001	0.004
Cobalt as Co (Dissolved)	mg.l^{-1}		< 0.001	< 0.001	< 0.001	< 0.001
Ammoniacal Nitrogen as N	mg.l^{-1}		0.46	0.3	0.3	0.37
Nitrite as N	mg.l^{-1}		< 0.01	< 0.01	< 0.01	< 0.01
Nitrate as N	mg.l^{-1}		< 0.2	< 0.2	< 0.2	< 0.2
Phosphate as P	mg.l^{-1}		< 0.01	< 0.01	< 0.01	< 0.01
Chemical Oxygen Demand (Settled)	mg.l^{-1}		250	210	240	280
Total Organic Carbon	mg.l^{-1}		0.43	0.48	0.54	0.54
Salinity	ppt		38.2	38.3	36.3	35.8
Turbidity N.T.U	NTU		< 1	< 1	6	2
Bromide as Br	mg.l^{-1}		211	237	845	665
Iodide as I	mg.l^{-1}		< 2	< 2	< 2	< 2
Barium as Ba (Total)	mg.l^{-1}		< 0.01	< 0.01	< 0.01	0.02
Lithium as Li (DIssolved)	mg.l^{-1}		0.07	0.08	0.06	0.07
Silicon as Si (Total)	mg.l^{-1}		0.3	0.3	0.3	1.8
MBAS as Lauryl Sulphate	µg.l^{-1}		< 20	< 20	20	40
Chlorophyll A	µg.l^{-1}		< 10	< 10	< 10	< 10
Biochemical Oxygen Demand	mg.l^{-1}		< 2	< 2	< 2	< 2
Dissolved Organic Carbon	mg.l^{-1}		0.28	0.32	0.48	0.37
Total petroleum	mg.l^{-1}		0.3	0.5	< 0.3	< 0.3

Analysis – Station 12	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**			
			08/04/10 Surface	**08/04/10 Near-bed**	**17/01/11 Surface**	**17/01/11 Near-bed**
hydrocarbons (FTIRPER)						
Total Viable Count @ 22°C	Counts.ml^{-1}		81	188	880	944
Total petroleum hydrocarbons (GC)	mg.l^{-1}		< 0.01	< 0.01	0.02	0.12
2,4,6-tribromophenol	µg.l^{-1}		< 0.20	< 0.20	< 0.20	< 0.20
Cationic Detergents	mg.l^{-1}		< 1	< 1	< 1	< 1
Dibromoacetic acid	µg.l^{-1}		< 1	< 1	< 1	< 1
Dibromoacetonitrile	µg.l^{-1}		< 10	< 10	< 0.10	< 0.10
Hydrazine (measurement not reliable)	µg.l^{-1}		0.5	0.5	2.2	16.0
Hydrazine (TZW)	µg.l^{-1}		-	-	< 0.01	< 0.01
Morpholine	mg.l^{-1}		< 10	< 10	< 10	< 10
bis(2-Chloroisopropyl) ether	mg.l^{-1}		< 0.005	< 0.005	< 0.005	< 0.005
2-Methylnaphthalene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002
1-Methylnaphthalene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002
Biphenyl	mg.l^{-1}	0.025	< 0.002	< 0.002	< 0.002	< 0.002
Acenaphthene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002
Dibenzofuran	mg.l^{-1}		< 0.005	< 0.005	< 0.005	< 0.005
Fluorene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002
Phenanthrene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002
Anthracene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002	< 0.002
Fluoranthene	mg.l^{-1}	0.0001	< 0.002	< 0.002	< 0.002	< 0.002
Pyrene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002
bis(2-ethylhexyl) phthalate	mg.l^{-1}	0.0013	< 0.005	0.009	< 0.005	0.015
Benzo[k]fluoranthene	mg.l^{-1}	0.000003	< 0.002	< 0.002	< 0.002	< 0.002
Benzo[a]pyrene	mg.l^{-1}	0.000005	< 0.002	< 0.002	< 0.002	< 0.002
Indeno[1,2,3-cd]pyrene	mg.l^{-1}	0.000002 (sum of concns)	< 0.002	< 0.002	< 0.002	< 0.002
Benzo[g,h,i]perylene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002
Dibenzo[a,h]anthracene	mg.l^{-1}		< 0.002	< 0.002	< 0.002	< 0.002
Toluene	µg.l^{-1}	10	< 1	< 1	< 1	< 1
Ethylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1
m and p-Xylene	µg.l^{-1}	30	< 1	< 1	< 1	< 1
o-Xylene	µg.l^{-1}	30	< 1	< 1	< 1	< 1
Bromoform	µg.l^{-1}		< 1	< 1	< 1	< 1
iso-Propylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1
Propylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1

Analysis – Station 12	**Units**	**EQS (annual average concentration)**	**Concentration/value (ND = none detected)**			
			08/04/10 Surface	**08/04/10 Near-bed**	**17/01/11 Surface**	**17/01/11 Near-bed**
1,3,5-Trimethylbenzene	$\mu g.l^{-1}$		< 1	< 1	< 1	< 1
1,2,4-Trimethylbenzene	$\mu g.l^{-1}$		< 1	< 1	< 1	< 1

Analysis – Station 12	Units	EQS (annual average concentration)	Concentration/value (ND = none detected)			
			08/04/10 Surface	08/04/10 Near-bed	17/01/11 Surface	17/01/11 Near-bed
sec-Butylbenzene	µg.l^{-1}		< 1	< 1	< 1	< 1
p-Isopropyltoluene	µg.l^{-1}		< 1	< 1	< 1	< 1
Tentatively identified semi-volatile organic compounds:						
2,4-Dibromophenol	mg.l^{-1}		< 0.002	< 0.002	< 0.02	< 0.02
2,6-Dibromophenol	mg.l^{-1}		< 0.002	< 0.002	< 0.02	< 0.02
2-Oxazolidone	mg.l^{-1}		ND	ND	ND	0.019
Tentatively identified volatile organic compounds:						
	µg.l^{-1}		ND	ND	ND	ND

Appendix B Silt Density Index (SDI) and Modified Fouling Index (MFI) measurements for sea water samples

SILT DENSITY INDEX (SDI) AND MODIFIED FOULING INDEX (MFI) MEASUREMENTS FOR SEA WATER SAMPLES

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Date:	March 2011
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B1 Introduction

Cefas commissioned WRc to undertake analysis of sea water samples for:

- SDI (Silt Density Index) – 15 minutes (or 10 or 5 minutes, depending on fouling rate);
- MFI (Modified Fouling Index) - same as SDI with time integration.

This report summarises the results of SDI and MFI analyses on 71 samples submitted by Cefas over the period to March 2010 to March 2011:

- 19 on 12 March 2010
- 14 on 13 April 2010
- 2 on 23 April 2010
- 2 on 20 May 2010
- 10 on 23 July 2010
- 18 on 5 January 2011
- 6 on 8 March 2011

B2 Measurement Methods

B2.1 Silt Density Index

Silt Density Index (SDI) indicates the quantity of particulate matter and colloidal solids in a sample of water. It is calculated from the rate of "plugging" of a 47 mm, 0.45 µm membrane filter, when the sample of water is applied to the filter at a constant pressure of 30 psi (pounds per square inch) - the filter outlet is at atmospheric pressure. The reference method is given in: ASTM D4189-07.

The time (in seconds) it takes to collect the first 500 ml of filtrate after commencement of filtration is recorded. The time to collect 500 ml of filtrate *after* 5, 10, and 15 minutes of filtration is also recorder. The times are denoted t_0, t_5, t_{10}, and t_{15}, respectively, with t_0 being the time taken for the first 500 ml of water to pass through the filter.

The SDI is calculated according the following equation:

$$SDI_T = \frac{\% P_{30}}{T} = \frac{\left(1 - \frac{t_0}{t_T}\right) \times 100}{T}$$

where $\% P_{30}$ refers to percentage plugging at a pressure of 30 psi, T stands for the elapsed time in minutes and t_T = the time to collect the specified volume (usually 500 ml) after T.

For Swindon tap water with a starting temperature of 9°C, values of $t_0 = 30$ s and $t_{15} = 100$ s were recorded. SDI_{15} is then calculated as follows:

$$SDI_{15} = \frac{\left(1 - \frac{30}{100}\right) \times 100}{15} = 4.7$$

Information from the supplier of the SDI equipment (Applied membranes Inc.) used by WRc suggests that SDI_{15} is usually the lowest value for SDI and is recommended for the purpose of filter sizing.

If fouling is substantial (defined in ASTM as when t_0 is > 110 % of t_0 for a "non-plugging" water) it is recommended that smaller volumes – either 250 ml or 100 ml – be used. Furthermore, if % P_{30} exceeds 75 % for the 15 minute value, then shorter times – either 10 minutes or 5 minutes - should be used. If % P_{30} still exceeds 75 % for 100 ml volume and 5 minutes, then ASTM recommends that, rather than SDI, other (unspecified) test methods should be used to analyse for particulate matter.

SDI measurements were made using equipment (SDI-2000) supplied by Applied Membranes Inc. with 47mm, 0.45 µm HA membrane filters supplied by Millipore.

B2.2 Modified Fouling Index

The Modified Fouling Index (MFI) is also related to the concentration of suspended matter, and has been reported to be a more reliable index of fouling than the SDI. The method is similar to the SDI, and uses the same equipment, except that the volume passing through the filter is recorded every 30 seconds over a 15 minute filtration period. The MFI is obtained graphically from the slope of the straight part of the curve when t/V is plotted against V, where t is the time in seconds to collect a filtrate volume of V in litres. An example is given in **Figure B2.1**. The first part of the curve is referred to as blocking filtration and is not included in the MFI determination. The second, linear, part of the curve is referred to as cake filtration and this is where the MFI is determined. The third part of the curve is a combination of cake filtration with clogging and/or cake compression and is not part of the MFI determination.

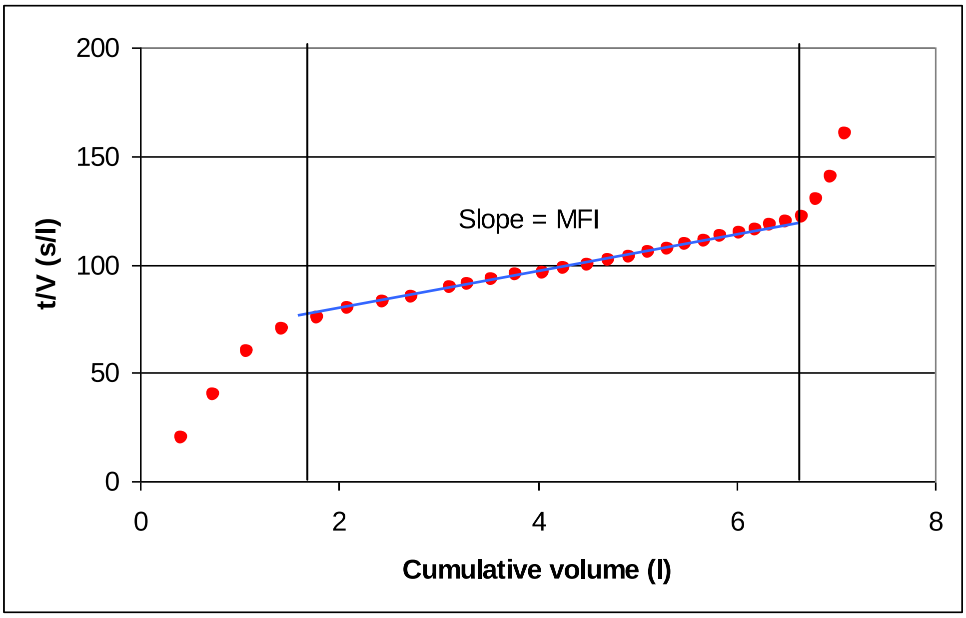

Figure B2.1 Determination of MFI: example of t/V vs volume

B2.3 Method as used for Cefas samples

Temperature during test

The temperature was measured before the samples were transferred to the vessel used to supply sample at 30 psi to the SDI membrane equipment, and after filtration.

According to the ASTM standard, temperature should remain constant (± 1 °C) during a test. In order to process samples quickly, and reduce the rate of any biological activity, filtration was started within 5 minutes of transfer of samples from the chiller and to the pressurised vessel.

Temperature measurements from typical runs showed that sample temperature at the start was in the range 6 to 8 ^{o}C, and filtrate temperature ranged between approximately 10 to 15 ^{o}C as the sample warmed.

B2.4 MFI analysis

The quantification of a linear part of the t/V vs. volume curves was generally undertaken on all of the whole data set but without the first three data points, so as to obtain a reasonably linear part of the filtrate vs. time curve.

B3 Results

B3.1 Samples received and condition

Batch 1

19 samples of sea water were received at WRc on 12 March 2010, the majority as either 2 or 3, x one litre sub-samples. All measurements of SDI and MFI were made during w/c 15 March.

The samples had previously been frozen and were partially thawed. It was found that a significant quantity of particles had settled out in the sample bottle, and samples were therefore thoroughly mixed before the analysis started. Samples not being measured were stored in one of WRc's chiller cabinets.

Batches 2 and 3

14 samples of sea water were received at WRc on 13 April 2010, as either 1 or 3 x one litre sub-samples. All measurements of SDI and MFI were made between 14 and 16 April.

A further 2 samples, as 2 x one litre sub-samples were received on 23 April and these were measured on 26 April 2010.

Unlike the samples in Batch 1, the samples in Batch 2 had not previously been frozen. A significant quantity of particles had still settled out in the bottles and samples were also thoroughly mixed before the analysis started.

Batches 4 and 5

2 samples were received on 20 May and 10 samples (as 2 x 1 litre sub-samples) were received on 23 July 2010. The samples had not been frozen.

Batches 6 and 7

18 samples were received on 5 January 2011 and 6 samples (as 2 x 1 litre sub-samples) were received on 8 March 2011.

B3.2 Silt Density Index

B3.2.1 Tap water reference

As a reference, the SDI of a sample of Swindon tap water was previously measured. The results are summarised in Table B3.1. As expected, the SDI is greater at the longer filtration times. Approximately 7.5 l of water had passed through the filter by the end of the test.

Table B3.1 SDI_{15} values for Swindon tap water

Time/min	t/s	SDI/min
0	30	
5	62	10.3
10	81	6.3
15	100	4.7

The value for SDI_{15} of 4.7 is consistent with a low fouling rate. The results also indicate the variation in SDI values that occurs with different filtration times.

B3.2.2 Seawater samples

Batch 1

The samples from Batch 1 were found to block the filters very rapidly and in only in a few cases was it possible to collect > 500 ml of filtrate within 15 minutes. It was therefore not possible to calculate the SDI_{15} for the samples. The sample volume was therefore reduced to the minimum quoted in ASTM (100 ml) and sample time also reduced to the minimum (5 minutes) suggested in ASTM.

The % P_{30} was calculated for this volume and time, as described in Section **0**, to clarify whether it was suitable to use the SDI as a measure for particulate matter. ASTM states that if % P_{30} exceeds 75 % after 5 minutes, then other (unspecified) test methods should be used to analyse for particulate matter.

From the results, Table 3.2, it can be seen, only 3 samples have a % P_{30} < 75 %. Thus, SDI was not suitable method for estimating particulate matter in the majority of the samples in Batch 1. Clearly the rate of fouling of the samples was very high.

Batches 2 and 3

The samples from Batch 2 and 3 were found to block the filters rapidly but not as rapidly as in Batch 1, although it was again not possible to calculate the SDI_{15} for the samples for 500 ml volumes. In order to compare with previous samples, the sample volume was again reduced to the minimum quoted in ASTM (100 ml) and sample time also reduced to the minimum (5 minutes). For these tests, the time (generally < 30 s) for the initial 100 ml of filtrate to be collected was measured, as well as the cumulative filtrate volume every 30 s over the duration of the run.

The % P_{30} was calculated for this volume and time, as described in Section **0**, to check whether it was appropriate to use the SDI as a measure for particulate matter.

Table B3.2 SDI5 for 100 ml sample size, Batch 1

Sample information			Temp at start/ °C	SDI_5	% P_{30}
Site	Date	Time			
2	25/2	945	6.5	17.2	86
3	25/2	1038	6.4	16.9	85
3B	25/2	1125	6.5	16.8	84
4	25/2	1220	6.4	17.7	89
5	25/2	1305	6.4	17.5	88
5B	25/2	1325	6.5	17.5	88
5	2/3	1100	6.3	16.9	85
5	2/3	1200	6.5	15.8	79
5	2/3	1300	6.3	15.5	77
5	2/3	1400	6.5	13.3	67
5	2/3	1500	9.0	15.3	76
5	2/3	1600	9.0	13.3	67
5	2/3	1700	7.1	16.4	82
5	2/3	1800	7.5	17.2	86
5	2/3	1900	6.5	14.1	71
5	2/3	1900	7.5	16.9	84
5	2/3	2100	7.5	16.0	80
5	2/3	2200	7.1	17.6	88
5	2/3	2300	9.0	17.6	88

From the results, Table B3.3, it can be seen that no samples have a % P_{30} < 75 %. Thus, SDI is not suitable method for estimating particulate matter in the majority of the samples. Clearly the rate of fouling as indicates by SDI_5 is still high.

It is noted that even though the related MFI tests confirm a generally lower particulate content for the Batch 2 samples, this is not apparent from the SDI_5 measurements. This seems consistent with the ASTM guidance that SDI – certainly at the minimum volume and time limits - is not a sensitive measure of fouling rate for these samples.

The samples from Site 10 surface and Site 11 surface were supplied as 1 litre samples. As all of the sample from these sites had passed through the filter with 5 minutes, it was not possible to calculate a SDI_5 or % P_{30} for these two samples.

Table B3.3 SDI$_5$ for 100 ml sample size, Batches 2 and 3

Sample information			Temp at start/ °C	Temp at end/ °C	SDI$_5$	% P$_{30}$
Site	Date	Time				
1 bed	7/4		6.9	12.8	18.1	91
1 surface	7/4	1245	6.5	11.3	18.3	91
5 surface	8/4	1830	6.7	13.8	18.4	92
6 surface	7/4	1415	6.8	12.2	17.6	88
7 bed	8/4	1730	7.3	14.5	18.6	93
7 surface	8/4	1715	6.9	14.4	19.0	95
8 surface	8/4	1645	7.8	14.1	17.8	89
9 bed	8/4	1530	7.2	13.7	16.2	81
9 surface	8/4	1500	6.3	15.1	18.2	91
10 bed	7/4	1130	7.8	14.3	18.1	91
10 surface	7/4	1120	6.6	10	N/A*	N/A*
11 surface	7/4	1445	6.5	11.3	N/A*	N/A*
12 bed	8/4	1400	7.5	15.2	19.0	95
12 surface	8/4	1230	7.3	12.8	18.9	94
5 surface	21/4	0945	6.5	10.4	18.9	94
11 surface	21/4	1045	6.3	11.6	18.3	91

* Insufficient sample volume for measurement.

Batches 4 and 5

As before the sample volume was reduced to the minimum quoted in ASTM (100 ml) and sample time also reduced to the minimum (5 minutes) suggested in ASTM.

From the results in Table B3.4 it can be seen that, except for Site 11 20/7, all samples have a % P$_{30}$ > 75 %. SDI was therefore not a suitable method for estimating particulate matter in the samples.

The entire sample from Site 11 20/7 had passed through the filter within 5 minutes and it was therefore not possible to calculate either SDI$_5$ or % P$_{30}$.

Table B3.4 SDI$_5$ for 100 ml sample size, Batches 4 and 5

Sample information			Temp at start/ °C	Temp at end/ °C	SDI$_5$	% P$_{30}$
Site	Date	Time				
11	19/5	0945	-	-	18.6	93
5	19/5	0845	-	-	18.9	94
5	7/6	1040	11.2	19.8	19.2	96
5	22/6	0930	9.0	18.1	19.2	96
5	6/7	1230	9.6	18.1	19.2	96
5	20/7		10.1	17.7	18.6	93
11	7/6	1040	12.0	16.0	16.0	80
11	22/6	1000	8.4	18.1	18.7	93
11	6/7	1015	9.7	19.1	18.5	93
11	20/7	1300	8.4	13.1	N/A*	N/A*
13	7/6	0830	9.2	16.1	18.0	90
Harbour	20/7		8.6	16.2	18.2	91

* Insufficient sample volume for measurement.

Batches 6 and 7

As before the sample volume was reduced to the minimum quoted in ASTM (100 ml) and sample time also reduced to the minimum (5 minutes) suggested in ASTM.

From the results in **Table B3.5** it can be seen that, except for Site 11 17/01/2011, all samples have a % P_{30} > 75 %. SDI was therefore not a suitable method for estimating particulate matter in the samples.

Table B3.5 SDI$_5$ for 100 ml sample size, Batches 6 and 7

Sample information			Temp at start/ °C	Temp at end/ °C	SDI$_5$	% P_{30}
Site	Date	Time				
5	11/8	0920	6.4	13.6	19.4	97
5	18/8	1205	6.5	14.1	19.1	96
5	9/9	0945	6.9	14.2	17.7	89
5	14/9	1045	6.6	14.5	18.5	92
5	28/9	1050	7.7	15.9	19.0	95
5	14/10	1015	8.4	14.9	18.3	92
5	15/11	1200	7.1	14.7	18.1	91
5	6/12	1008	7.5	14.3	18.7	93
5	15/12	1140	8.4	14.7	16.4	82
5	17/01/2011	?	8.1		13.9	69
5	31/1/2011	1400	6.6	14.5	18.0	90
5	?	?	6.5	17.3	18.6	93
11	11/8	1008	5.9	13.7	19.2	96
11	18/8	1305	7.2	13.5	18.9	94
11	9/9	1040	6.3	13.2	18.7	94
11	14/9	1015	6.1	13.6	19.0	95
11	28/9	1000	7.9	14.1	19.0	95
11	14/10	1115	7.2	13.3	19.3	97
11	15/11	1000	7.5	15.7	18.0	90
11	6/12	0930	7.5	14.6	19.2	96
11	15/12	1032	7.5	15.1	18.4	92
11	17/01/2011	?	6.8	16.2	11.7	58
11	31/1/2011	1010	6.6	14.5	17.5	88
11	?	?	7.8	16.3	19.3	96

B3.3 Modified Fouling Index

B3.3.1 Tap water

As a reference the MFI of tap water at 8.9 °C was previously measured. Approximately 7.1 l of water passed through the filter during the 15 minute measurement, resulting in a MFI of 9.4 s/l^2.

B3.3.2 Seawater samples

Batch 1

The MFI values of Batch 1 samples are summarised in

Table B3.6. As can be seen, the MFI values are very large compared with tap water, and more variable than the SDI measurements and probably more sensitive.

Due to the rapid blocking of the filter, it is not clear whether MFI is being estimated from the linear or the third section of the curve shown in **Figure B2.1**. The results from these and subsequent tests should therefore be treated with caution. The collected data is shown graphically in Figure A3.1; raw data is given in Appendix A, Annex Tables 1 and 2.

The repeatability of the measurements (as judged from the duplicate measurement on sample 5, 2/3, 1900) seems to be relatively poor. This may be due to the small volumes passing through the filter. For the duplicate sample, the difference in total volume passing through the filter over 15 minutes was only 40 ml, but this is enough to give a difference in the MFI of nearly 900 s/l^2. It is also possible that the sample was slightly different, as it was taken from a different sub-sample.

Table B3.6 MFI of seawater samples, Batch 1

Sample Information			T/ °C	MFI/ s/l^2
Site	Date	Time		
2	25/2	945	6.5	1680
3	25/2	1038	6.4	2120
3B	25/2	1125	6.5	2560
4	25/2	1220	6.4	2430
5	25/2	1305	6.4	3300
5B	25/2	1325	6.5	2900
5	2/3	1100	6.3	1830
5	2/3	1200	6.5	4900
5	2/3	1300	6.3	6260
5	2/3	1400	6.5	7370
5	2/3	1500	9.0	4420
5	2/3	1600	9.0	4130
5	2/3	1700	7.1	5110
5	2/3	1800	7.5	3360
5	2/3	1900	6.5	4860*
5	2/3	1900	7.5	3980*
5	2/3	2100	7.5	5350
5	2/3	2200	7.1	3780
5	2/3	2300	9.0	3890
Tap water			8.9	9.4

*Duplicates

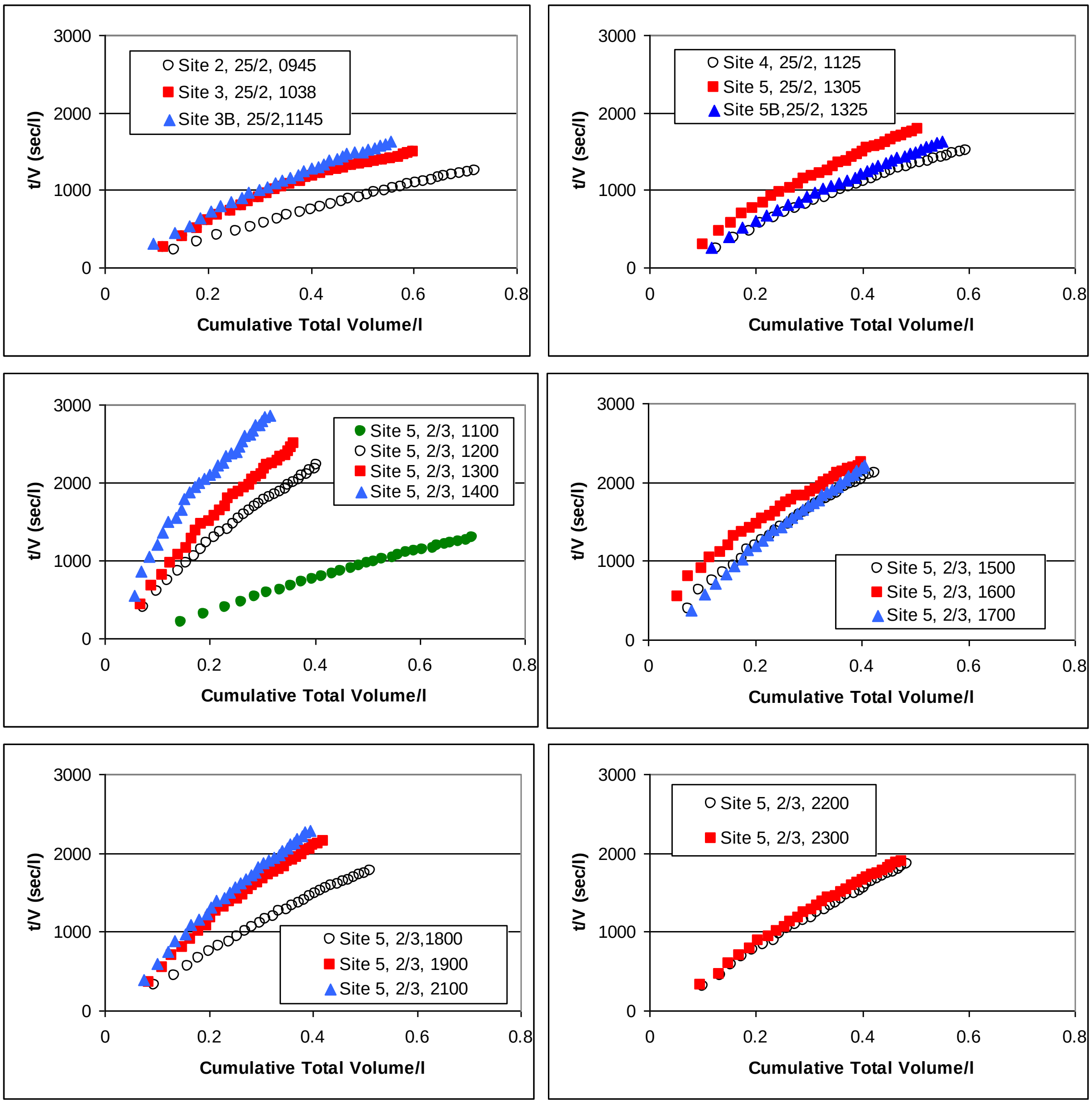

Figure B3.1 Charts of t/V vs volume used to determine MFI: samples in Batch 1

Batches 2 and 3

The MFI values of the Batch 2 and 3 samples are summarised in **Table B3.7**. As can be seen, the MFI values are large compared with tap water and again more variable than the SDI measurements. The surface samples from sites 10 and 11 on 7/4 have particularly low MFI and the surface samples from sites 1 (7/4) and 12 (8/4) and the samples from 21/4 also have relatively low MFI. The collected data is shown graphically in Figure B3.2; raw data is given in Appendix A, Annex Tables 3 to 5.

It is clear from the Batch 2 results of the samples with lowest MFI are from a relatively linear set of data points, and that, at least as a relative measure, the MFI values allow discrimination between the samples whereas the SDI_5 values do not.

Table B3.7 MFI of seawater samples, Batches 2 and 3

Sample Information			T/ °C	T/ °C	MFI/ s/l^2
Site	Date	Time	Start	End	
1 bed	7/4		6.9	12.8	1819
1 surface	7/4	1245	6.5	11.3	532
5 surface	8/4	1830	6.7	13.8	1598
6 surface	7/4	1415	6.8	12.2	1236
7 bed	8/4	1730	7.3	14.5	2611
7 surface	8/4	1715	6.9	14.4	2136
8 surface	8/4	1645	7.8	14.1	2303
9 bed	8/4	1530	7.2	13.7	2896
9 surface	8/4	1500	6.3	15.1	2028
10 bed	7/4	1130	7.8	14.3	1804
10 surface	7/4	1120	6.6	10	170
11 surface	7/4	1445	6.5	11.3	106
12 bed	8/4	1400	7.5	15.2	1585
12 surface	8/4	1230	7.3	12.8	610
5 surface	21/4	0945	6.5	10.4	451
11 surface	21/4	1045	6.3	11.6	581
Tap water			8.9		9.4

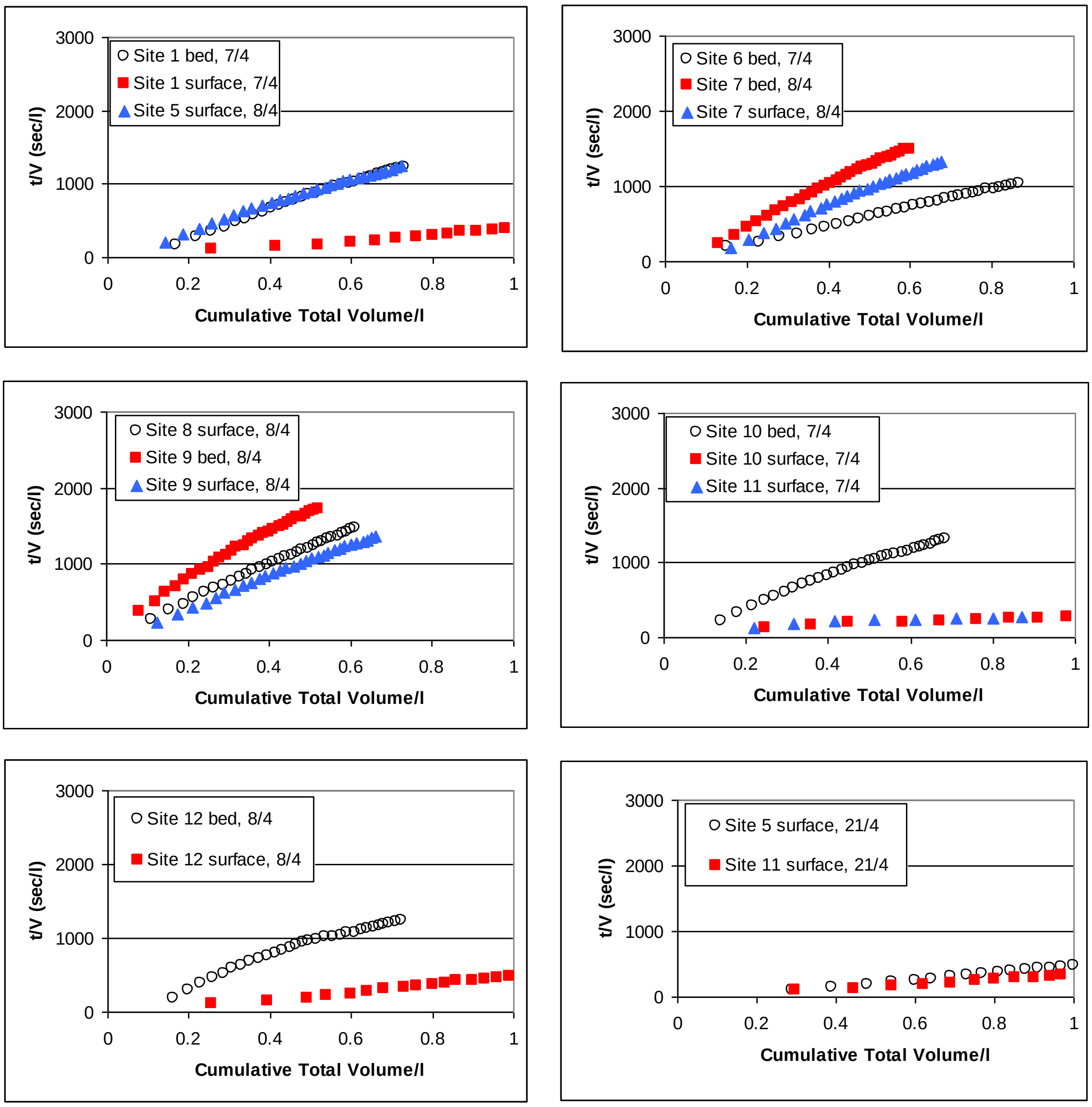

Figure B3.2 Charts of t/V vs volume used to determine MFI for all samples from Batches 2 and 3

Batches 4 and 5

The MFI values of the sea water samples are summarised in **Table B3.8**. The collected data is shown graphically in Figure B3.3; raw data is given in Appendix A, Annex Tables 5 and 6.

Table B3.8 MFI of seawater samples, Batches 4 and 5

Sample Information			T/ °C	T/ °C	MFI/ s/l^2
Site	**Date**	**Time**	**Start**	**End**	
11	19/5	0945	-	-	869
5	19/5	0845	-	-	1230
5	7/6	1040	11.2	19.8	1255
5	22/6	0930	9.0	18.1	2328
5	6/7	1230	9.6	18.1	1401
5	20/7		10.1	17.7	658
11	7/6	1040	12.0	16.0	75
11	22/6	1000	8.4	18.1	734
11	6/7	1015	9.7	19.1	1154
11	20/7	1300	8.4	13.1	17
13	7/6	0830	9.2	16.1	277
Harbour	20/7		8.6	16.2	420
Tap water			8.9	-	9.4

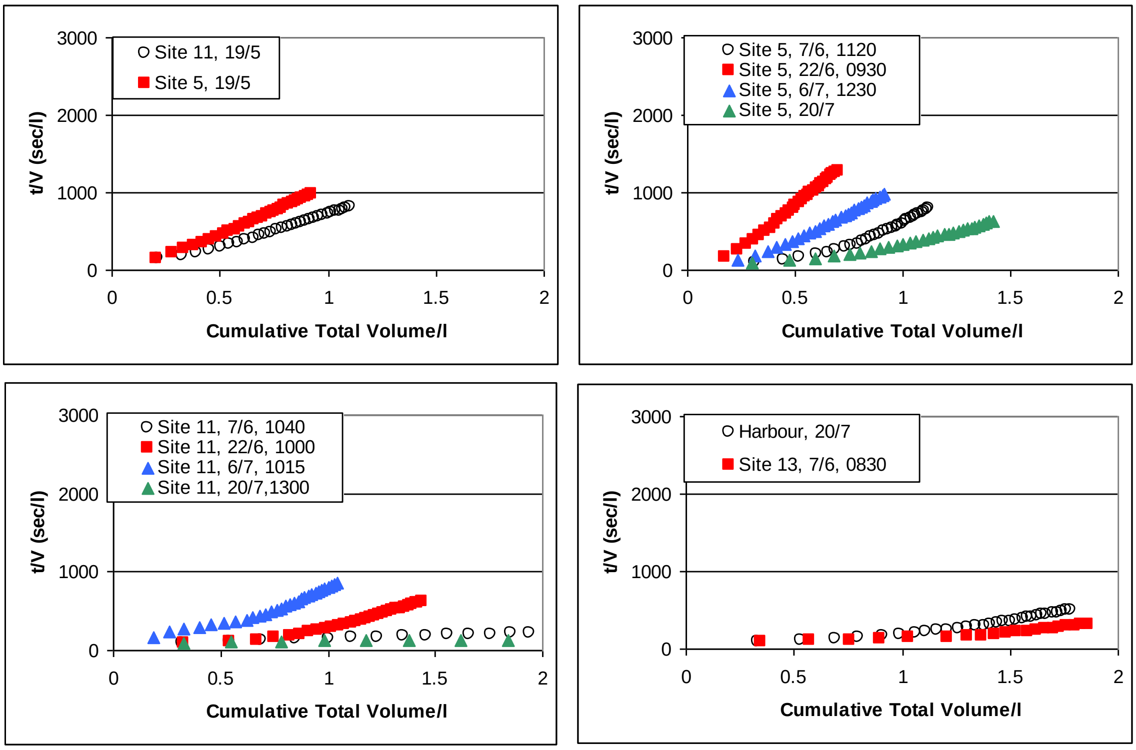

Figure B3.3 Charts of t/V vs volume used to determine MFI for sample Batches 4 and 5

Batches 6 and 7

The MFI values of the sea water samples are summarised in **Table B3.9**. Two samples from batch 7 were only labelled with the station name: there was no reference to either time or date. The collected data is shown graphically in Figures B3.5 and B3.6; raw data is given in Appendix A, Annex Tables 7 to 10. The two samples taken on the 17/1/2011 showed an unusual curvature when plotted (Figure B3.5), the reason for this is unknown.

Table B3.9 MFI of seawater samples, Batches 6 and 7

Sample information			**Temp/ °C**	**Temp/ °C**	**MFI/ s/l^2**
Site	**Date**	**Time**	**Start**	**End**	
5	11/8	0920	6.4	13.6	1115
5	18/8	1205	6.5	14.1	823
5	9/9	0945	6.9	14.2	2030
5	14/9	1045	6.6	14.5	2560
5	28/9	1050	7.7	15.9	1830
5	14/10	1015	8.4	14.9	974
5	15/11	1200	7.1	14.7	1895
5	6/12	1008	7.5	14.3	1205
5	15/12	1140	8.4	14.7	1271
5	17/01/2011	?	8.1		1442
5	31/1/2011	1400	6.6	14.5	1770
5	-	-	6.5	17.3	1405
11	11/8	1008	5.9	13.7	984
11	18/8	1305	7.2	13.5	632
11	9/9	1040	6.3	13.2	875
11	14/9	1015	6.1	13.6	997
11	28/9	1000	7.9	14.1	538
11	14/10	1115	7.2	13.3	661
11	15/11	1000	7.5	15.7	1402
11	6/12	0930	7.5	14.6	2051
11	15/12	1032	7.5	15.1	2199
11	17/01/2011	?	6.8	16.2	654
11	31/1/2011	1010	6.6	14.5	578
11	-	-	7.8	16.3	2218

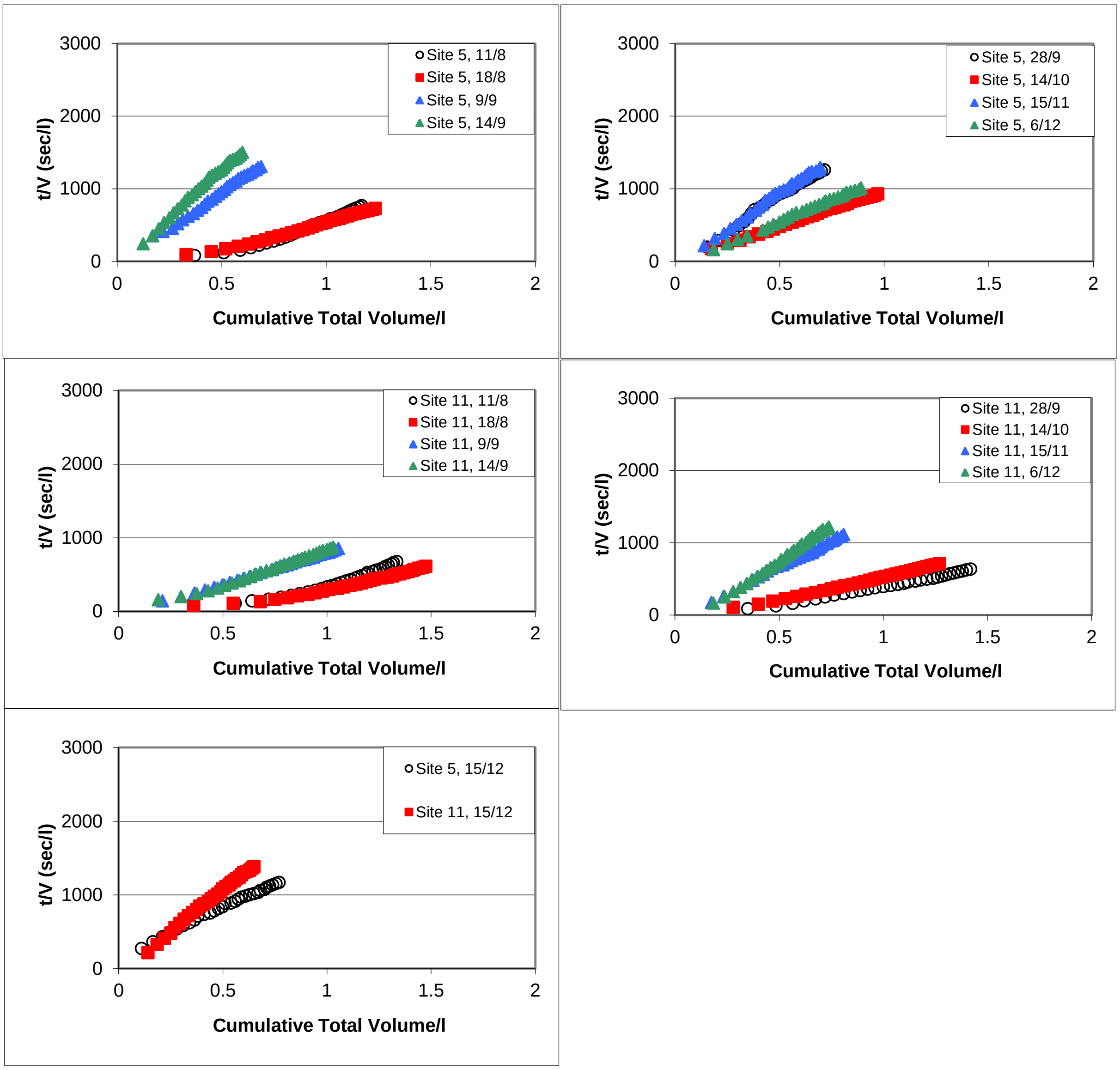

Figure B3.4 Charts of t/V vs volume used to determine MFI for sample Batch 6

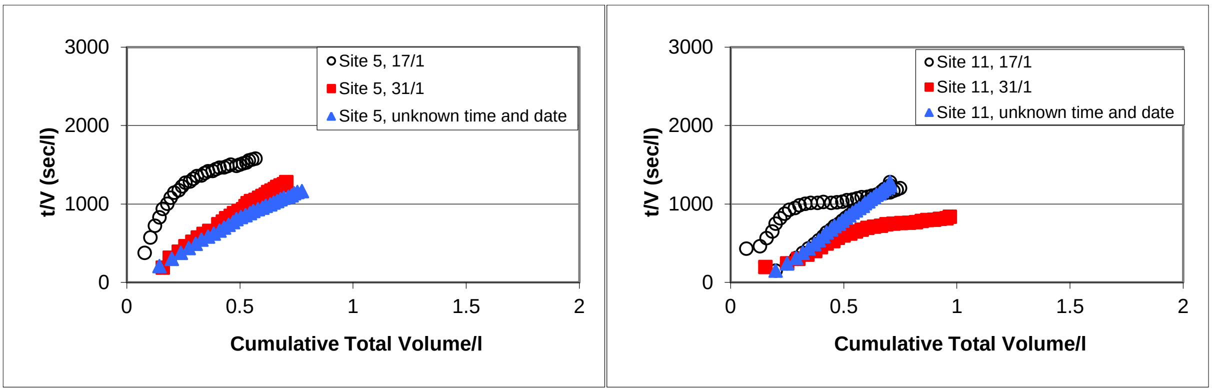

Figure B3.5 Charts of t/V vs volume used to determine MFI for sample Batch 7

ANNEX A CUMULATIVE VOLUME OF FILTRATE WITH TIME FOR ALL SAMPLES

Annex Table 1 Raw data for MFI measurements on Batch 1, Part 1

Site	**2**	**3**	**3B**	**4**	**5**	**5B**	**5**	**5**	**5**	**5**
Date	**25/2**	**25/2**	**25/2**	**25/2**	**25/2**	**25/2**	**2/3**	**2/3**	**2/3**	**2/3**
Time	**945**	**1038**	**1125**	**1220**	**1305**	**1325**	**1100**	**1200**	**1300**	**1400**
Time/s	**Cumulative volume/l**									
30	0.135	0.115	0.095	0.125	0.100	0.115	0.145	0.075	0.070	0.055
60	0.180	0.150	0.135	0.160	0.130	0.150	0.190	0.100	0.090	0.070
90	0.220	0.180	0.165	0.190	0.155	0.175	0.230	0.120	0.110	0.085
120	0.255	0.200	0.185	0.210	0.175	0.200	0.260	0.140	0.125	0.100
150	0.285	0.220	0.205	0.235	0.195	0.220	0.285	0.155	0.140	0.110
180	0.310	0.245	0.225	0.255	0.215	0.240	0.310	0.170	0.155	0.120
210	0.335	0.265	0.245	0.275	0.230	0.260	0.335	0.185	0.165	0.135
240	0.355	0.280	0.265	0.295	0.245	0.280	0.355	0.195	0.175	0.145
270	0.380	0.300	0.280	0.310	0.265	0.295	0.375	0.210	0.185	0.150
300	0.400	0.315	0.300	0.330	0.280	0.310	0.395	0.220	0.200	0.160
330	0.420	0.330	0.315	0.345	0.290	0.325	0.415	0.235	0.210	0.170
360	0.440	0.345	0.330	0.360	0.305	0.340	0.435	0.245	0.220	0.180
390	0.460	0.360	0.345	0.375	0.320	0.355	0.450	0.255	0.230	0.190
420	0.475	0.380	0.360	0.390	0.335	0.370	0.470	0.265	0.235	0.200
450	0.495	0.390	0.375	0.405	0.345	0.385	0.485	0.275	0.245	0.210
480	0.510	0.405	0.385	0.420	0.355	0.395	0.500	0.285	0.255	0.215
510	0.525	0.420	0.400	0.430	0.370	0.410	0.515	0.295	0.265	0.225
540	0.545	0.435	0.415	0.445	0.380	0.420	0.530	0.305	0.275	0.230
570	0.560	0.450	0.425	0.455	0.390	0.430	0.550	0.315	0.280	0.240
600	0.575	0.465	0.435	0.470	0.400	0.445	0.560	0.325	0.290	0.250
630	0.590	0.480	0.450	0.485	0.410	0.455	0.575	0.335	0.300	0.255
660	0.605	0.495	0.460	0.495	0.425	0.465	0.590	0.345	0.305	0.260
690	0.620	0.510	0.470	0.510	0.435	0.480	0.605	0.350	0.310	0.265
720	0.635	0.525	0.485	0.525	0.445	0.490	0.625	0.360	0.320	0.275
750	0.650	0.540	0.500	0.535	0.455	0.500	0.635	0.370	0.330	0.280
780	0.660	0.555	0.512	0.550	0.465	0.510	0.650	0.375	0.335	0.285
810	0.675	0.570	0.525	0.560	0.475	0.520	0.660	0.385	0.345	0.295
840	0.690	0.580	0.535	0.570	0.485	0.530	0.675	0.390	0.350	0.300
870	0.705	0.590	0.545	0.585	0.495	0.540	0.690	0.400	0.355	0.305
900	0.720	0.600	0.555	0.595	0.505	0.550	0.700	0.405	0.360	0.315

Annex Table 2 Raw data for MFI measurements on Batch 1, Part 2 and tap water reference

Site	5	5	5	5	5	5	5	5	5	Swindon tap water
Date	2/3	2/3	2/3	2/3	2/3	2/3	2/3	2/3	2/3	
Time	1500	1600	1700	1800	1900	1900	2100	2200	2300	
Time/s	Cumulative volume/l									
30	0.075	0.055	0.080	0.095	0.085	0.090	0.075	0.100	0.095	0.420
60	0.095	0.075	0.105	0.135	0.110	0.120	0.100	0.135	0.130	0.740
90	0.120	0.100	0.125	0.160	0.130	0.140	0.120	0.155	0.150	1.080
120	0.140	0.115	0.145	0.180	0.150	0.160	0.135	0.175	0.170	1.440
150	0.160	0.135	0.160	0.200	0.165	0.180	0.155	0.195	0.190	1.790
180	0.175	0.150	0.175	0.220	0.180	0.200	0.165	0.215	0.205	2.100
210	0.185	0.160	0.185	0.240	0.195	0.215	0.180	0.235	0.225	2.440
240	0.200	0.175	0.200	0.255	0.205	0.230	0.195	0.245	0.240	2.740
270	0.215	0.190	0.215	0.270	0.215	0.245	0.205	0.260	0.255	3.120
300	0.230	0.205	0.225	0.285	0.230	0.255	0.215	0.275	0.265	3.300
330	0.240	0.215	0.235	0.300	0.240	0.270	0.230	0.290	0.280	3.540
360	0.250	0.230	0.250	0.310	0.255	0.280	0.240	0.305	0.290	3.790
390	0.265	0.240	0.260	0.325	0.265	0.295	0.250	0.315	0.305	4.050
420	0.275	0.250	0.270	0.335	0.275	0.305	0.260	0.330	0.315	4.270
450	0.285	0.260	0.280	0.350	0.285	0.320	0.270	0.340	0.325	4.500
480	0.295	0.270	0.290	0.360	0.295	0.330	0.280	0.350	0.335	4.720
510	0.305	0.280	0.300	0.375	0.305	0.340	0.290	0.360	0.350	4.920
540	0.315	0.295	0.310	0.385	0.315	0.350	0.295	0.370	0.360	5.120
570	0.325	0.305	0.320	0.395	0.325	0.360	0.305	0.385	0.370	5.310
600	0.335	0.315	0.325	0.405	0.335	0.370	0.315	0.395	0.380	5.490
630	0.345	0.325	0.335	0.415	0.345	0.380	0.325	0.405	0.390	5.680
660	0.355	0.330	0.345	0.425	0.350	0.390	0.335	0.410	0.400	5.850
690	0.360	0.340	0.355	0.435	0.360	0.400	0.340	0.420	0.410	6.040
720	0.370	0.350	0.360	0.450	0.370	0.410	0.350	0.430	0.420	6.195
750	0.380	0.355	0.370	0.460	0.380	0.420	0.355	0.440	0.430	6.350
780	0.390	0.365	0.375	0.470	0.385	0.425	0.365	0.450	0.440	6.510
810	0.400	0.375	0.385	0.480	0.395	0.435	0.370	0.460	0.450	6.670
840	0.405	0.385	0.390	0.490	0.400	0.445	0.380	0.470	0.455	6.810
870	0.415	0.395	0.400	0.500	0.410	0.455	0.385	0.475	0.465	6.950
900	0.425	0.400	0.405	0.510	0.420	0.460	0.395	0.485	0.475	7.100

Annex Table 3 Raw data for MFI measurements, Batch 2, Part 1

Site	**1 bed**	**1 surface**	**5 surface**	**6 surface**	**7 bed**	**7 surface**	**8 surface**
Date	**7/4**	**7/4**	**8/4**	**7/4**	**8/4**	**8/4**	**8/4**
Time		**1245**	**1830**	**1415**	**1730**	**1715**	**1645**
Time/s	**Cumulative volume/l**						
30	0.170	0.255	0.140	0.150	0.130	0.160	0.110
60	0.220	0.415	0.185	0.230	0.170	0.205	0.155
90	0.255	0.520	0.225	0.280	0.200	0.240	0.190
120	0.290	0.600	0.255	0.325	0.225	0.270	0.215
150	0.315	0.660	0.285	0.360	0.250	0.295	0.240
180	0.340	0.710	0.310	0.390	0.270	0.315	0.265
210	0.360	0.760	0.335	0.420	0.290	0.340	0.290
240	0.385	0.800	0.355	0.450	0.310	0.355	0.310
270	0.405	0.840	0.380	0.475	0.330	0.380	0.330
300	0.425	0.870	0.405	0.500	0.345	0.395	0.345
330	0.440	0.910	0.425	0.525	0.360	0.415	0.360
360	0.460	0.950	0.445	0.545	0.375	0.430	0.380
390	0.480	0.980	0.460	0.570	0.390	0.445	0.395
420	0.495	1.010	0.480	0.590	0.405	0.460	0.410
450	0.515		0.500	0.610	0.420	0.475	0.425
480	0.530	1 litre	0.515	0.630	0.430	0.495	0.440
510	0.545	sample	0.535	0.650	0.445	0.510	0.455
540	0.560		0.550	0.670	0.455	0.525	0.470
570	0.575		0.565	0.685	0.470	0.540	0.480
600	0.595		0.580	0.705	0.480	0.550	0.495
630	0.610		0.595	0.720	0.495	0.565	0.510
660	0.625		0.615	0.740	0.510	0.580	0.520
690	0.640		0.630	0.755	0.520	0.590	0.530
720	0.650		0.645	0.770	0.530	0.605	0.545
750	0.665		0.660	0.785	0.545	0.615	0.555
780	0.680		0.675	0.805	0.555	0.630	0.570
810	0.690		0.685	0.820	0.565	0.640	0.580
840	0.700		0.700	0.835	0.575	0.655	0.590
870	0.715		0.710	0.850	0.585	0.665	0.600
900	0.730		0.725	0.865	0.600	0.675	0.610

Annex Table 4 Raw data for MFI measurements, Batch 2, Part 2

Site	**9 bed**	**9 surface**	**10 bed**	**10 surface**	**11 surface**	**12 bed**	**12 surface**
Date	**8/4**	**8/4**	**7/4**	**7/4**	**7/4**	**8/4**	**8/4**
Time	**1530**	**1500**	**1130**	**1120**	**1445**	**1400**	**1230**
Time/s	**Cumulative volume/l**						
30	0.080	0.125	0.140	0.245	0.220	0.160	0.255
60	0.120	0.175	0.180	0.360	0.315	0.200	0.395
90	0.145	0.210	0.215	0.450	0.415	0.230	0.490
120	0.170	0.245	0.245	0.580	0.510	0.260	0.540
150	0.190	0.270	0.270	0.670	0.610	0.285	0.600
180	0.210	0.290	0.295	0.760	0.710	0.305	0.640
210	0.230	0.315	0.315	0.840	0.800	0.330	0.680
240	0.250	0.335	0.340	0.910	0.870	0.350	0.730
270	0.265	0.355	0.360	0.980		0.375	0.760
300	0.280	0.375	0.380			0.395	0.800
330	0.295	0.390	0.400	1 litre	1 litre	0.415	0.830
360	0.310	0.410	0.415	sample	sample	0.430	0.860
390	0.320	0.425	0.435			0.450	0.900
420	0.340	0.440	0.450			0.465	0.930
450	0.350	0.460	0.465			0.480	0.960
480	0.360	0.475	0.485			0.495	0.990
510	0.375	0.490	0.500			0.515	1.010
540	0.385	0.505	0.515			0.535	1.040
570	0.400	0.520	0.530			0.555	1.060
600	0.410	0.535	0.545			0.575	1.080
630	0.425	0.545	0.560			0.590	1.110
660	0.435	0.560	0.580			0.610	1.130
690	0.445	0.575	0.595			0.625	1.150
720	0.455	0.585	0.610			0.640	1.180
750	0.465	0.600	0.625			0.655	1.200
780	0.480	0.615	0.635			0.670	1.230
810	0.490	0.630	0.650			0.680	1.250
840	0.500	0.640	0.660			0.695	1.270
870	0.510	0.650	0.670			0.710	1.290
900	0.520	0.660	0.685			0.725	1.310

Annex Table 5 Raw data for MFI measurements, Batch 3 and 4

Site	**5 surface**	**11 surface**	**11**	**5**
Date	**21/4**	**21/4**	**19/5**	**19/5**
Time	**0945**	**1045**	**0945**	**0845**
Time/s	**Cumulative volume/l**			
30	0.295	0.290	0.215	0.205
60	0.445	0.390	0.325	0.280
90	0.540	0.480	0.395	0.335
120	0.620	0.540	0.450	0.380
150	0.690	0.600	0.505	0.420
180	0.750	0.640	0.545	0.455
210	0.800	0.690	0.585	0.485
240	0.850	0.730	0.620	0.515
270	0.900	0.770	0.655	0.540
300	0.940	0.810	0.685	0.570
330	0.970	0.840	0.710	0.590
360	1.010	0.880	0.740	0.615
390	1.050	0.910	0.765	0.635
420	1.080	0.940	0.790	0.655
450	1.110	0.970	0.815	0.675
480	1.140	1.000	0.835	0.695
510	1.180	1.020	0.860	0.715
540	1.210	1.050	0.880	0.735
570	1.240	1.080	0.900	0.750
600	1.260	1.100	0.920	0.770
630	1.290	1.130	0.940	0.785
660	1.320	1.150	0.960	0.800
690	1.350	1.170	0.980	0.815
720	1.380	1.200	1.000	0.835
750	1.400	1.220	1.015	0.850
780	1.430	1.240	1.035	0.865
810	1.450	1.270	1.055	0.880
840	1.480	1.290	1.070	0.895
870	1.500	1.310	1.085	0.910
900	1.520	1.330	1.100	0.925

Annex Table 6 Raw data for MFI measurements, Batch 5

Site	**5**	**5**	**5**	**5**	**11**	**11**	**11**	**11**	**13**	**Harbour**
Date	**7/6**	**22/6**	**6/7**	**20/7**	**7/6**	**22/6**	**6/7**	**20/7**	**7/6**	**20/7**
Time	**1040**	**930**	**1230**		**1040**	**1000**	**1015**	**1300**	**830**	
Time/s	**Cumulative volume/l**									
30	0.315	0.175	0.235	0.300	0.320	0.330	0.190	0.330	0.345	0.330
60	0.445	0.230	0.315	0.475	0.540	0.540	0.260	0.550	0.570	0.530
90	0.520	0.275	0.370	0.590	0.690	0.670	0.325	0.780	0.760	0.690
120	0.600	0.305	0.415	0.680	0.850	0.750	0.400	0.980	0.900	0.800
150	0.650	0.335	0.450	0.750	1.000	0.820	0.455	1.180	1.030	0.910
180	0.690	0.360	0.485	0.800	1.110	0.870	0.515	1.380	1.210	0.990
210	0.730	0.385	0.510	0.850	1.230	0.910	0.570	1.620	1.300	1.060
240	0.760	0.405	0.540	0.890	1.350	0.950	0.620	1.840	1.370	1.110
270	0.790	0.420	0.565	0.930	1.460	0.990	0.650		1.430	1.160
300	0.810	0.440	0.590	0.970	1.560	1.020	0.680		1.480	1.210
330	0.830	0.460	0.610	1.000	1.660	1.050	0.710		1.530	1.260
360	0.850	0.475	0.630	1.030	1.760	1.080	0.735		1.580	1.300
390	0.870	0.490	0.650	1.060	1.850	1.110	0.760		1.620	1.340
420	0.890	0.500	0.670	1.090	1.940	1.130	0.780		1.660	1.380
450	0.910	0.520	0.690	1.120		1.160	0.800		1.700	1.410
480	0.930	0.530	0.710	1.140		1.180	0.820		1.730	1.440
510	0.950	0.545	0.730	1.160		1.200	0.840		1.760	1.470
540	0.970	0.560	0.745	1.190		1.220	0.860		1.800	1.500
570	0.980	0.570	0.760	1.210		1.240	0.875		1.830	1.530
600	1.000	0.585	0.775	1.230		1.260	0.890		1.860	1.560
630	1.010	0.600	0.790	1.260		1.280	0.910			1.580
660	1.020	0.610	0.805	1.280		1.300	0.925			1.600
690	1.040	0.620	0.820	1.300		1.320	0.940			1.630
720	1.050	0.635	0.835	1.320		1.340	0.955			1.650
750	1.060	0.645	0.850	1.330		1.360	0.970			1.670
780	1.070	0.655	0.860	1.350		1.380	0.985			1.700
810	1.090	0.665	0.875	1.370		1.390	1.000			1.720
840	1.100	0.675	0.890	1.390		1.410	1.015			1.740
870	1.110	0.690	0.905	1.400		1.420	1.030			1.760
900	1.120	0.700	0.915	1.420		1.440	1.045			1.780

Annex Table 7 Raw data for MFI measurements, Batch 6, Part 1

Site	**5**	**5**	**5**	**5**	**5**	**5**	**5**
Date	**11/8**	**18/8**	**9/9**	**14/9**	**28/9**	**14/10**	**15/11**
Time	**920**	**1205**	**945**	**1045**	**1050**	**1015**	**1200**
Time/s	**Cumulative volume/l**						
30	0.370	0.330		0.125	0.155	0.175	0.140
60	0.510	0.450	0.170	0.170	0.210	0.250	0.190
90	0.590	0.520	0.220	0.200	0.250	0.310	0.235
120	0.640	0.580	0.265	0.225	0.280	0.355	0.265
150	0.680	0.630	0.290	0.250	0.305	0.400	0.295
180	0.715	0.670	0.315	0.270	0.330	0.440	0.320
210	0.750	0.710	0.340	0.290	0.350	0.470	0.345
240	0.780	0.740	0.365	0.310	0.365	0.500	0.360
270	0.805	0.775	0.385	0.325	0.380	0.530	0.385
300	0.830	0.810	0.405	0.340	0.405	0.560	0.400
330	0.850	0.835	0.420	0.360	0.425	0.590	0.420
360	0.870	0.865	0.435	0.375	0.440	0.610	0.430
390	0.890	0.890	0.455	0.390	0.460	0.635	0.450
420	0.910	0.915	0.470	0.405	0.475	0.660	0.465
450	0.925	0.935	0.485	0.420	0.490	0.680	0.480
480	0.945	0.955	0.500	0.430	0.510	0.700	0.500
510	0.965	0.980	0.515	0.440	0.530	0.720	0.520
540	0.990	1.000	0.525	0.455	0.550	0.745	0.540
570	1.010	1.020	0.540	0.470	0.565	0.765	0.550
600	1.020	1.040	0.555	0.485	0.575	0.785	0.560
630	1.045	1.065	0.570	0.500	0.590	0.810	0.580
660	1.060	1.080	0.580	0.510	0.605	0.825	0.590
690	1.075	1.105	0.595	0.520	0.620	0.840	0.605
720	1.090	1.120	0.610	0.530	0.635	0.860	0.620
750	1.105	1.140	0.625	0.540	0.650	0.880	0.630
780	1.115	1.160	0.640	0.555	0.660	0.900	0.640
810	1.130	1.180	0.650	0.570	0.675	0.920	0.655
840	1.145	1.200	0.665	0.580	0.690	0.940	0.675
870	1.160	1.220	0.675	0.590	0.700	0.955	0.690
900	1.170	1.235	0.690	0.600	0.715	0.970	0.695

Annex Table 8 Raw data for MFI measurements, Batch 6, Part 2

Site	5	5	11	11	11	11	11
Date	6/12	15/12	11/8	18/8	9/9	14/9	28/9
Time	1008	1140	1008	1305	1040	1015	1000
Time/s	Cumulative volume/l						
30	0.185	0.110	0.360	0.360	0.210	0.190	0.350
60	0.250	0.165	0.560	0.550	0.300	0.300	0.485
90	0.300	0.210	0.640	0.680	0.365	0.375	0.565
120	0.345	0.245	0.720	0.750	0.415	0.430	0.620
150		0.280	0.780	0.810	0.460	0.475	0.675
180	0.420	0.310	0.830	0.860	0.500	0.510	0.720
210	0.445	0.340	0.870	0.910	0.535	0.545	0.765
240	0.470	0.365	0.910	0.945	0.570	0.580	0.810
270	0.500	0.380	0.945	0.980	0.600	0.605	0.850
300	0.520	0.410	0.975	1.010	0.630	0.635	0.890
330	0.540	0.440	1.000	1.050	0.660	0.655	0.925
360	0.560	0.460	1.025	1.080	0.685	0.680	0.960
390	0.580	0.480	1.050	1.110	0.710	0.710	1.000
420	0.610	0.500	1.070	1.140	0.740	0.735	1.035
450	0.630	0.510	1.090	1.165	0.760	0.755	1.070
480	0.650	0.540	1.115	1.190	0.785	0.775	1.100
510	0.670	0.560	1.135	1.210	0.810	0.795	1.120
540	0.690	0.575	1.150	1.230	0.830	0.820	1.155
570	0.710	0.590	1.170	1.260	0.850	0.840	1.180
600	0.720	0.610	1.185	1.290	0.870	0.860	1.210
630	0.740	0.630	1.195	1.315	0.895	0.880	1.240
660	0.760	0.650	1.220	1.330	0.915	0.895	1.260
690	0.780	0.670	1.235	1.350	0.935	0.915	1.280
720	0.800	0.680	1.255	1.370	0.950	0.935	1.300
750	0.810	0.700	1.270	1.390	0.970	0.950	1.320
780	0.820	0.710	1.280	1.410	0.990	0.965	1.340
810	0.840	0.725	1.295	1.420	1.010	0.980	1.360
840	0.860	0.740	1.310	1.440	1.025	1.000	1.380
870	0.880	0.755	1.320	1.460	1.040	1.015	1.400
900	0.890	0.770	1.335	1.475	1.055	1.030	1.420

Annex Table 9 Raw data for MFI measurements, Batch 6, Part 3

Site	**11**	**11**	**11**	**11**
Date	**14/10**	**15/11**	**6/12**	**15/12**
Time	**1115**	**1000**	**930**	**1032**
Time/s	**Cumulative volume/l**			
30	0.280	0.175	0.185	0.140
60	0.400	0.235	0.240	0.185
90	0.470	0.280	0.280	0.220
120	0.530	0.315	0.315	0.250
150	0.585	0.345	0.345	0.270
180	0.630	0.375	0.370	0.295
210	0.675	0.400	0.395	0.315
240	0.715	0.425	0.420	0.335
270	0.750	0.445	0.440	0.355
300	0.780	0.465	0.460	0.375
330	0.815	0.490	0.480	0.390
360	0.850	0.520	0.500	0.410
390	0.880	0.540	0.510	0.430
420	0.910	0.560	0.530	0.445
450	0.935	0.580	0.540	0.460
480	0.960	0.600	0.560	0.475
510	0.985	0.620	0.570	0.490
540	1.010	0.640	0.590	0.500
570	1.035	0.660	0.600	0.515
600	1.060	0.670	0.610	0.530
630	1.085	0.690	0.630	0.540
660	1.105	0.700	0.640	0.555
690	1.130	0.710	0.650	0.565
720	1.150	0.730	0.660	0.580
750	1.170	0.740	0.680	0.590
780	1.190	0.760	0.690	0.600
810	1.210	0.770	0.700	0.615
840	1.230	0.780	0.710	0.630
870	1.250	0.800	0.730	0.640
900	1.270	0.810	0.740	0.650

Annex Table 10 Raw data for MFI measurements, Batch 7

Site	**5**	**5**	**5**	**11**	**11**	**11**
Date	**17/1**	**31/1**	**?**	**17/1**	**31/1**	**?**
Time	**?**	**1400**	**?**	**?**	**1010**	**?**
Time/s	**Cumulative volume/l**					
30	0.080	0.160	0.145	0.070	0.155	0.200
60	0.105	0.190	0.200	0.130	0.250	0.250
90	0.125	0.230	0.240	0.160	0.300	0.290
120	0.145	0.260	0.275	0.185	0.340	0.320
150	0.160	0.290	0.305	0.200	0.375	0.345
180	0.180	0.315	0.330	0.220	0.400	0.370
210	0.195	0.340	0.360	0.240	0.425	0.390
240	0.210	0.365	0.385	0.260	0.455	0.410
270	0.230		0.410	0.285	0.475	0.425
300	0.245	0.405	0.430	0.305	0.500	0.445
330	0.260	0.425	0.450	0.330	0.530	0.460
360	0.280	0.440	0.470	0.355	0.555	0.480
390	0.295	0.460	0.485	0.385	0.580	0.495
420	0.310	0.475	0.505	0.410	0.605	0.510
450	0.330	0.495	0.525	0.445	0.635	0.525
480	0.345	0.515	0.545	0.470	0.665	0.540
510	0.360	0.525	0.560	0.495	0.690	0.555
540	0.380	0.535	0.580	0.515	0.720	0.570
570	0.395	0.550	0.600	0.540	0.755	0.585
600	0.410	0.570	0.615	0.560	0.790	0.595
630	0.430	0.585	0.635	0.580	0.820	0.610
660	0.445	0.600	0.650	0.605	0.845	0.620
690	0.460	0.615	0.665	0.625	0.870	0.635
720	0.485	0.625	0.680	0.645	0.900	0.645
750	0.500	0.640	0.695	0.665	0.925	0.660
780	0.515	0.655	0.715	0.685	0.955	0.670
810	0.530	0.665	0.730	0.705	0.970	0.680
840	0.540	0.680	0.740	0.720		0.695
870	0.555	0.695	0.755	0.735		0.705
900	0.570	0.705	0.775	0.750		0.705

Appendix C Radionuclide analysis results

Customer: Dean Foden

From: CEFAS Laboratory
Pakefield Road
Lowestoft
Suffolk
NR33 0HT

1875

RADIOANALYTICAL SERVICE
Test Report

Contract / Sub-contract No: C5043H

Type of analysis: Gross Alpha & Beta, Tritium, Gamma Spec and Carbon-14

Description of sample(s): Sizewell Sea waters

Date of receipt of sample(s): 19/05/10

Description of methods of analysis used: various

Date of analysis: Jun-10

Report authorised by: Dr Kins Leonard & Steph Cogan

Date: 02/07/10

The results follow and relate only to the samples as indicated

Sample date	Sample Lsn	Gross Alpha Bq/l	% error	Gross Beta Bq/l	% error	Tritium Bq/l	% error	Cs-134 Bq/l	% error	Cs-137 Bq/l	% error	K-40 Bq/l	% error	Artificial C-14 Bq/l	% error	Natural C-14 Bq/l
19/05/2010	Site 5	< 3.80	*-	< 5.30	*-	4.44	22.90	< 0.107	*-	< 0.105	*-	10.215	10.27	< 2.045	*-	3.570
19/05/2010	Site 11	< 3.80	*-	< 5.30	*-	< 3.19	*-	< 0.109	*-	< 0.107	*-	11.229	9.97	< 0.056	*-	3.330

Comments:

All results are expressed as **Bq/l wet**
< indicates that the result is below the limit of detection of the counting equipment.
% error for Cs-134, Cs-137 & K-40 indicates 1 sigma Total uncertainty
% error for the rest of the results indicates 1 sigma counting statistics only
* inapplicable when result is below detection limit.

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Customer: Dean Foden

From:
CEFAS Laboratory
Pakefield Road
Lowestoft
Suffolk
NR33 0HT

1875

RADIOANALYTICAL SERVICE
Test Report

Type of analysis: Gross Alpha & Beta, Tritium, Gamma Spec and Carbon-14

Contract / Sub-contract No: C5043H

Date of receipt of sample(s): Jan/Feb-11

Description of sample(s): Sizewell Sea waters

Description of methods of analysis used: various

Date of analysis: Feb & Mar-11

Report authorised by: Dr Kins Leonard & Steph Cogan

Date: 05/04/11

The results follow and relate only to the samples as indicated

Sampled date	Sample Lsn	Site	Gross Alpha Bq/l	% error	Gross Beta Bq/l	% error	Tritium Bq/l	% error	Artificial C-14 Bq/l	% error	Natural C-14 Bq/l
17/01/2011	17	5	< 3.80	*-	< 5.30	*-	1.77	56.50	< 1960	*-	3.84
17/01/2011	18	11	< 3.80	*-	11.13	26.90	2.23	44.90	< 1960	*-	3.63
14/02/2011	100	5	< 3.80	*-	< 5.30	*-	2.46	41.66	< 1960	*-	3.27

All results are expressed as **Bq/l wet**

Comments:

< indicates that the result is below the limit of detection of the counting equipment.

% error for Cs-134, Cs-137 & K-40 indicates 1 sigma Total uncertainty

% error for the rest of the results indicates 1 sigma counting statistics only

* inapplicable when result is below detection limit.

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VOLUME 2 APPENDIX 21C

SIZEWELL SUPPLEMENTARY WATER QUALITY MONITORING DATA 2014/2015.

2019. BEEMS TECHNICAL REPORT TR314

TR314 Sizewell supplementary water quality monitoring data 2014/2015

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List of Tables and Figures

Tables

Please note that the red line boundary was amended after this document was finalised, therefore figures in this document do not reflect the boundaries in respect of which development consent has been sought in this application. However, amendments to the red line boundary does not have any impact on the findings set out in this document and all other information remains correct.

Figures

Executive summary

A review of a water quality survey programme conducted at Sizewell in 2009/10 (BEEMS Technical Report TR189) indicated that ammonia data from a contract laboratory analysis was not reliable. The aim of this study was, therefore, to provide data primarily for nutrients including ammonia but also to supplement information on seawater metals concentrations, temperature, salinity and dissolved oxygen. Additional measurements of chlorine produced oxidants present as a result of the existing Sizewell B discharge were also made. Sampling was conducted:

- spatially, over 4 key sites in the Sizewell area; and
- temporally, over two annual seasonal cycles.

This report covers sampling conducted from February 2014 to January 2016.

Water sampling was conducted on a monthly basis in conjunction with BEEMS plankton surveys. Each survey took place during a single day at four different locations in the Sizewell area corresponding to a reference site labelled ‘SZ3’, the Sizewell B intake, the Sizewell B outfall and the proposed site of the Sizewell C intake and outfall

The measured temperature variation between Sizewell B outfall and the other three sites was more pronounced between March 2014 and February 2015, after which it was broadly similar at all sites. Temperatures reached a maximum of 24.14°C in August 2014 at Sizewell B outfall and a minimum of 4.48˚C in February 2015 at the reference site. Salinity varied seasonally but fell within a relatively narrow range 32.79 – 34.39. During the survey period dissolved oxygen concentrations were between 6.96 and 11 mg l^{-1} which was well above the requirement for High status (5.7 mg l^{-1}). Lowest measured vales were in summer with the lowest values of 6.96 -7.04 mg l^{-1} recorded in July 2015.

With the exception of zinc, the mean measured concentrations of all of the priority metals in the water samples were below their respective environmental quality standards.

Under the Water Framework Directive nutrients assessment, the 99 percentile winter dissolved inorganic nitrogen concentration (425 µg l^{-1}) fell within the Good status boundaries for coastal waters of intermediate turbidity. The mean phosphate concentration during the survey period was 33.48 µg l^{-1} which is used as the site background in support of the Sizewell C H1 report (BEEMS Technical Report TR193). Ammonia concentrations were lower than during earlier Environment Agency surveys but they were of a similar order of magnitude and were considered to be representative of current site conditions. The mean and 95 percentile NH_4-N values together with relevant pH, salinity and temperature data were used to derive a background concentration of unionised ammonia of 0.09 µg l^{-1} NH_3-N which was well below the EQS of 21 µg l^{-1} NH_3-N.

The majority of chlorine produced oxidant concentrations measured (over 80%) were ≤0.04 mg l^{-1}. Unsurprisingly samples taken from the outfall at Sizewell B showed the highest values.

A range of physical and chemical parameters including priority substances and specific pollutants that are of relevance to the Sizewell C planned new build were measured over an almost two-year period at several locations within the Suffolk Waterbody. The background conditions indicated by the range in magnitude and concentration of these parameters indicated that based on these data the waterbody would be judged to be of Good to High status. TRO concentration exceeded the recommended 95 percentile EQS within the influence of the existing Sizewell B discharge as might be expected with some samples taken within the mixing zone for the plume. Dissolved zinc concentrations at all of the sites also exceeded the annual average EQS and this was likely to be due to the influence of elevated zinc concentrations within riverine discharges to the Southern North Sea.

1 Introduction

1.1 Background

EDF Energy operates a nuclear power station at Sizewell B in Suffolk. In addition to the existing facility, Sizewell has been proposed as a potential location for a new nuclear build, Sizewell C. Nuclear power stations require industrial-sized cooling systems, and those located on the coast typically use seawater as coolant. Using a “once-through” system, large quantities of seawater are pumped into the station, run through a condenser to condense the turbine steam for power generation, and then discharged back to sea. Chlorine is used as an anti-foulant to prevent the settlement and growth of marine organisms in the cooling water systems. Chlorine use is favoured over that of other anti-foulants because it decays rapidly (Davis and Coughlan, 1983). As a component of the BEEMS programme, the potential toxicological effects of chlorinated cooling water discharge to the fauna present at Sizewell are being examined. When chlorine is added to seawater, a range of residual oxidants and chlorination by-products (CBPs) are produced, and these may be toxic to non-target marine life in the wider environment (Scott, 1983; Abarnou and Miossec, 1992).

As part of the Sizewell C project, SZC Co has commissioned Cefas to characterise environmental resources in the Sizewell area and to assess the potential sensitivity of key physical, chemical and biological features of the habitat to the proposed Sizewell C power station (the BEEMS programme). This includes looking at the potential effects of the cooling water that is discharged to sea. Therefore, a marine water quality monitoring programme has been established to assess baseline conditions at Sizewell prior to construction and operation of a new power station at this site.

1.2 Aims and objectives

A water quality survey programme was conducted at Sizewell in 2009/10 (BEEMS Technical Report TR189) but ammonia data from a contract laboratory were subsequently considered unreliable and therefore required repeating. Historic Environment Agency data for the Suffolk Coastal waterbody (but with no measurements taken in Sizewell Bay) are available and indicate mean ammonia values of approximately 20 - 27 $\mu g\ l^{-1}$ NH_4- N (BEEMS Technical Report TR131). The aim of this study was therefore to provide data primarily for nutrients including ammonia but also to supplement information on seawater concentrations of metals as well as data for temperature, salinity and dissolved oxygen. Opportunity was also taken to acquire additional measurements of chlorine produced oxidants present as a result of the existing Sizewell B discharge. Sampling was conducted;

- spatially, over 4 key sites in the Sizewell area; and
- temporally, over two annual seasonal cycles.

This report covers sampling conducted from February 2014 to January 2016.

1.3 The physical environment near Sizewell

The coastline near Sizewell B consists of a coarse beach of sand and gravel. The shore slopes down to a depth of 7 to 11 m below chart datum. A subtidal sand bank exists approximately 1.5 km offshore. This feature is charted as two separate entities, Sizewell Bank and Dunwich Bank, though in reality it is a single, continuous feature aligned parallel to the shore and with minimum depths of less than 3 m at its southern end. The whole bank extends for approximately 8 km from north to south and isolates the shallow coastal channel from deeper water offshore of the bank where depths fall to below 15 m.
The tides in the area are rectilinear and flood-dominated, with the flood tide currents travelling to the south and the ebb tide currents travelling to the north. Tidal ranges are approximately 3 m during spring tides and 1.5 m during neap tides. Mean tidal current speeds of 0.5 ms^{-1} are experienced and the maximum current speeds are approximately 1.5 ms^{-1}.

Waves at Sizewell come predominantly from the ENE and the SSE. The mean significant wave height is between 0.5 and 1 m with an annual expected maximum wave height of around 4 m. The maximum expected significant wave height during a 100-year period is approximately 5.5 m, rising to approximately 6.5m in 1,000 years.

2 Methods

2.1 Sampling plan

In conjunction with BEEMS plankton surveys, water sampling was conducted on a monthly basis. Each survey took place during a single day at 4 different locations in the Sizewell area. In order to assess any temporal variation surveys took place throughout 2014 and 2015. Surveys were conducted from the vessel FV Our Josie Grace.

2.2 Site locations

Four different sampling locations were chosen and corresponded to the Sizewell B intake, the Sizewell B outfall, the proposed area of the Sizewell C intakes and outfalls and a reference site that BEEMS has labelled SZ3 (Figure 1). The co-ordinates are shown in Table 1. Due to the shallow water depth, the Sizewell B outfall site has been split into 3 separate sites (SZ 142. 143 and 144). Some of these sites were not accessible at certain stages of the tide, so it was necessary to have alternative sites at Sizewell B outfall where sampling could take place. The sites were all very close to one another, so for the purposes of this report they have all been grouped under the heading ‘Sizewell B outfall’.

Table 1 Sizewell sampling locations and their co-ordinates

Site	Site code	Latitude	Longitude
BEEMS (Reference)	SZ3	52º 16’ 0’’N	01º 38’ 30’’E
Sizewell B Intake (Sizewell B intake)	SZ 140	52º 12’ 53’’N	01º 38’ 0’’E
Sizewell B Outfall (Sizewell B outfall)	SZ 142,143 and 144	52º 12’ 55’’N	01º 37’ 36’’E
Sizewell C Intake and Outfall (Sizewell C)	SZ 141	52º 13’ 7’’N	01º 40’ 5’’E

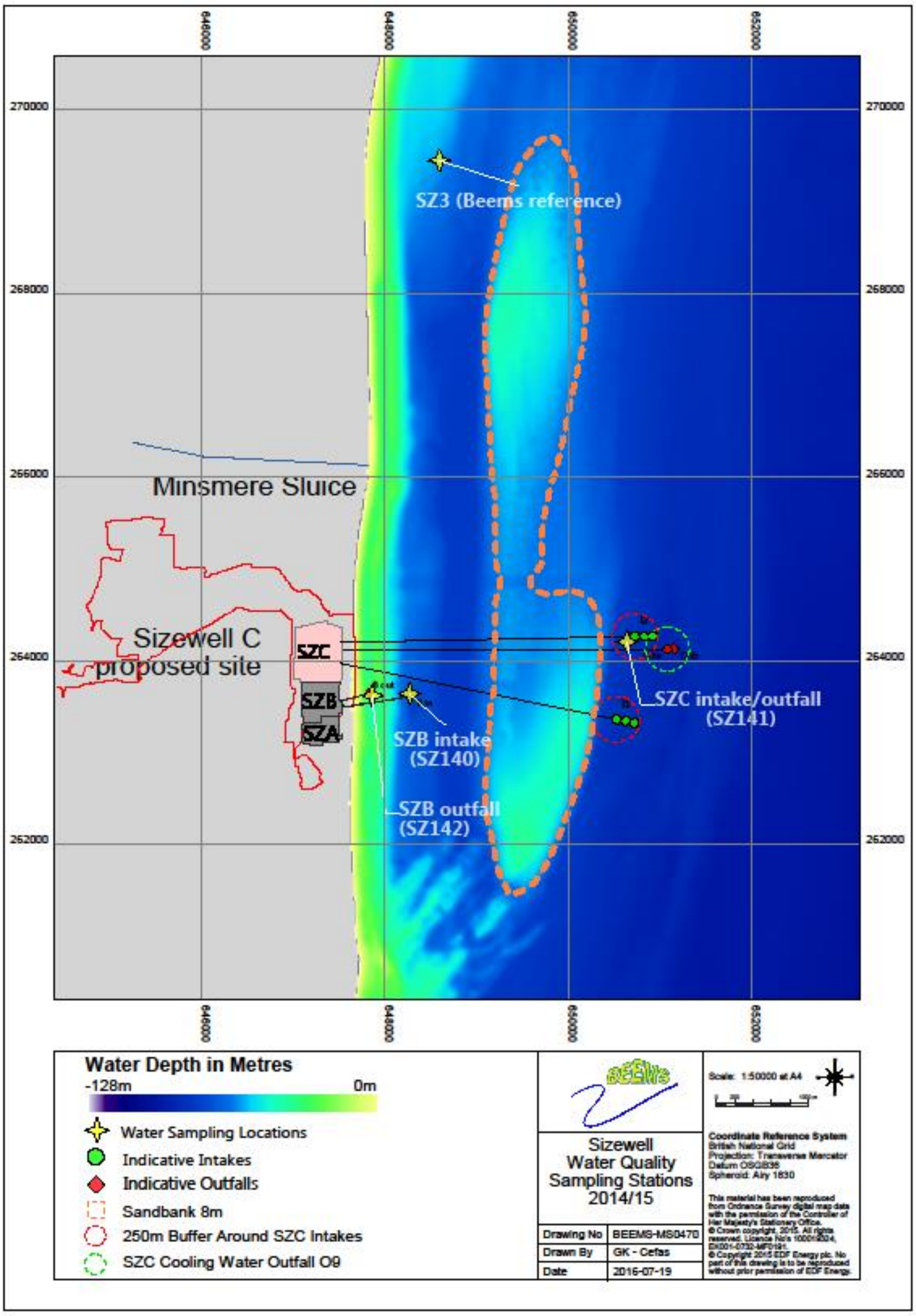

Figure 1 Map showing the marine water quality sampling locations during 2014/15 at Sizewell B intake and outfall, the Sizewell C planned intake/outfall and a BEEMS reference position labelled as ‘SZ3’

2.3 Water sampling

At each sampling location a profiler was deployed to determine different environmental parameters in the water column, water samples were taken for subsequent chemistry analysis and TRO levels of the surface water were analysed for chlorine.

For most surveys, a bucket was used to collect surface water samples for analysis of nutrient and chlorophyll a concentration, and of phytoplankton community structure. This method of water sampling is consistent with current WFD guidance (Devlin et al., 2014).

2.3.1 ESM2 profiler

An ESM2 profiler which is a data logger associated with various probes for measuring different physical parameters in the water column was deployed on a winched vertical profile to sample the water column for temperature (^{0}C), salinity (PSS-78) and dissolved oxygen concentration (mg l^{-1}). After the survey the data from the profiler was downloaded, processed and quality checked. Calibration coefficients were applied to the data during processing. The factory coefficients were used for the conductivity data, whilst temperature coefficients were derived from in-house calibrations. Salinity was calculated as per the International Association for Physical Sciences of the Ocean (IAPSO) standard. Any anomalous data, such as resulting from the profiler being out of the water were flagged as bad and discarded. The calculated salinity was compared with in-situ bottle samples to correct for drift and metalwork effects on the conductivity cell using a standard linear model. Oxygen measurements were corrected for pressure and salinity as per the sensor manufacturer's recommendations (Tengberg, 2009).

Differing response speeds of various sensors on the logger can cause a degree of distortion in the co-dependent measurements. The conductivity sensor responds to changes quicker than the temperature sensor and both are significantly quicker than the oxygen sensor. The faster the sensors are dragged through the water, the greater the degree of distortion, therefore the profiler needs extra time to settle to collect accurate readings. During the initial surveys in 2014 the profiler was deployed and recovered too quickly, which caused significant distortion of the oxygen data. As a result of this a mean surface value has been created by defining a 0.2 – 4 m depth band, only using the data where the oxygen sensor was given enough time to settle. Previous monitoring studies showed the water column at Sizewell to be well mixed (BEEMS TR189) and so a single depth averaged mean value is provided here.

2.3.2 Water chemistry

Water chemistry samples were sent to the National Laboratory Service (NLS) for analysis after each survey. The samples were analysed for a range of metals, inorganics and physical parameters and relevant marine water quality standards for these are presented in tabular form below (Table 2). The range of substances and physical parameters measured are shown in Tables 3 – 6 together with the applicable analysis accreditation status. All Minimum Reporting Values displayed are based upon ideal analysis conditions. Matrix contamination present within the sample or insufficient sample volume may cause an elevation in the limit of detection due to dilution.

2.3.3 Nutrient analysis

2.3.3.1 Background

Dissolved inorganic nitrogen (or DIN – ammonia, nitrite and nitrate), phosphorus and silicate are essential for phytoplankton growth. In winter, concentrations of these nutrients in coastal waters are generally at their highest, but phytoplankton growth is limited by low temperatures and low light conditions. In spring, increased temperatures and light availability promote the growth of phytoplankton and the development of so-called 'spring blooms', characterised by high biomass and high total cell abundance.

The Water Framework Directive requires the classification of all surface waterbodies into one of five ecological status classes: High, Good, Moderate, Poor or Bad (UKTAG 2008). Development of the UK nutrient standards was based on the offshore values established for OSPAR and aligned with freshwater reference values assuming conservative behaviour between nutrients and salinity. At present, coastal and transitional waters are assessed using only the winter value for concentrations of dissolved inorganic nitrogen (DIN, the sum of nitrate, nitrite and ammonia, measured in micromoles per litre, µM), as DIN is recognised as the primary driver of eutrophication. Impacts of dissolved inorganic phosphorus and other limiting nutrients are still under investigation.

WFD assessments of nutrients are based on winter (November to February inclusive) values of DIN, taking account of mitigation of impacts by light limitation. The concentration of suspended particulate matter (SPM) is used as a surrogate for light (Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015.), and is used to designate waterbodies as “clear” or “not clear”. For transitional and coastal water:

- “Clear waters” are described as waters with an annual mean of SPM of <10 mg l^{-1}. The average winter DIN concentration from waterbodies designated as clear is assigned to one of five classes with four defined WFD boundaries (high/good, good/moderate, moderate/poor, poor/bad) based on the value of the normalised winter DIN.

- “Not clear” waters are described as waterbodies with an annual mean SPM of >10 mg l^{-1}. Not clear waters are grouped further by the mean annual SPM value, and described along a continuous gradient of “intermediate” (10<SPM<100 mg l^{-1}), “turbid” (100<SPM<300 mg l^{-1}) or “very turbid” (>300 mg l^{-1}) conditions. For not clear water bodies the 99th percentile of winter DIN is assigned to one of four boundary conditions which separate the five classes of waterbody designation.

2.3.3.1 Methods

Seawater samples were filtered through Whatman™ glass fibre filter papers (GF/F). Sub-samples (60 ml) of the filtrate were transferred to polycarbonate containers, and preserved with 0.1 ml of 16 g l^{-1} mercuric chloride solution (final concentration 20 µg ml^{-1}). The polycarbonate containers were then stored in a fridge at 4^0 C until analysis. Nutrient analyses were performed using a SKALAR™ San++ continuous flow analyser (CFA) via conventional colorimetric assays (Kirkwood, 1996). All analyses were completed within two weeks of sample collection.

Samples were analysed for the following dissolved inorganic nutrients: total oxidised nitrogen (TOxN; nitrate+nitrite), nitrite, phosphate, silicate and ammonia. Nitrite and ammonia levels are both often much lower than nitrate due to being energetically less expensive to assimilate. Nitrate and ammonia range from undetectable to 2 µmoles in coastal waters, compared with typical nitrate levels of up to 600 µmoles (except in polluted regions). Hence, for the purposes of this assessment, nitrate and TOxN are considered to be approximately equivalent. (Collos & Berges, 2003). All results are expressed in µmoles per litre.

2.3.4 TRO analysis

Surface water samples at each site were analysed for TRO in situ by the survey staff. TRO water sampling was conducted every 3 months. The Camlab colorimeter (model CW1000, which uses a LED and wavelength of 528 nm) was calibrated using chlorine reference standards purchased from Lovibond. A zero reading for absorbance was obtained using a 0.2 µm filtered sub-sample of the test solution. The detection limit was 0.02 mg l^{-1}.

From each site 3 separate samples of surface water were obtained for analysis, with triplicate samples from each of these, resulting in a total of 9 samples. Each measurement required a 10 ml sample of seawater to be taken with a mechanical pipette and added to a test tube containing Hach® DPD total chlorine reagent. The water samples were mixed with DPD as soon as possible to arrest any decay of TRO. After a reaction time of 3 minutes the sample was filtered through a syringe fitted with a 0.2 µm filter into a 10 ml reading cell and analysed with the colorimeter.

2.3.5 Marine water quality standards and guidelines

Various chemical and physical standards have been developed to form the basis of a risk-based approach to the management of water quality. Standards relevant to marine environment and to the chemical parameters expected within discharges from the EPR units during all phases of the development are shown in Table 2. The dissolved inorganic nitrogen (DIN) value referenced in Table 2 is based on the 99th percentile of the winter DIN values for ‘Not clear’ waterbodies for classification of waterbodies as High, Good, Moderate, or Poor. The threshold value shown in Table 2 is based on an annual suspended particulate matter (SPM) concentration of between 10 - 100 mg l^{-1} which places the site in the 'intermediate' category. The annual mean measured SPM at the site in 2010 was 74 mg l^{-1} (BEEMS Technical Report TR131).

Table 2 Marine water quality standards referenced in assessment of planned discharges during the Sizewell C development – these represent Environmental Quality Standards (EQS) for other surface waters (TraC Waters) for priority hazardous substances and other pollutants (Directive 2013/39/EU) and (Defra, 2014)

Determinands	**WFD EQS Annual average values (µg l^{-1})**	**WFD EQS Maximum Allowable Concentration (MAC) values (as 95 percentile) (µg l^{-1})**
Cadmium and its compounds	0.2	1.5
Lead and its compounds	1.3	14
Nickel and its compounds	8.6	34
Chromium VI (dissolved)	0.6	32
Mercury and its compounds	-	0.07[1]
Arsenic (dissolved)	25	Not applicable
Copper (dissolved)	3.76 (2.677 x ((DOC/2) - 0.5)) µg/l dissolved, where dissolved organic carbon (DOC) > 1 mg l^{-1}	Not applicable
Iron (dissolved)	1000	Not applicable
Zinc	6.8 (plus ambient background 1.1 in salt water)	Not applicable
Boron (Total)	7000 (pre Water Framework recommended standard)[2]	-
Chlorine	-	10
Unionised ammonia (NH_3)	21	-
Winter dissolved inorganic nitrogen		980[3]

[1] A biota EQS of 20 µg kg-1 of tissue wet weight is also available and relates specifically to fish; [2]Mance et al, 1988; [3]EQS for nitrogen is based on WFD 99 percentile standard for Good status at suspended solids of 50 mg l^{-1}

Table 3, priority analytes MRV- minimum reporting values, UKAS accredited to ISO/IEC 17025

Test	Analyte	MRV	Units	Accreditation
Arsenic Dissolved µg/l	Arsenic Dissolved	1	µg l^{-1}	UKAS
ICPMS Saline Dissolved µg/l	Cadmium, Dissolved	0.03	µg l^{-1}	UKAS
	Copper, Dissolved	0.2	µg l^{-1}	UKAS
	Nickel, Dissolved	0.3	µg l^{-1}	UKAS
	Zinc, Dissolved	0.4	µg l^{-1}	UKAS
OES Saline Dissolved	Iron, Dissolved	100	µg l^{-1}	UKAS
Mercury Dissolved µg	Mercury, Dissolved	0.01	µg l^{-1}	UKAS
Chromium Saline Dissolved µg/l	Chromium, Dissolved	0.5	µg l^{-1}	UKAS

Table 4, environmental parameters MRV- minimum reporting values, UKAS accredited to ISO/IEC 17025

Test	Analyte	MRV	Units	Accreditation
BOD mg/l	BOD 5 Day ATU[1]	1	mg l^{-1}	UKAS
Chloride Saline mg l^{-1}	Chloride	10	mg l^{-1}	None
Dissolved Organic Carbon mg l^{-1}	Carbon, Organic, Dissolved as C :- {DOC}	0.2	mg l^{-1}	UKAS
Phosphate Total mg l^{-1}	Phosphate : Total as P	0.02	mg l^{-1}	UKAS
Fluoride mg/l	Fluoride	0.05	mg l^{-1}	UKAS
pH conductivity & turbidity	pH	0.05	pH units	UKAS
Bromide + Bromate mg/l	Bromide	0.005	mg l^{-1}	None
Suspended Solids (with high total diss solids)	Solids, Suspended at 105 C	3	mg l^{-1}	UKAS

[1] Allylthiourea (ATU) is used in this method to suppress nitrification

Table 5 Other metals 1 MRV- minimum reporting values, UKAS accredited to ISO/IEC 17025

Test	Analyte	MRV	Units	Accreditation
Arsenic Total	Arsenic	1	µg l^{-1}	UKAS
Selenium Dissolved	Selenium Dissolved	1	µg l^{-1}	UKAS
Selenium Total	Selenium	1	µg l^{-1}	UKAS
ICPMS NR Saline Dissolved µg/l	Aluminium, Dissolved	40	µg l^{-1}	None
	Cobalt, Dissolved	10	µg l^{-1}	UKAS
	Molybdenum, Dissolved	30	µg l^{-1}	UKAS
ICPMS NR Saline Total	Cobalt	10	µg l^{-1}	UKAS
	Molybdenum	30	µg l^{-1}	UKAS
ICPMS Saline Total	Cadmium	0.03	µg l^{-1}	UKAS
	Copper	0.2	µg l^{-1}	UKAS
	Lead	0.04	µg l^{-1}	UKAS
	Nickel	0.3	µg l^{-1}	UKAS
	Zinc	0.4	µg l^{-1}	UKAS

Table 6 Other metals 2 and 3 MRV- minimum reporting values, UKAS accredited to ISO/IEC 17025

Test	Analyte	MRV	Units	Accreditation
OES Saline Dissolved	Boron, Dissolved	700	µg l^{-1}	UKAS
	Calcium, Dissolved	10	mg l^{-1}	UKAS
	Magnesium, Dissolved	3	mg l^{-1}	UKAS
	Manganese, Dissolved	20	µg l^{-1}	UKAS
	Potassium, Dissolved	10	mg l^{-1}	UKAS
	Sodium, Dissolved	20	mg l^{-1}	UKAS
	Strontium, Dissolved	200	µg l^{-1}	UKAS
	Sulphate, Dissolved as SO4	5	mg l^{-1}	UKAS
	Barium	100	µg l^{-1}	UKAS
OES Saline Total	Boron	700	µg l^{-1}	UKAS
	Calcium	10	mg l^{-1}	UKAS
	Iron	100	µg l^{-1}	UKAS
	Magnesium	3	mg l^{-1}	UKAS
	Potassium	1	mg l^{-1}	UKAS
	Strontium	200	µg l^{-1}	UKAS
Mercury Total	Mercury	0.01	µg l^{-1}	UKAS
Chromium Saline Total	Chromium	0.5	µg l^{-1}	UKAS

3 Results and Discussion

3.1 ESM2 profiler

The results from the ESM2 profiler are shown in section 3 and have been split into sections relating to temperature, salinity and dissolved oxygen. The spatial and temporal variation in all three parameters are shown in figures 3, 4 and 5. Omitted results indicate no data due to adverse weather conditions. Considerable variation in temperature between Sizewell B Outfall and all the other sites is evident in Figure 2 and is generally around ~3°C. This is due to the discharge of heated seawater from Sizewell B power station. The temperature variation between Sizewell B outfall and the other three sites is more pronounced between March 2014 and February 2015, after which it is broadly similar at all sites. Temperatures reached a maximum of 24.14°C in August 2014 at Sizewell B outfall and a minimum of 4.48°C in February 2015 at the reference site SZ3. Figure 3 shows the seasonal variation in salinity for the four sampling locations. Salinity varies seasonally but falls within a relatively narrow range 32.79 – 34.39. Figure 4 shows the seasonal dissolved oxygen concentration variation across the four sample sites. In the marine environment acute and chronic oxygen deficiency occurs when levels fall between 2.0 and 6.0 mg l^{-1} O_2. During the survey period water samples remained at high oxygen concentrations throughout the whole season with lowest values 6.96 -7.04 mg l^{-1} in July 2015. Tables 16 – 23, 24 -32 and 25 – 41 in the Appendix show the mean temperature, salinity and dissolved oxgen, concentrations respectively measured at each site throughout the survey period.

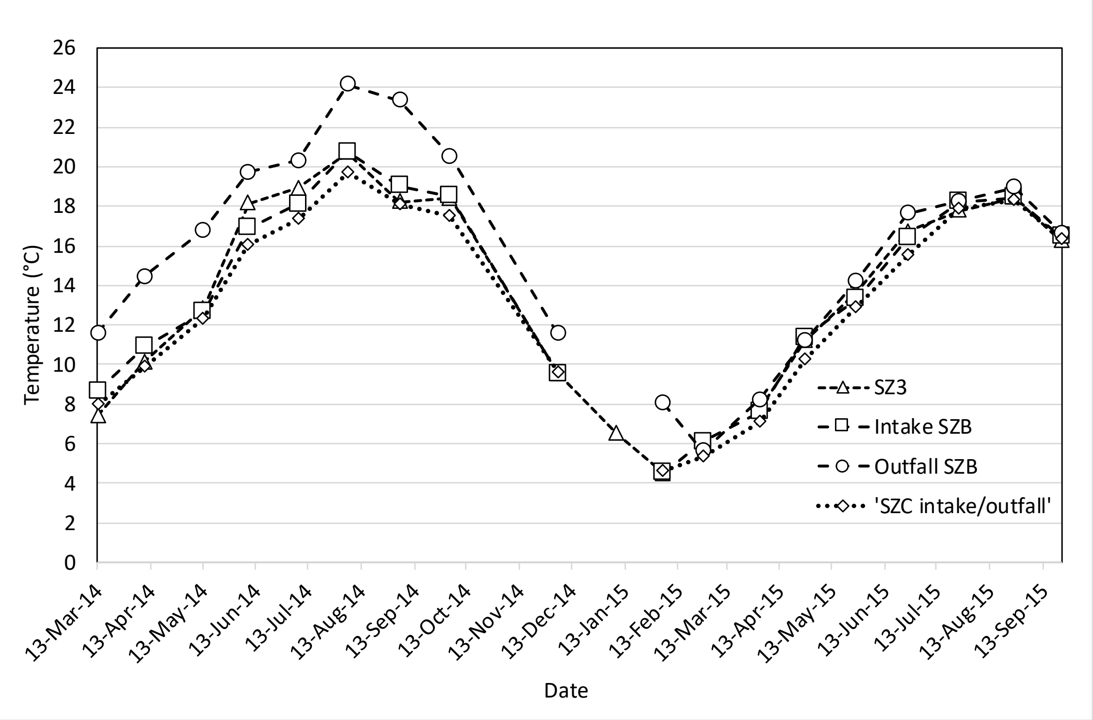

Figure 2 Spatial and temporal variation in temperature throughout the survey period, units are (°C)

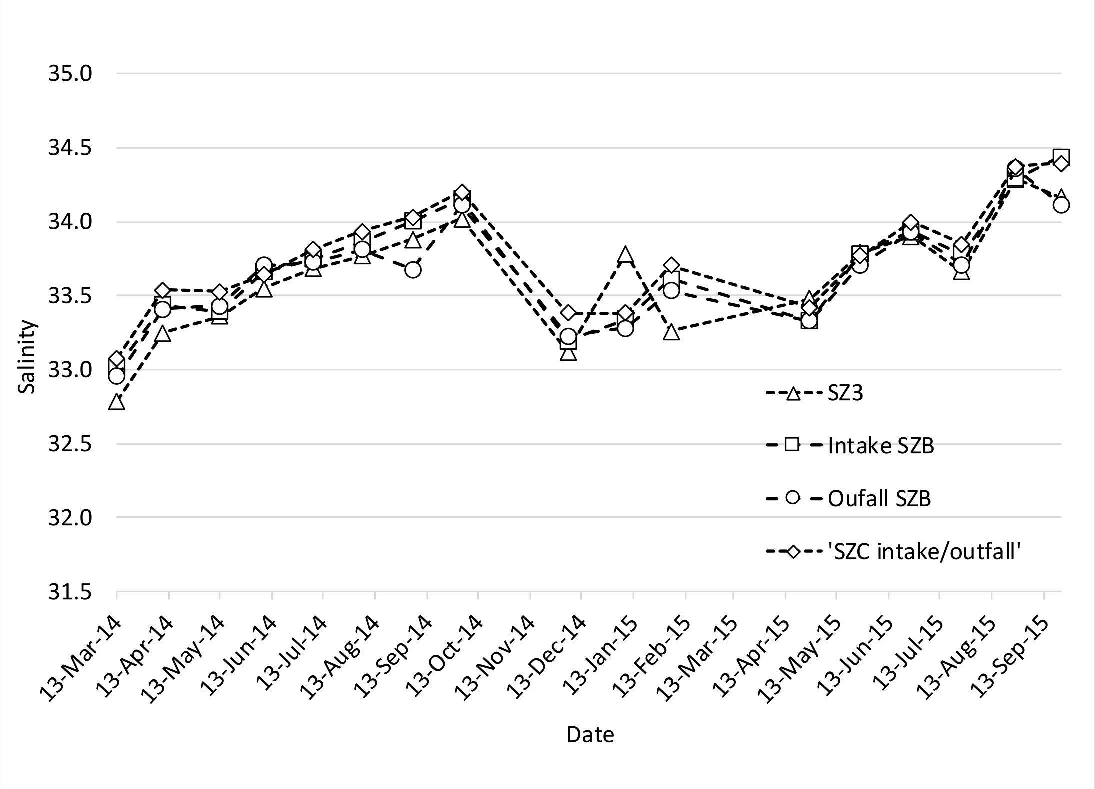

Figure 3 Spatial and temporal variation in salinity throughout the survey period, units are (PSS-78)

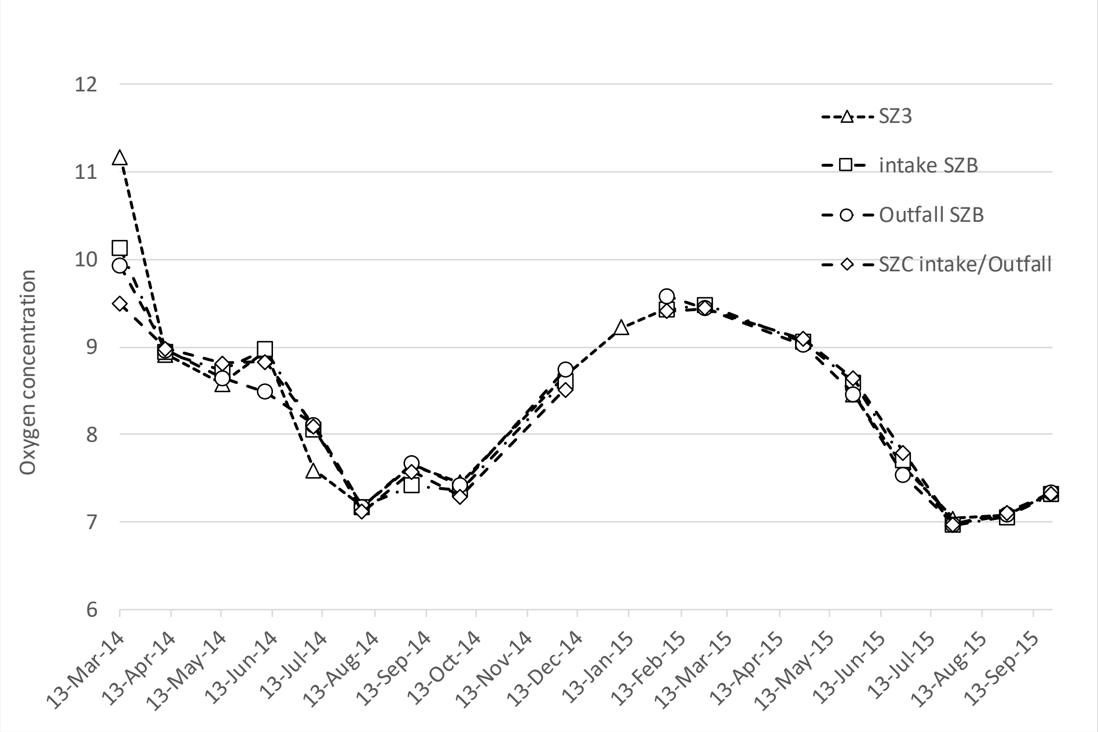

Figure 4 Spatial and temporal variation in oxygen throughout the survey period, units are (mg l^{-1})

3.2 Water chemistry

The water chemistry analyses were separated by site and into several categories; priority analytes, environmental parameters and other metals. Priority analytes include dissolved and total arsenic, cadmium, copper, nickel, zinc, iron, mercury and chromium. Environmental parameters include Biochemical Oxygen demand (BOD 5 Day ATU), chloride, carbon, organic (dissolved as C {DOC}), phosphate (total as P), fluoride, pH, bromide and solids (Suspended at 105^{o}C). Other dissolved metals and inorganics include aluminium, manganese, sodium and sulphate (dissolved as SO_4). Other metals and inorganics measured as both dissolved and total include selenium, cobalt, molybdenum, boron, calcium, magnesium, potassium, strontium, boron. Barium was measured as total only. Omitted results indicate no data, due to adverse weather conditions.

The mean concentration of each analyte and the measure of variance around the mean from each site across the whole survey period is summarised below (Table 7). Values listed below the limits of detection for that particular analyte have been recorded as 0.5 x detection limit for calculating averages.

Table 7, Survey mean and standard deviation of priority analytes at SZ3, Sizewell C intake/outfall and Sizewell B outfall

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(7.9)[2]	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 maximum allowable concentrations (MACs) set as a 95 percentile EQS, for mercury there is only a 95 percentile defined, [1]The EQS of zinc is adjusted by addition of 1.1 to account for ambient background for saltwater

With the exception of zinc, the mean measured concentrations of all of the priority metals in the water samples were below their respective environmental quality standards (Table 7). Summary data for total metals and inorganics are shown in Tables 8 to 10.

Tables 42 - 56 in the Appendix show the individual measured values for each parameter in the water quality assessment.

Table 8, Survey averages and standard deviation of environmental parameters at SZ3, Sizewell C intake/outfall and Sizewell B outfall.

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

The BOD measure is the biochemical oxygen demand. BOD is defined as the mass of oxygen required by a specific volume of liquid for the process of biochemical oxidation over a 5-day period at 20°C in the dark. The result is expressed as milligrams of oxygen per litre of sample. Allyl thiourea (ATU) is added to suppress nitrification hence the name of this specific method. The mean values measured across all of the sites are between 1.02 – 1.31 mg l^{-1} and the 90 percentile value is 1.7 mg l^{-1} which indicates that there is no evidence of the presence of substances at concentrations that are likely to influence significantly the natural background concentrations of oxygen. For riverine water samples a BOD of 3 – 4 as a 90 percentile is associated with High status.

Table 9, Survey averages and standard deviation of total metals at SZ3, Sizewell C intake/outfall and Sizewell B outfall.

Analyte	***Units***	**SZ3**		**Sizewell C intake/outfall**		**Sizewell B Outfall**	
		Mean	**St dev**	**Mean**	**St dev**	**Mean**	**St dev**
Arsenic	µg l^{-1}	2.37	1.21	2.44	1.05	3.40	1.72
Cadmium	µg l^{-1}	0.03	0.02	0.05	0.03	0.07	0.09
Copper	µg l^{-1}	2.60	1.49	1.90	0.94	3.68	2.91
Nickel	µg l^{-1}	1.43	0.53	0.78	0.20	2.11	0.93
Zinc	µg l^{-1}	14.64	7.97	14.36	11.51	25.90	14.76
Iron	µg l^{-1}	1236.00	1066.17	1378.00	887.81	2012.72	1347.75
Mercury	µg l^{-1}	0.03	0.02	0.01	0.02	0.07	0.20
Chromium	µg l^{-1}	1.46	1.25	1.73	1.26	2.60	1.61
Lead	µg l^{-1}	1.82	1.10	1.91	0.94	2.88	1.82
Selenium Dissolved	µg l^{-1}	<1	0	<1	0	<1	0
Selenium	µg l^{-1}	<1	0	<1	0	<1	0
Aluminium, Dissolved	µg l^{-1}	22.09	9.56	<40	0	21.59	6.74
Cobalt, Dissolved	µg l^{-1}	<10	0	<10	0	<10	0
Cobalt	µg l^{-1}	<10	0	<10	0	<10	0
Molybdenum, Dissolved	µg l^{-1}	<30	0	<30	0	16.04	4.43
Molybdenum	µg l^{-1}	<30	0	<30	0	<30	0

Table 10, Survey averages and standard deviation of other metals and inorganics at SZ3, Sizewell C intake/outfall and Sizewell B outfall.

Analyte	***Units***	**SZ3**		**Sizewell C intake/outfall**		**Sizewell B Outfall**	
		Mean	**St dev**	**Mean**	**St dev**	**Mean**	**St dev**
Boron, Dissolved	µg l^{-1}	4236.67	177.35	4193.33	232.76	4216.67	158.75
Boron	µg l^{-1}	4187.62	280.68	4272.78	309.66	4210.00	238.25
Calcium, Dissolved	mg l^{-1}	1240.95	74.49	399.28	20.71	401.39	14.71
Calcium	mg/l	399.38	22.47	407.61	26.36	405.89	17.36
Magnesium, Dissolved	mg l^{-1}	1.09	5.00	1256.11	51.12	1237.78	81.06
Magnesium	mg l^{-1}	1237.14	69.44	1258.33	61.86	1230.56	73.84
Sulphate, Dissolved as SO_4	mg l^{-1}	1240.95	74.49	2553.89	101.53	2589.44	186.94
Potassium, Dissolved	mg l^{-1}	10038.57	592.75	394.00	19.57	392.28	26.67
Potassium	mg l^{-1}	396.81	33.51	398.83	34.44	385.83	21.49
Sodium, Dissolved	mg l^{-1}	7261.43	274.01	10196.67	371.89	10060.00	626.10
Strontium, Dissolved	µg l^{-1}	2595.24	134.08	7192.78	278.54	7245.00	223.48
Strontium	µg l^{-1}	7123.33	388.33	7271.11	468.79	7190.00	262.77
Manganese, Dissolved	µg l^{-1}	393.24	28.55	<20	0	2.65	7.80
Barium	µg l^{-1}	<100	0	<100	0	<100	0

3.3 Nutrient including ammonia data

Nitrogen (N) and phosphorus (P) are both essential nutrients in the marine environment for primary production. Table 11 provides a summary of the phosphate, dissolved inorganic nitrogen (DIN) and ammonia concentrations measured at Sizewell. At present, coastal and transitional waters are assessed using only the winter value for concentrations of DIN (the sum of nitrate, nitrite and ammonia, measured in micromoles per litre, µM), as it is recognised as the primary driver of eutrophication. Impacts of dissolved inorganic phosphorus and other limiting nutrients are under investigation. Under the Water Framework Directive, the 99 percentile winter (November-February) DIN is derived for a given site and is compared to a standard value which takes account of the light penetration based on suspended particulate matter concentration. For coastal waters of intermediate turbidity (defined as 10 - <100 mg l^{-1} of solid particulate matter) the 99 percentile DIN is 980 µg l^{-1} and 1470 µg l^{-1} for Good and Moderate status respectively (Water Framework Directive Standards and Classification Directions 2015). Therefore, the measured DIN for the sites surveyed in this report (425 µg l^{-1}) falls within the Good status boundaries value that is applied for not clear waterbodies (annual average SPM >10 mg l^{-1}), to assess status under WFD. The measured phosphate concentration (33.48 µg l^{-1}) is the site background value which is used in the H1 assessment as is the ammonia data (mean and 95 percentile) which together with relevant pH, salinity and temperature data is used to derive the background concentration of unionised ammonia. The average winter DIN to dissolved inorganic phosphorus (DIP) ratio is identified under the OSPAR Common Procedure (COMP, OSPAR Commission 2005), as another indicator of undesirable disturbance. Ratios outside of 8:1 – 24:1 are considered to indicate potential undesirable disturbance. The average ratio for all Sizewell sites was just over this value at 26:1 with values at the SZ3 site and Sizewell C intake/outfall below 24:1 and the other sites above.

Table 11, Survey averages and standard deviation of nutrients at WFD, Sizewell C intake/outfall and Sizewell B outfall.

Analyte	***Units***	**All sites**	**SZ3**		**Sizewell C intake/outfall**		**Sizewell B Outfall**		**Sizewell B Intake**	
		Annual average	**Mean**	**Std dev**	**Mean**	**Std dev**	**Mean**	**Std dev**	**Mean**	**Std dev**
Phosphate PO_4 - P	µg l^{-1}	33.48	45.02	48.26	26.47	20.21	29.50	20.52	37.73	43.39
Phosphate	µmol	1.56	1.45	1.56	0.85	0.65	0.95	0.66	1.22	1.4
DIN (winter)	µg l^{-1}	306.8	313.6	82.39	273.8	88.76	368.9	28.75	297.6	86.40
DIN (winter)	µmol	21.9	22.40	5.88	19.56	6.34	26.35	2.05	21.26	6.17
DIN 99 percentile (winter)	µg l^{-1}	425	423.64	-	395.3	-	407.46	-	414.98	-
DIN 99 percentile (winter)	µmol	30	30.26	-	28.24	-	29.10	-	29.64	-
NH_4-N	Mean	11.38	11.27	7.75	12.01	6.03	12.08	6.80	11.93	8.07
NH_3-N*	Mean 95%	0.09 0.19								

*The unionised ammonia concentration is derived using the raw data for total ammonia NH_4- N measured at each of the sites together with the respective pH, temperature and salinity the equivalent unionised ammonia concentration is then derived using the Environment Agency calculator (Clegg and Whitfield, 1995).

3.4 TRO data

Table 12-15 and Figure 5 show the measured TRO concentrations at Sizewell in the vicinity of Sizewell B outfall and the proposed Sizewell C intake/outfall as well as at the SZ3 sampling point to the north of Sizewell B. Survey data from April has not been included due to an error in the measurement protocol. The majority of the measurements (over 80%) were ≤0.04 mg l^{-1}. Unsurprisingly samples taken from the outfall at Sizewell B show some of the highest values. However, when TRO values are ≤0.04 mg l^{-1} Sizewell B does not always show the highest values for all sampling dates (e.g. April 2015). The replicated TRO measurements are shown in Tables 12 – 15.

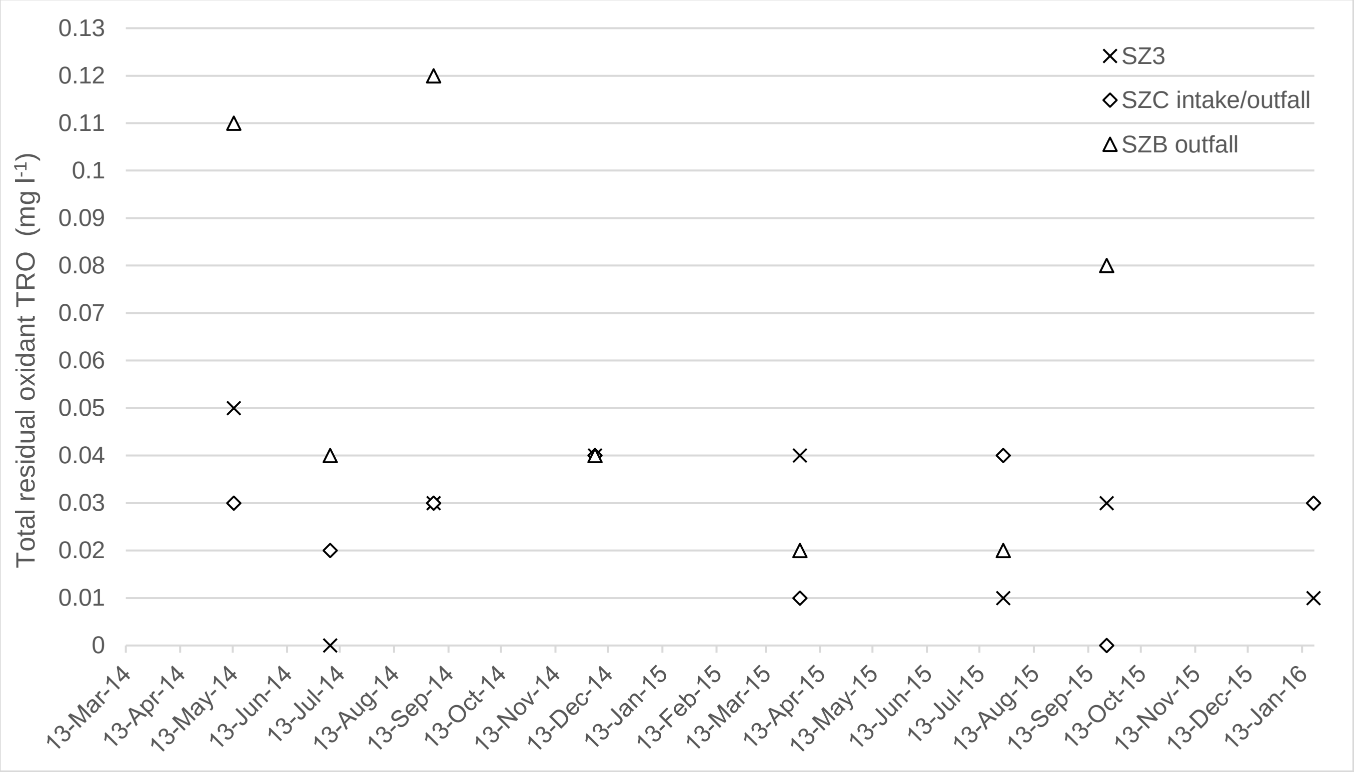

Figure 5 Spatial and temporal variation in mean total residual oxidant concentration expressed as mg l^{-1} chlorine equivalent.

The total residual oxidant concentrations measured at the reference site and at the planned Sizewell C intake/outfall have 95 percentiles of 0.07 and 0.06 TRO as mg l^{-1} chlorine respectively and at the Sizewell B discharge a 95 percentile of 0.14 mg l^{-1}. These values represent the background values at Sizewell with those measured at Sizewell B heavily influenced by proximity to the discharge plume and the values at the other two sites falling below the EQS for TRO in seawater.

Table 11 SZ3 reference site TRO results (mg l^{-1})

Date	Survey	Replicate	Mean concentration	St dev	Survey mean concentration
May 14	3_14	Sample 1	0.04	0.03	0.05
		Sample 2	0.06	0.02	
		Sample 3	0.04	0.02	
July 14	5_14	Sample 1	0.00	0.00	0.00
		Sample 2	0.00	0.00	
		Sample 3	0.00	0.00	
September 14	7_14	Sample 1	0.03	0.02	0.03
		Sample 2	0.02	0.02	
		Sample 3	0.03	0.02	
December 14	11_14	Sample 1	0.03	0.03	0.04
		Sample 2	0.01	0.01	
		Sample 3	0.08	0.03	
April	6_15	Sample 1	0.03	0.01	0.04
		Sample 2	0.04	0.01	
		Sample 3	0.05	0.02	
July	13_15	Sample 1	0.02	0.01	0.01
		Sample 2	0.01	0.01	
		Sample 3	0.00	0.01	
September	15_15	Sample 1	0.00	0.00	0.03
		Sample 2	0.01	0.02	
		Sample 3	0.07	0.03	
January		Sample 1	0.01	0.02	0.01
		Sample 2	0.01	0.01	
		Sample 3	NA	NA	

Table 12 Sizewell C intake and outfall TRO results (mg l^{-1})

Date	Survey	Replicate	Mean concentration	St dev	Survey mean concentration
May 14	3_14	Sample 1	0.03	0.01	0.03
		Sample 2	0.02	0.01	
		Sample 3	0.03	0.01	
July 14	5_14	Sample 1	0.00	0.00	0.02
		Sample 2	0.07	0.12	
		Sample 3	0.00	0.00	
September 14	7_14	Sample 1	0.03	0.01	0.03
		Sample 2	0.02	0.02	
		Sample 3	0.03	0.01	
December 14	11_14	Sample 1	0.05	0.02	0.04
		Sample 2	0.04	0.03	
		Sample 3	0.03	0.04	
April	6_15	Sample 1	0.01	0.01	0.01
		Sample 2	0.01	0.02	
		Sample 3	0.01	0.01	
July	13_15	Sample 1	0.03	0.01	0.04
		Sample 2	0.04	0.01	
		Sample 3	0.05	0.01	
September	15_15	Sample 1	0.00	0.00	0.00
		Sample 2	0.00	0.00	
		Sample 3	0.00	0.00	
January		Sample 1	0.02	0.01	0.03
		Sample 2	0.07	0.06	
		Sample 3	0	0	

Table 13 Sizewell B outfall TRO results, May - December (mg l^{-1})

Date	Survey	Time	Replicate	Mean concentration	St dev	Survey mean concentration
May 14	3_14	08:36	Sample 1	0.08	0.01	0.11
			Sample 2	0.09	0.01	
			Sample 3	0.11	0.01	
		13:52	Sample 1	0.10	0.01	
			Sample 2	0.13	0.01	
			Sample 3	0.16	0.02	
July 14	5_14	08:20	Sample 1	0.05	0.01	0.04
			Sample 2	0.13	0.14	
			Sample 3	0.04	0.03	
		13:52	Sample 1	0.00	0.00	
			Sample 2	0.00	0.00	
			Sample 3	0.00	0.00	
September 14	7_14	Time not recorded	Sample 1	0.08	0.07	0.12
			Sample 2	0.10	0.02	
			Sample 3	0.11	0.06	
		15:36	Sample 1	0.10	0.04	
			Sample 2	0.13	0.11	
			Sample 3	0.18	0.17	
December 14	11_14	11:15	Sample 1	0.07	0.02	0.04
			Sample 2	0.04	0.01	
			Sample 3	0.04	0.01	
		15:20	Sample 1	0.04	0.03	
			Sample 2	0.03	0.01	
			Sample 3	0.02	0.00	

Table 14 Sizewell B outfall TRO results TRO results, April - January (mg l-1)

Date	Survey	Time	Replicate	Mean concentration	St dev	Survey mean concentration
April 15	6_15	08:59	Sample 1	0.03	0.02	0.02
			Sample 2	0.00	0.00	
			Sample 3	0.01	0.01	
		10:15	Sample 1	0.02	0.02	
			Sample 2	0.01	0.01	
			Sample 3	0.04	0.02	
July	13_15	05:20	Sample 1	0.01	0.01	0.02
			Sample 2	0.04	0.07	
			Sample 3	0.00	0.00	
		06:43	Sample 1	0.03	0.03	
			Sample 2	0.02	0.02	
			Sample 3	0.03	0.02	
September	15_15	06:31	Sample 1	0.00	0.00	0.08
			Sample 2	0.06	0.09	
			Sample 3	0.12	0.08	
		07:45	Sample 1	0.08	0.11	
			Sample 2	0.08	0.12	
			Sample 3	0.15	0.13	
January		Site not sampled				

4 Summary and Conclusions

4.1 Summary

Temperature data indicate that during 2014 samples taken in the vicinity of the Sizewell B outfall were ~3˚C higher than at the other sampling locations. During 2015 this difference was not so apparent, probably due to differences in the timing of the sampling in relation to the location of the Sizewell B discharge plume. Temperature across the sites was between 4.48 and 24.14˚C over the period of the survey. The calculated 98 percentile value was 22.2˚C which was within the boundaries for Good status for transitional and coastal waters (20 – 23˚C). Salinity measurements across the sites fell in a relatively narrow range between 32.5 and 34.5 and dissolved oxygen concentrations were between 7 and 11 mg l^{-1} which was well above the requirement for High status (5.7 mg l^{-1}). The biochemical oxygen demand of samples taken at all sites over the survey were low and indicative of no or low influence of the presence of substances likely to impact natural oxygen background concentrations.

In a previous water quality survey at Sizewell (2009/10, BEEMS TR189) ammonia concentration data were found be unreliable i.e. values were exceptionally high (420 µg l^{-1} NH_4- N) at all sites surveyed in comparison to Environment Agency data for sites immediately to the north and south of Sizewell. In this study the mean NH_4- N concentration for all four sites surveyed was 11.38 µg l^{-1} and the 95 percentile was 26.3 µg l^{-1}. Water quality data from Environment Agency surveys carried out between 1992 – 2007 gave a higher mean range of 24 - 35 µg l^{-1} NH_4- N for four sites within the Suffolk Waterbody (BEEMS TR131). Whilst total ammonia concentrations in the present study were lower than those measured in earlier Environment Agency surveys they are of a similar order of magnitude and are considered to be representative of current site conditions. Using the raw data for total ammonia NH_4- N measured at each of the sites included in this report together with the respective pH, temperature and salinity, the equivalent unionised ammonia concentration can be derived using the Environment Agency calculator (Clegg and Whitfield, 1995). The derived mean and 95 percentile unionised ammonia concentrations across all sites were 0.09 and 0.19 µg l^{-1} NH_3-N respectively. These values were considerably lower than the 95 percentile EQS for unionised ammonia of 21 µg l^{-1} NH_3-N and provide the background source term against which to assess any station discharges containing ammonia.

The 99 percentile dissolved inorganic nitrogen concentration (winter period, 1st November- 28th February) measured across all sites surveyed in this report was 425 µg l^{-1}. For transitional and coastal waters of intermediate turbidity (defined as 10 - <100 mg l^{-1} of solid particulate matter) the 99 percentile is 980 µg l^{-1} and 1470 µg l^{-1} for Good and Moderate status respectively (Water Framework Directive Standards and Classification Directions 2015). Therefore, the measured DIN value corresponds to a Good status.

Overall mean and 95 percentile dissolved concentrations of the priority metals cadmium and nickel for all sites were below their respective annual average EQS values. For dissolved mercury there is only a 95 percentile standard and this was not exceeded by the 95 percentile value calculated across sites. For metals defined as specific pollutants (arsenic, copper, iron, chromium) the annual average values across all sites were also below their respective EQS. Chromium also has an EQS MAC defined as a 95 percentile and the calculated 95 percentile dissolved chromium concentration across all sites was below this standard. The chromium EQS is set specifically for chromium VI and, as the analysis conducted did not discriminate between different chromium species, the conservative assumption was made that the measurement was entirely of chromium VI. For lead, only total concentrations were measured during this sampling programme and these values exceeded the dissolved EQS for lead. However, dissolved concentrations of lead measured at Sizewell in a previous sampling campaign (BEEMS TR189) indicated all values at the intake and outfall of Sizewell B and the planned intake and outfall for Sizewell C to be <1 µg l^{-1} and hence below the annual average EQS.

The total residual oxidant concentrations measured at the reference site and at the planned Sizewell C intake/outfall had 95 percentiles of 0.07 and 0.06 TRO as mg l^{-1} chlorine respectively and at the Sizewell B discharge a measured 95 percentile of 0.14 mg l^{-1}. These values represent the background values for Sizewell with those values measured at Sizewell B heavily influenced by proximity to the discharge plume and measurements at the other two sites falling below the EQS for TRO in seawater.

4.2 Conclusions

A range of physical and chemical parameters including priority substances and specific pollutants that are of relevance to the proposed Sizewell C new build were measured over an almost two-year period at several locations within the Suffolk Waterbody. The background conditions indicated by the range in magnitude and concentration of these parameters indicated that based on these data the waterbody would be judged to be of Good to High status.

The TRO concentration exceeds the recommended 95 percentile EQS within the influence of the existing Sizewell B discharge as might be expected with some samples taken within the mixing zone for the plume.

Dissolved zinc concentrations at all of the sites also exceed the annual average EQS and this is likely to be due to the influence of elevated zinc concentrations within riverine discharges.to the Southern North Sea region.

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5 Appendix A

5.1 Temperature

5.1.1 2014

Table 15, ESM2 profiler 2014 temperature data, March – April, 0-4m depth

Date (14)		Site	Site code	Station	Mean	Count	St Dev
13th March	SZ 1/14	Reference site	SZ3	1	7.42	26	0.01
		Sizewell B Intake	SZ 140	7	7.74	89	0.01
				20	9.29	92	0.03
				26	8.94	100	0.02
		Sizewell C Intake and Outfall	SZ 141	4	7.64	104	0.01
				22	8.37	84	0.04
				28	7.91	95	0.07
		Sizewell B Outfall	SZ 142	9	10.59	89	0.67
				15	12.27	100	0.85
				17	11.86	99	0.91
9th April	SZ 2/14	Reference Site	SZ3	33	10.13	194	0.01
		Sizewell B Intake	SZ 140	10	9.92	225	0.02
				18	11.93	170	1.26
				28	10.83	190	0.02
		Sizewell C Intake and Outfall	SZ 141	11	9.66	167	0.02
				22	9.92	210	0.14
				31	9.97	254	0.04
		Sizewell B Outfall	SZ 142	1	14.67	204	0.67
				16	14.32	142	0.16
				24	14.37	20	0.45

Table 16, ESM2 profiler 2014 temperature data, May – June, 0-4m depth

Date (14)		Site	Site code	Station	Mean	Count	St Dev
13th May	SZ 3/14	Reference site	SZ3	30	12.84	168	0.07
		Sizewell B Intake	SZ 140	5	12.73	210	0.02
				10	12.45	171	0.02
				15	12.28	225	0.03
				24	13.15	159	0.02
		Sizewell C Intake and Outfall	SZ 141	1	12.03	134	0.06
				11	12.24	152	0.03
				14	12.31	201	0.05
				22	12.74	180	0.06
		Sizewell B Outfall	SZ 142	8	17.08	145	0.75
				19	16.82	139	1.02
				28	16.47	210	1.06
8th June	SZ 4/14	Reference Site	SZ3	30	18.16	146	0.84
		Sizewell B Intake	SZ 140	6	17.08	31	0.21
				14	17.13	166	0.14
				25	16.46	133	0.10
		Sizewell C Intake and Outfall	SZ 141	1	16.12	99	0.02
				13	16.39	152	0.13
				20	15.54	143	0.02
		Sizewell B Outfall	SZ 142	10	17.63	214	0.85
				19	20.48	166	0.99
				28	21.00	185	0.31

Table 17, ESM2 profiler 2014 temperature data, July – August, 0-4m depth

Date (14)		Site	Site code	Station	Mean	Count	St Dev
7th July	SZ 5/14	Reference Site	SZ3	21	18.91	37	0.01
		Sizewell B Intake	SZ 140	4	18.45	34	0.03
				14	17.79	38	0.01
		Sizewell C Intake and Outfall	SZ 141	8	17.47	26	0.01
				16	17.20	17	0.02
		Sizewell B Outfall	SZ 142	2	19.36	78	0.71
				10	22.27	25	0.12
				19	19.33	45	0.19
5th August	SZ 6/14	Reference Site	SZ3	30	20.69	167	0.02
		Sizewell B Intake	SZ 140	4	19.76	162	0.03
				14	21.90	179	0.49
				23	20.53	193	0.18
		Sizewell C Intake and Outfall	SZ 141	9	19.49	171	0.06
				18	19.83	163	0.02
				21	19.80	167	0.03
		Sizewell B Outfall	SZ 142	2	24.42	173	0.76
				12	24.48	270	0.50
				27	23.52	190	0.44

Table 18, ESM2 profiler 2014 temperature data, September – October, 0-4m depth

Date (14)		Site	Site code	Station	Mean	Count	St Dev
4th September	SZ 7/14	Reference Site	SZ3	27	18.20	161	0.03
		Sizewell B Intake	SZ 140	3	18.73	27	0.16
				13	18.90	151	0.15
				21	19.41	143	0.34
		Sizewell C Intake and Outfall	SZ 141	7	18.17	177	0.02
				15	17.96	186	0.02
				19	18.04	146	0.03
		Sizewell B Outfall	SZ 142	2	22.19	247	1.48
				9	24.21	249	0.55
				25	23.58	34	0.36
3rd October	SZ 9/14	Reference Site	SZ3	27	18.40	108	0.01
		Sizewell B Intake	SZ 140	4	18.18	158	0.04
				15	17.63	158	0.04
				20	19.70	140	1.01
		Sizewell C Intake and Outfall	SZ 141	9	17.36	138	0.01
				16	17.47	175	0.02
				21	17.63	119	0.02
		Sizewell B Outfall	SZ 142	3	21.28	130	1.29
				10	20.18	178	2.03
				26	20.09	210	1.39

Table 19, ESM2 profiler 2014 temperature data, December, 0-4m depth

Date (14)		Site	Site code	Station	Mean	Count	St Dev
5th December	SZ 11/14	Reference Site	SZ3	28	9.52	142	0.02
		Sizewell B Intake	SZ 140	4	9.44	141	0.01
				14	9.51	148	0.02
				22	9.62	160	0.03
		Sizewell C Intake and Outfall	SZ 141	2	9.55	143	0.01
				10	9.59	150	0.03
				20	9.72	41	0.06
		Sizewell B Outfall	SZ 142	8	11.28	164	0.25
				16	10.55	136	0.40
				26	12.82	65	0.70

5.1.2 2015

Table 20, ESM2 profiler 2015 temperature data, January - April

Date (15)		Site	Site code	Station	Mean	Count	St Dev
8th January	1/15	Reference Site	SZ3	1	6.51	116	0.02
				3	6.52	141	0.03
4th February	2/15	Reference Site	SZ3	11	4.47	133	0.01
				12	4.48	105	0.01
				13	4.48	127	0.01
		Sizewell B Intake	SZ 140	4	4.53	101	0.01
		Sizewell C Intake and Outfall	SZ 141	9	4.60	119	0.02
		Sizewell B Outfall	SZ 142	2	8.03	109	0.65
27th February	3/15	Sizewell B Intake	SZ 140	14	5.40	26	0.03
				19	6.73	20	0.64
				25	6.13	18	0.03
		Sizewell C Intake and Outfall	SZ 141	17	5.31	41	0.04
				23	5.33	27	0.13
		Sizewell B Outfall	SZ 143	2	6.16	136	0.08
				7	5.31	85	0.02
				11	5.35	24	0.05
1st April	6/15	Reference Site	SZ3	29	7.71	15	0.06
		Sizewell B Intake	SZ 140	5	7.46	45	0.01
				21	8.00	22	0.03
				27	7.36	22	0.01
		Sizewell C Intake and Outfall	SZ 141	2	7.00	125	0.01
				17	6.99	14	0.01
				24	7.25	13	0.02
		Sizewell B Outfall	SZ 143	8	8.37	29	0.72
				11	8.26	22	0.84
				14	8.05	21	0.07

Table 21, ESM2 profiler 2015 temperature data, April - May

Date (15)		Site	Site code	Station	Mean	Count	St Dev
27th April	8/15	Reference Site	SZ3	30	11.18	14	0.15
		Sizewell B Intake	SZ 140	11	11.81	48	0.59
				17	10.91	16	0.08
				23	11.39	15	0.01
		Sizewell C Intake and Outfall	SZ 141	15	10.51	12	0.02
				21	10.21	31	0.02
				28	9.97	28	0.07
		Sizewell B Outfall	SZ 143	3	11.35	74	0.94
				6	11.01	20	0.14
				9	11.25	23	0.22
27th May	10/15	Reference Site	SZ3	30	13.69	22	0.25
		Sizewell B Intake	SZ 140	13	13.25	44	0.03
				19	13.71	36	0.02
				25	12.95	43	0.03
		Sizewell C Intake and Outfall	SZ 141	16	13.42	30	0.06
				22	12.83	23	0.08
				28	12.50	19	0.02
		Sizewell B Outfall	SZ 143	3	13.32	69	0.01
				6	15.36	55	0.37
				9	13.98	46	0.07

Table 22, ESM2 profiler 2015 temperature data, June - July

Date (15)		Site	Site code	Station	Mean	Count	St Dev
26th June	12/15	Reference Site	SZ3	29	16.73	37	0.13
		Sizewell B Intake	SZ 140	12	17.11	30	0.16
				18	16.44	35	0.02
				24	15.60	27	0.02
		Sizewell C Intake and Outfall	SZ 141	15	15.84	17	0.04
				21	15.67	77	0.01
				27	14.97	78	0.03
		Sizewell B Outfall	SZ 143	3	17.61	55	0.32
				6	18.41	42	0.91
			SZ 144	9	16.84	38	0.20
26th July	13/15	Reference Site	SZ3	1	17.52	17	0.01
				36	18.01	75	0.02
		Sizewell B Intake	SZ 140	16	18.09	54	0.03
				22	18.26	17	0.05
				28	18.31	43	0.08
		Sizewell C Intake and Outfall	SZ 141	19	17.78	22	0.01
				25	18.01	76	0.01
				31	17.90	30	0.01
		Sizewell B Outfall	SZ 143	5	18.38	19	0.43
			SZ 144	10	18.32	38	0.04
				13	18.07	28	0.03

Table 23, ESM2 profiler 2015 temperature data, August - September

Date (15)		Site	Site code	Station	Mean	Count	St Dev
27th August	14/15	Reference Site	SZ3	2	18.43	100	0.01
				34	18.51	35	0.01
				36	18.41	40	0.01
		Sizewell B Intake	SZ 140	15	18.40	35	0.02
				21	18.36	176	0.01
				27	18.53	67	0.03
		Sizewell C Intake and Outfall	SZ 141	18	18.37	27	0.02
				24	18.30	24	0.01
				30	18.31	58	0.02
		Sizewell B Outfall	SZ 143	6	18.45	206	0.01
				9	19.46	31	0.70
23rd September	15/15	Reference Site	SZ3	2	15.81	34	0.02
				4	15.81	305	0.02
				33	16.67	117	0.02
				35	16.64	8	0.04
		Sizewell B Intake	SZ 140	18	16.66	98	0.01
				24	16.32	79	0.01
				30	16.34	22	0.01
		Sizewell C Intake and Outfall	SZ 141	15	16.33	23	0.01
				21	16.29	11	0.01
				27	16.30	12	0.01
		Sizewell B Outfall	SZ 144	6	16.01	136	0.15
				9	16.42	121	0.10
				12	17.53	40	0.25

5.2 Salinity

5.2.1 2014

Table 24, ESM2 profiler 2014 salinity data, March - April

Date (14)		Site	Site code	Station	Mean	Count	St Dev
13th March	SZ 1/14	Reference Site	SZ3	1	32.79	26	0.02
		Sizewell B Intake	SZ 140	7	32.92	89	0.02
				20	33.04	92	0.02
				26	33.09	100	0.03
		Sizewell C Intake and Outfall	SZ 141	4	32.94	104	0.03
				22	33.09	84	0.02
				28	33.20	95	0.09
		Sizewell B Outfall	SZ 142	9	32.96	89	0.32
				15	32.98	100	0.64
				17	32.92	99	0.56
9th April	SZ 2/14	Reference Site	SZ3	33	33.25	194	0.02
		Sizewell B Intake	SZ 140	10	33.49	225	0.02
				18	33.52	170	0.13
				28	33.29	190	0.02
		Sizewell C Intake and Outfall	SZ 141	11	33.54	167	0.03
				22	33.61	210	0.06
				31	33.46	254	0.04
		Sizewell B Outfall	SZ 142	1	33.23	204	0.40
				16	33.52	142	0.08
				24	33.48	20	0.14

Table 25, ESM2 profiler 2014 salinity data, May - June

Date (14)		Site	Site code	Station	Mean	Count	St Dev
13th May	SZ 3/14	Reference Site	SZ3	30	33.36	168	0.06
		Sizewell B Intake	SZ 140	5	33.38	210	0.04
				10	33.45	171	0.02
				15	33.35	225	0.04
				24	33.48	159	0.09
		Sizewell C Intake and Outfall	SZ 141	1	33.59	134	0.07
				11	33.57	152	0.03
				14	33.46	201	0.05
				22	33.49	180	0.02
		Sizewell B Outfall	SZ 142	8	33.39	145	0.14
				19	33.38	139	0.27
				28	33.52	210	0.21
8th June	SZ 4/14	Reference Site	SZ3	30	33.55	146	0.07
		Sizewell B Intake	SZ 140	6	33.48	31	0.05
				14	33.75	166	0.04
				25	33.75	133	0.03
		Sizewell C Intake and Outfall	SZ 141	1	33.48	99	0.03
				13	33.66	152	0.04
				20	33.78	143	0.02
		Sizewell B Outfall	SZ 142	10	33.61	212	0.31
				19	33.78	166	0.22
				28	33.72	185	0.14

Table 26, ESM2 profiler 2014 salinity data, July – September

Date (14)		Site	Site code	Station	Mean	Count	St Dev
7th July	SZ 5/14	Reference Site	SZ3	21	33.68	37	0.03
		Sizewell B Intake	SZ 140	4	33.67	34	0.01
				14	33.82	38	0.03
		Sizewell C Intake and Outfall	SZ 141	8	33.76	26	0.01
				16	33.86	17	0.02
		Sizewell B Outfall	SZ 142	2	33.74	78	0.28
				10	33.77	25	0.06
				19	33.66	45	0.06
5th August	SZ 6/14	Reference Site	SZ3	30	33.77	167	0.04
		Sizewell B Intake	SZ 140	4	33.90	162	0.02
				14	33.88	179	0.06
				23	33.81	193	0.04
		Sizewell C Intake and Outfall	SZ 141	9	34.07	171	0.07
				18	33.87	163	0.03
				21	33.87	167	0.03
		Sizewell B Outfall	SZ 142	2	33.77	173	0.21
				12	33.85	270	0.09
				27	33.82	190	0.11
4th September	SZ 7/14	Reference Site	SZ3	27	33.88	161	0.03
		Sizewell B Intake	SZ 140	3	33.90	27	0.03
				13	34.10	151	0.05
				21	34.01	143	0.06
		Sizewell C Intake and Outfall	SZ 141	7	34.00	177	0.04
				15	34.06	186	0.03
				19	34.03	146	0.03
		Sizewell B Outfall	SZ 142	2	33.76	246	0.52
				9	33.35	244	3.74
				25	33.92	34	0.27

Table 27, ESM2 profiler 2014 salinity data, October - December

Date (14)		Site	Site code	Station	Mean	Count	St Dev
3rd October	SZ 9/14	Reference Site	SZ3	27	34.02	108	0.03
		Sizewell B Intake	SZ 140	4	34.12	158	0.02
				15	34.19	158	0.02
				20	34.15	140	0.06
		Sizewell C Intake and Outfall	SZ 141	9	34.16	138	0.01
				16	34.26	175	0.02
				21	34.19	119	0.02
		Sizewell B Outfall	SZ 142	3	34.07	130	0.40
				10	34.17	178	0.26
				26	34.10	210	0.35
5th December	SZ 11/14	Reference Site	SZ3	28	33.12	142	0.04
		Sizewell B Intake	SZ 140	4	33.23	141	0.02
				14	33.05	148	0.03
				22	33.31	160	0.04
		Sizewell C Intake and Outfall	SZ 141	2	33.32	143	0.03
				10	33.37	150	0.04
				20	33.45	41	0.06
		Sizewell B Outfall	SZ 142	8	33.11	164	0.09
				16	33.15	136	0.20
				26	33.42	65	0.23

5.2.2 2015

Table 28, ESM2 profiler 2015 salinity data, January - April

Date (15)		Site	Site code	Station	Mean	Count	St Dev
8th January	1/15	Reference Site	SZ3	1	33.83	116	0.03
				3	33.74	141	0.07
4th February	2/15	BEEMS reference	SZ3	11	33.27	133	0.03
				12	33.25	105	0.03
				13	33.26	127	0.02
		Sizewell B Intake	SZ 140	4	33.34	101	0.02
		Sizewell C Intake and Outfall	SZ 141	9	33.38	119	0.02
		Sizewell B Outfall	SZ 142	2	33.28	109	0.20
27th February	3/15	Sizewell B Intake	SZ 140	14	33.55	26	0.02
				19	33.71	20	0.14
				25	33.58	18	0.04
		Sizewell C Intake and Outfall	SZ 141	17	33.53	41	0.03
				23	33.88	27	0.08
		Sizewell B Outfall	SZ 143	2	33.54	136	0.03
				7	33.52	85	0.03
				11	33.57	24	0.06
1st April	6/15	Reference Site	SZ3	29	NA	NA	NA
		Sizewell B Intake	SZ 140	5	NA	NA	NA
				21	NA	NA	NA
				27	NA	NA	NA
		Sizewell C Intake and Outfall	SZ 141	2	NA	NA	NA
				17	NA	NA	NA
				24	NA	NA	NA
		Sizewell B Outfall	SZ 143	8	NA	NA	NA
				11	NA	NA	NA
				14	NA	NA	NA

Table 29, ESM2 profiler 2015 salinity data, April - May

Date (15)		Site	Site code	Station	Mean	Count	St Dev
27th April	8/15	Reference Site	SZ3	30	33.48	14	0.09
		Sizewell B Intake	SZ 140	11	33.33	48	0.17
				17	33.31	16	0.07
				23	33.35	15	0.04
		Sizewell C Intake and Outfall	SZ 141	15	33.32	12	0.02
				21	33.39	31	0.02
				28	33.55	28	0.04
		Sizewell B Outfall	SZ 143	3	33.41	74	0.20
				6	33.30	20	0.09
				9	33.27	23	0.05
27th May	10/15	Reference Site	SZ3	30	33.79	22	0.06
		Sizewell B Intake	SZ 140	13	33.80	44	0.03
				19	33.76	36	0.04
				25	33.79	43	0.02
		Sizewell C Intake and Outfall	SZ 141	16	33.72	30	0.02
				22	33.79	23	0.02
				28	33.80	19	0.02
		Sizewell B Outfall	SZ 143	3	33.68	69	0.02
				6	33.74	55	0.07
				9	33.71	46	0.03

Table 30, ESM2 profiler 2015 salinity data, June - July

Date (15)		Site	Site code	Station	Mean	Count	St Dev
26th June	12/15	Reference Site	SZ3	29	33.90	37	0.03
		Sizewell B Intake	SZ 140	12	33.92	30	0.05
				18	33.91	35	0.01
				24	33.98	27	0.05
		Sizewell C Intake and Outfall	SZ 141	15	33.94	17	0.01
				21	33.96	77	0.04
				27	34.09	78	0.04
		Sizewell B Outfall	SZ 143	3	33.91	55	0.13
				6	33.97	42	0.17
			SZ 144	9	33.91	38	0.04
26th July	13/15	Reference Site	SZ3	1	33.61	17	0.03
				36	33.71	75	0.02
		Sizewell B Intake	SZ 140	16	33.73	54	0.02
				22	33.77	17	0.03
				28	33.84	43	0.03
		Sizewell C Intake and Outfall	SZ 141	19	33.78	22	0.02
				25	33.85	76	0.02
				31	33.91	30	0.01
		Sizewell B Outfall	SZ 143	5	33.78	19	0.08
			SZ 144	10	33.67	38	0.02
				13	33.67	28	0.02

Table 31, ESM2 profiler 2015 salinity data, August - September

Date (15)		Site	Site code	Station	Mean	Count	St Dev
27th August	14/15	Reference Site	SZ3	2	34.29	100	0.01
				34	34.29	35	0.01
				36	34.28	40	0.02
		Sizewell B Intake	SZ 140	15	34.28	35	0.03
				21	34.28	176	0.02
				27	34.32	67	0.03
		Sizewell C Intake and Outfall	SZ 141	18	34.38	27	0.02
				24	34.35	24	0.01
				30	34.39	58	0.02
		Sizewell B Outfall	SZ 143	6	34.31	206	0.02
				9	34.41	31	0.12
23rd September	15/15	Reference Site	SZ3	2	34.09	34	0.02
				4	34.11	305	0.01
				33	34.21	117	0.02
				35	34.24	8	0.01
		Sizewell B Intake	SZ 140	18	34.40	98	0.01
				24	34.46	79	0.01
				30	34.46	22	0.01
		Sizewell C Intake and Outfall	SZ 141	15	34.28	23	0.03
				21	34.41	11	0.01
				27	34.49	12	0.01
		Sizewell B Outfall	SZ 144	6	34.06	136	0.04
				9	34.08	121	0.05
				12	34.21	40	0.05

5.3 Oxygen

5.3.1 2014

Table 32, ESM2 profiler 2014 oxygen data, March - April

Date (14)		Site	Site code	Station	Mean	Count	St Dev
13th March	SZ 1/14	Reference Site	SZ3	1	11.17	2	0.63
		Sizewell B Intake	SZ 140	7	11.06	8	0.09
				20	10.35	9	0.60
				26	8.96	9	0.01
		Sizewell C Intake and Outfall	SZ 141	4	10.16	9	0.41
				22	9.07	7	0.01
				28	9.23	8	0.01
		Sizewell B Outfall	SZ 142	9	10.63	8	0.25
				15	10.00	9	0.25
				17	9.16	9	0.22
9th April	SZ 2/14	Reference Site	SZ3	33	8.91	15	0.02
		Sizewell B Intake	SZ 140	10	8.95	18	0.01
				18	8.95	13	0.07
				28	8.90	15	0.01
		Sizewell C Intake and Outfall	SZ 141	11	8.96	13	0.01
				22	9.01	16	0.02
				31	8.96	21	0.01
		Sizewell B Outfall	SZ 142	1	8.82	17	0.13
				16	9.10	11	0.02

Table 33, ESM2 profiler 2014 oxygen data, May - June

Date (14)		Site	Site code	Station	Mean	Count	St Dev
13th May	SZ 3/14	Reference Site	SZ3	30	8.58	13	0.04
		Sizewell B Intake	SZ 140	5	9.35	17	0.83
				10	8.46	13	0.01
				15	8.52	19	0.01
				24	8.57	13	0.02
		Sizewell C Intake and Outfall	SZ 141	1	9.63	10	0.93
				11	8.53	12	0.01
				14	8.53	16	0.01
				22	8.55	15	0.02
		Sizewell B Outfall	SZ 142	8	8.55	12	0.08
				19	8.60	10	0.08
				28	8.79	17	0.08
8th June	SZ 4/14	Reference Site	SZ3	30	8.95	10	0.86
		Sizewell B Intake	SZ 140	6	7.93	1	NA
				14	8.40	6	0.76
				25	10.59	10	3.22
		Sizewell C Intake and Outfall	SZ 141	1	8.03	8	0.02
				13	10.39	11	3.36
				20	8.07	10	0.01
		Sizewell B Outfall	SZ 142	10	7.99	18	0.12
				19	8.65	10	0.51
				28	8.81	15	0.66

Table 34, ESM2 profiler 2014 oxygen data, July - September

Date (14)		Site	Site code	Station	Mean	Count	St Dev
7th July	SZ 5/14	Reference Site	SZ3	21	7.59	1	NA
		Sizewell B Intake	SZ 140	4	7.84	3	0.01
				14	8.28	4	0.02
		Sizewell C Intake and Outfall	SZ 141	8	8.09	1	NA
		Sizewell B Outfall	SZ 142	2	7.81	5	0.03
				10	8.26	1	NA
				19	8.26	2	0.03
5th August	SZ 6/14	Reference Site	SZ3	30	7.17	17	0.02
		Sizewell B Intake	SZ 140	4	7.11	15	0.01
				14	7.17	17	0.03
				23	7.22	19	0.05
		Sizewell C Intake and Outfall	SZ 141	9	7.06	17	0.01
				18	7.12	15	0.03
				21	7.15	16	0.02
		Sizewell B Outfall	SZ 142	2	7.16	16	0.08
				12	7.19	26	0.03
				27	7.17	17	0.05
4th September	SZ 7/14	Reference Site	SZ3	27	7.64	15	0.03
		Sizewell B Intake	SZ 140	3	7.46	2	0.01
				13	7.46	14	0.03
				21	7.33	14	0.56
		Sizewell C Intake and Outfall	SZ 141	7	7.39	17	0.02
				15	7.40	18	0.02
				19	7.93	14	1.92
		Sizewell B Outfall	SZ 142	2	7.58	24	0.11
				9	7.75	22	1.47
				25	7.67	2	0.03

Table 35, ESM2 profiler 2014 oxygen data, October - December

Date (14)		Site	Site code	Station	Mean	Count	St Dev
3rd October	SZ 9/14	Reference Site	SZ3	27	7.45	10	0.02
		Sizewell B Intake	SZ 140	4	7.34	14	0.02
				15	7.34	15	0.02
				20	7.40	13	0.05
		Sizewell C Intake and Outfall	SZ 141	9	7.23	12	0.01
				16	7.28	17	0.01
				21	7.34	11	0.01
		Sizewell B Outfall	SZ 142	3	7.29	11	0.15
				10	7.44	16	0.11
				26	7.50	20	0.10
5th December	SZ 11/14	Reference Site	SZ3	28	8.67	13	0.01
		Sizewell B Intake	SZ 140	4	8.58	13	0.01
				14	8.65	14	0.01
				22	8.60	15	0.01
		Sizewell C Intake and Outfall	SZ 141	2	8.54	13	0.01
				10	8.52	14	0.01
				20	8.47	3	0.01
		Sizewell B Outfall	SZ 142	8	8.79	15	0.04
				16	8.70	13	0.04
				26	8.73	6	0.11

5.3.2 2015

Table 36, ESM2 profiler 2015 oxygen data, January - February

Date (15)		Site	Site code	Station	Mean	Count	St Dev
8th January	1/15	Reference Site	SZ3	1	9.20	2	0.01
				3	9.25	13	0.02
4th February	2/15	BEEMS reference	SZ3	11	9.44	12	0.01
				12	9.44	10	0.01
				13	9.44	12	0.02
		Sizewell B Intake	SZ 140	4	9.42	10	0.01
		Sizewell C Intake and Outfall	SZ 141	9	9.41	11	0.01
		Sizewell B Outfall	SZ 142	2	9.58	10	0.07
27th February	3/15	Sizewell B Intake	SZ 140	14	9.45	2	0.01
				19	9.55	1	NA
				25	9.44	1	NA
		Sizewell C Intake and Outfall	SZ 141	17	9.45	3	0.01
				23	9.43	1	NA
		Sizewell B Outfall	SZ 143	2	9.39	13	0.02
				7	9.45	7	0.02
				11	9.49	1	NA

Table 37, ESM2 profiler 2015 oxygen data, April

Date (15)		Site	Site code	Station	Mean	Count	St Dev
1st April	6/15	Reference Site	SZ3	29	NA	NA	NA
		Sizewell B Intake	SZ 140	5	NA	NA	NA
				21	NA	NA	NA
				27	NA	NA	NA
		Sizewell C Intake and Outfall	SZ 141	2	NA	NA	NA
				17	NA	NA	NA
				24	NA	NA	NA
		Sizewell B Outfall	SZ 143	8	NA	NA	NA
				11	NA	NA	NA
				14	NA	NA	NA
27th April	8/15	Reference Site	SZ3	30	NA	NA	NA
		Sizewell B Intake	SZ 140	11	9.11	4	0.10
				17	9.10	1	NA
				23	8.96	1	NA
		Sizewell C Intake and Outfall	SZ 141	15	NA	NA	NA
				21	9.02	3	0.01
				28	9.15	2	0.01
		Sizewell B Outfall	SZ 143	3	9.15	7	0.09
				6	9.01	1	NA
				9	8.90	1	NA

Table 38, ESM2 profiler 2015 oxygen data, May - June

Date (15)		Site	Site code	Station	Mean	Count	St Dev
27th May	10/15	Reference Site	SZ3	30	8.45	2	0.04
		Sizewell B Intake	SZ 140	13	8.40	3	0.01
				19	8.64	3	0.02
				25	8.74	3	0.01
		Sizewell C Intake and Outfall	SZ 141	16	8.55	2	0.01
				22	8.67	2	0.00
				28	8.68	1	NA
		Sizewell B Outfall	SZ 143	3	8.45	5	0.01
				6	8.41	5	0.03
				9	8.53	4	0.00
26th June	12/15	Reference Site	SZ3	29	7.62	3	0.02
		Sizewell B Intake	SZ 140	12	7.58	2	0.01
				18	7.67	2	0.01
				24	7.84	2	0.00
		Sizewell C Intake and Outfall	SZ 141	15	7.72	1	NA
				21	7.77	6	0.01
				27	7.89	7	0.02
		Sizewell B Outfall	SZ 143	3	7.52	5	0.04
				6	7.50	3	0.03
			SZ 144	9	7.56	3	0.01

Table 39, ESM2 profiler 2015 oxygen data, July - August

Date (15)		Site	Site code	Station	Mean	Count	St Dev
26th July	13/15	Reference Site	SZ3	1	6.98	1	NA
				36	7.09	6	0.09
		Sizewell B Intake	SZ 140	16	6.94	5	0.01
				22	NA	NA	NA
				28	6.98	2	0.00
		Sizewell C Intake and Outfall	SZ 141	19	6.97	1	NA
				25	6.94	7	0.01
				31	7.00	2	0.00
		Sizewell B Outfall	SZ 143	5	6.92	1	NA
			SZ 144	10	7.01	2	0.01
				13	6.97	2	0.04
27th August	14/15	Reference Site	SZ3	2	7.07	9	0.01
				34	7.07	2	0.01
				36	7.08	3	0.01
		Sizewell B Intake	SZ 140	15	7.07	3	0.01
				21	7.03	16	0.01
				27	7.07	5	0.01
		Sizewell C Intake and Outfall	SZ 141	18	7.11	1	NA
				24	7.13	2	0.01
				30	7.08	5	0.01
		Sizewell B Outfall	SZ 143	6	7.08	20	0.01
				9	7.07	3	0.02

Table 40, ESM2 profiler 2015 oxygen data, September

Date (15)		Site	Site code	Station	Mean	Count	St Dev
23rd September	15/15	Reference Site	SZ3	2	7.29	3	0.01
				4	7.30	30	0.01
				33	7.37	11	0.01
				35	NA	NA	NA
		Sizewell B Intake	SZ 140	18	7.30	9	0.01
				24	7.33	7	0.01
				30	NA	NA	NA
		Sizewell C Intake and Outfall	SZ 141	15	7.32	2	0.00
				21	NA	NA	NA
				27	NA	NA	NA
		Sizewell B Outfall	SZ 144	6	7.37	12	0.03
				9	7.33	11	0.02
				12	7.30	3	0.01

6 Appendix B

6.1 Water chemistry

6.1.1 Priority analytes

Table 41 SZ3 water chemistry results for priority analytes, units are in µg l^{-1}

Analyte	*Apr-14*	*May-14*	*Jun-14*	*Jul-14*	*Aug-14*	*Sep-14*	*Oct-14*	*Nov-14*	*Dec-14*	*Jan-15*	*Feb-15*	*Mar-15*	*Apr-15*	*May-15*	*Jun-15*	*Jul-15*	*Aug-15*	*Sep-15*	*Oct-15*	*Nov-15*	*Dec-15*
Arsenic Dissolved	1.15	1.15	1.26	1.03	1.35	1.3	1.15	1.35	1.2	1.19	1.32	1.33	1.51	<1	<1	1.1	1.11	1.21	<1	<1	1.37
Cadmium, Dissolved	<0.03	<0.03	0.03	0.043	0.037	0.03	0.041	0.036	0.03	0.115	<0.03	<0.03	<0.03	<0.06	<0.03	<0.03	0.03	<0.03	0.097	<0.03	<0.03
Copper, Dissolved	4.74	4.74	1.06	1.36	2.75	1.66	1.58	2.04	1.34	1.43	0.724	0.698	1.15	1.34	1.19	0.908	2.11	1.48	4.82	2.84	2.07
Nickel, Dissolved	0.762	0.762	0.555	0.709	0.83	0.639	0.574	0.781	0.578	0.595	0.507	0.69	0.636	<0.6	0.501	0.711	0.955	0.648	0.625	0.753	1.02
Zinc, Dissolved	8.11	8.11	2.7	16.2	32.9	7.78	14.4	16.6	9.25	9.07	2.15	6.21	26.9	6.86	5.1	6.19	20.4	10.8	8.86	5.42	11.5
Iron, Dissolved	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Mercury, Dissolved	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.0134	<0.01	0.0137	<0.01	<0.01	0.0434
Chromium, Dissolved	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	8.08	2.22	<0.5	<0.5	<0.5	1.47	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Table 42 Sizewell C intake/outfall water chemistry results for priority analytes, units are in µg l^{-1}

Analyte	***Apr-14***	***May-14***	***Jun-14***	***Jul-14***	***Aug-14***	***Sep-14***	***Oct-14***	***Nov-14***	***Dec-14***	***Jan-15***	***Feb-15***	***Mar-15***	***Apr-15***	***May-15***	***Jun-15***	***Jul-15***	***Aug-15***	***Sep-15***	***Oct-15***	***Nov-15***	***Dec-15***
Arsenic Dissolved	1.35	1.35	1.42	NA	1.16	1.23	NA	1.26	1.19	NA	1.25	<1	1.28	1.03	<1	<1	1.1	1.07	1.07	1.34	1.36
Cadmium, Dissolved	0.034	0.034	0.123	NA	<0.03	0.068	NA	0.039	0.038	NA	<0.03	0.09	0.065	<0.03	0.045	<0.03	<0.03	<0.03	0.118	0.038	0.035
Copper, Dissolved	1.88	1.88	2.14	NA	1.93	2.47	NA	2.43	1.42	NA	0.734	2.05	1.57	1.12	1.61	0.922	1.56	1.16	4.17	4.05	1.18
Nickel, Dissolved	0.72	0.72	0.703	NA	0.716	0.746	NA	0.861	0.679	NA	0.5	1.03	1.17	0.532	1.16	0.574	0.72	0.67	0.646	1.09	0.812
Zinc, Dissolved	6.08	6.08	10.5	NA	12.2	17.9	NA	16.4	54.1	NA	2.25	19.2	8.05	21.5	9.91	3.16	11.2	13.2	20.5	17.6	8.57
Iron, Dissolved	<100	<100	<100	NA	<100	<100	NA	<100	<100	NA	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Mercury, Dissolved	<0.01	<0.01	<0.01	NA	0.011	<0.01	NA	<0.01	<0.01	NA	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium, Dissolved	<0.5	<0.5	<0.5	NA	<0.5	<0.5	NA	<0.5	<0.5	NA	<0.5	7.32	<0.5	<0.5	<0.5	0.617	2.69	<0.5	<0.5	1.06	0.984

Table 43 Sizewell B outfall water chemistry results for priority analytes, units are in $\mu g\ l^{-1}$

Analyte	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
Arsenic Dissolved	1.19	1.19	1.35	<1	1.17	1.27	1.05	1.17	<1	NA	1.12	1.16	NA	<1	<1	<1	1.08	1.16	NA	1.14	1.34
Cadmium, Dissolved	0.032	0.032	0.09	0.411	0.046	0.179	0.037	0.055	0.047	NA	<0.03	0.031	NA	0.062	0.056	<0.03	0.04	<0.03	NA	0.186	0.03
Copper, Dissolved	1.42	1.42	0.918	1.87	1.23	8.82	2.01	2.71	0.954	NA	0.762	1.34	NA	3.81	3.92	1.59	1.74	1.24	NA	9.65	1.09
Nickel, Dissolved	0.925	0.925	0.603	0.599	0.706	1.13	0.654	0.827	0.573	NA	0.564	0.956	NA	1.16	1.15	0.777	0.859	0.654	NA	2.19	0.941
Zinc, Dissolved	25.7	25.7	4.47	20.5	17	47	13.2	16.1	16.3	NA	1.94	19.6	NA	47	27.3	11.8	7.78	15	NA	45.5	6.02
Iron, Dissolved	1430	1430	<100	<100	<100	<100	<100	<100	<100	NA	<100	<100	NA	<100	<100	<100	<100	<100	NA	<100	<100
Mercury, Dissolved	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NA	<0.01	<0.01	NA	0.018	<0.01	<0.01	<0.01	<0.01	NA	<0.01	0.516
Chromium, Dissolved	<0.5	<0.5	1.36	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	NA	<0.5	2.17	NA	<0.5	<0.5	<0.5	<0.5	<0.5	NA	0.65	<0.5

6.1.2 Environmental parameters

Analyte	*Apr-14*	*May-14*	*Jun-14*	*Jul-14*	*Aug-14*	*Sep-14*	*Oct-14*	*Nov-14*	*Dec-14*	*Jan-15*	*Feb-15*	*Mar-15*	*Apr-15*	*May-15*	*Jun-15*	*Jul-15*	*Aug-15*	*Sep-15*	*Oct-15*	*Nov-15*	*Dec-15*
BOD 5 Day ATU	<2.92	<2.92	<1.00	1.59	<2.92	<1.00	1.2	1.25	<1.00	<2.92	<1.00	1.11	1.28	<1.00	1.03	1	1.1	<1.00	<1.00	1.35	1.19
Chloride	18300	18300	18800	18900	19000	18800	19100	18900	19100	19400	18700	18600	18000	18700	18300	16900	18100	18500	17200	18100	18300
Carbon, Organic, Dissolved as C {DOC}	1	1	1.34	1.19	1.2	1.4	1.19	1.19	1.22	1.17	1	1.2	1.06	0.73	1.07	0.87	0.64	1.15	0.9	0.65	1.22
Phosphate: Total as P	0.12	0.12	<0.02	<0.02	0.0464	0.0315	0.0278	0.0375	0.239	0.0917	0.0935	0.181	0.0417	0.0415	0.0217	0.0722	0.0978	0.0378	0.0312	0.0618	0.0974
Fluoride	1.17	1.17	1.18	1.27	1.51	1.24	1.31	1.34	1.28	1.26	1.25	1.21	1.16	1.27	1.26	1.31	1.25	1.22	1.27	1.17	1.3
pH	7.99	7.99	8.11	8.03	8.04	8.06	8.03	7.98	7.89	7.97	7.93	7.91	7.97	8.1	8.02	8	8.09	8.05	7.97	8.03	8.05
Bromide	60.2	60.2	64.2	64.1	64.5	61.7	64.3	62.1	62.1	61.3	62.6	63.7	64.1	65.7	64.5	63.7	65.2	62.6	64.1	67.7	66.7
Solids, Suspended at 105 C	111	111	8.9	9.6	21.5	21.2	9.9	11.6	54.9	75.9	74.2	195	29.8	34.1	17.6	55	89.8	26.2	18.8	47.3	77.8

Table 44 SZ3 water chemistry results for environmental parameters, units are in mg/l, except pH, which is in pH units

Table 45 Sizewell C intake/outfall water chemistry results for environmental parameters, units are in mg/l, except pH, which is in pH units

Analyte	*Apr-14*	*May-14*	*Jun-14*	*Jul-14*	*Aug-14*	*Sep-14*	*Oct-14*	*Nov-14*	*Dec-14*	*Jan-15*	*Feb-15*	*Mar-15*	*Apr-15*	*May-15*	*Jun-15*	*Jul-15*	*Aug-15*	*Sep-15*	*Oct-15*	*Nov-15*	*Dec-15*
BOD 5 Day ATU	<2.92	<2.92	1.39	NA	<2.92	1.3	NA	1.5	1.71	NA	<1.00	1.79	1.29	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	1.29	<1.00
Chloride	19100	19100	18900	NA	19200	19000	NA	19200	18800	NA	18800	18200	17900	18400	18600	17300	18200	18400	18200	18300	18700
Carbon, Organic, Dissolved as C {DOC}	0.94	0.94	1.46	NA	1.02	1.46	NA	0.93	1.29	NA	1.07	1.31	1.13	0.86	1.01	0.84	0.68	0.94	1.01	0.9	1.01
Phosphate: Total as P	0.0937	0.0937	<0.02	NA	0.0565	0.115	NA	0.0515	0.0735	NA	0.152	0.129	0.0446	0.0257	<0.02	0.0618	0.0515	0.0955	0.0448	0.0736	0.111
Fluoride	1.16	1.16	1.22	NA	1.49	1.24	NA	1.39	1.21	NA	1.19	1.18	1.26	1.32	1.31	1.24	1.31	1.18	1.22	1.2	1.28
pH	7.97	7.97	8.07	NA	8.1	8.06	NA	7.99	7.86	NA	7.94	7.84	8	8.07	8.03	8.02	8.12	8.03	7.99	8.01	8.07
Bromide	63.8	63.8	64.8	NA	64.3	62.5	NA	63	63.1	NA	62.1	64.3	63.8	65.9	64.5	64.2	64.5	63.3	64.7	67.4	67
Solids, Suspended at 105 C	80	80	4.1	NA	23.2	41	NA	29.1	68	NA	135	137	27.6	22.9	9.7	33.1	36.2	70.7	32	66.4	103

Table 46 Sizewell B outfall water chemistry results for environmental parameters, units are in mg/l, except pH, which is in pH units

Analyte	***Apr-14***	***May-14***	***Jun-14***	***Jul-14***	***Aug-14***	***Sep-14***	***Oct-14***	***Nov-14***	***Dec-14***	***Jan-15***	***Feb-15***	***Mar-15***	***Apr-15***	***May-15***	***Jun-15***	***Jul-15***	***Aug-15***	***Sep-15***	***Oct-15***	***Nov-15***	***Dec-15***
BOD 5 Day ATU	<2.92	<2.92	1.04	1.75	<2.92	2.22	1.86	1.19	1.25	NA	<1.00	1.65	NA	2	<1.00	1.22	1.08	<1.00	NA	1.99	<1.00
Chloride	18600	18600	18800	18500	19100	18700	19100	19300	18700	NA	19000	18600	NA	18400	18500	17400	18200	17600	NA	18100	18100
Carbon, Organic, Dissolved as C {DOC}	1.11	1.11	1.53	1.22	1.2	1.95	1.27	0.86	1.21	NA	0.96	1.19	NA	1.13	1.05	1.04	0.75	0.99	NA	1.04	1.09
Phosphate: Total as P	0.228	0.228	0.0491	<0.02	0.0732	0.0612	0.0365	0.0391	0.0793	NA	0.176	0.164	NA	0.0415	0.0392	0.0935	0.0975	0.0548	NA	0.146	0.115
Fluoride	1.17	1.17	1.13	1.22	1.38	1.23	1.2	1.41	1.21	NA	1.3	1.24	NA	1.14	1.2	1.29	1.26	1.2	NA	1.24	1.32
pH	7.97	7.97	8.08	8.11	8.05	7.98	8.05	8	7.91	NA	7.94	7.88	NA	8.02	8.01	7.98	8.1	8.03	NA	7.93	8.08
Bromide	63.6	63.6	64.8	64.9	64.4	61.8	64.6	63.2	61.5	NA	63.1	63.9	NA	65.5	64.1	63.5	64.5	62.3	NA	66.7	67.4
Solids, Suspended at 105 C	240	240	40.7	10.4	42.9	62.8	22	32.9	94	NA	172	171	NA	36.6	33.7	49.7	91	47.5	NA	146	96.9

6.1.3 Other metals

Analyte	***Apr-14***	***May-14***	***Jun-14***	***Jul-14***	***Aug-14***	***Sep-14***	***Oct-14***	***Nov-14***	***Dec-14***	***Jan-15***	***Feb-15***	***Mar-15***	***Apr-15***	***May-15***	***Jun-15***	***Jul-15***	***Aug-15***	***Sep-15***	***Oct-15***	***Nov-15***	***Dec-15***
Arsenic	3.99	3.99	1.17	1.14	1.73	1.66	1.47	1.49	2.53	2.96	2.92	5.96	1.71	1.59	1.22	2.65	3.07	1.53	1.4	2.48	3.06
Selenium Dissolved	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Selenium	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Aluminium, Dissolved	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	63.8	<40	<40	<40
Cobalt, Dissolved	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Molybdenum, Dissolved	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30
Cobalt	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Molybdenum	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30
Cadmium	<0.03	<0.03	0.03	0.042	0.042	0.03	0.045	0.04	<0.03	0.095	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.091	<0.03	<0.03
Copper	5.79	5.79	1.04	1.65	2.9	2.01	2.07	2.57	1.95	2.44	1.24	2.01	1.57	1.66	1.37	1.37	2.95	2.06	5.98	3.41	2.83
Lead	3.66	3.66	0.846	1.38	1.25	1.02	1.09	0.704	2.49	2.69	2.44	4.34	1.18	0.963	0.597	1.69	2.7	0.965	0.816	1.5	2.19
Nickel	2.15	2.15	0.864	0.707	1.29	1.12	0.796	1.09	1.52	1.69	1.53	2.52	1.17	1.1	0.764	1.59	2.04	1.13	0.982	1.75	2
Zinc	13.4	13.4	3.6	17.4	33.8	9.98	17.8	18.7	13.1	15.4	6.48	12.7	31.7	8.72	6.48	10.4	27.8	12.5	9.73	8.7	15.6

Table 47 SZ3 water chemistry results for other metals 1, units are in µg/l

Analyte	*Unit*	*Apr-14*	*May-14*	*Jun-14*	*Jul-14*	*Aug-14*	*Sep-14*	*Oct-14*	*Nov-14*	*Dec-14*	*Jan-15*	*Feb-15*	*Mar-15*	*Apr-15*	*May-15*	*Jun-15*	*Jul-15*	*Aug-15*	*Sep-15*	*Oct-15*	*Nov-15*	*Dec-15*
Boron, Dissolved	µg/l	4370	4370	4300	4100	4100	4260	4280	4220	4070	4390	4480	4250	4080	4320	4290	4340	4310	4010	4500	3720	4210
Calcium, Dissolved	mg/l	400	400	412	384	391	413	405	398	381	397	431	412	380	401	402	412	398	368	427	372	430
Magnesium, Dissolved	mg/l	1300	1300	1080	1100	1220	1260	1110	1300	1190	1230	1220	1230	1220	1220	1270	1280	1270	1250	1310	1370	1330
Manganese, Dissolved	µg/l	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	22.9	<20	<20	<20	<20	<20	<20	<20
Potassium, Dissolved	mg/l	408	408	357	351	389	414	478	407	369	368	375	397	365	377	386	396	394	370	413	411	425
Sodium, Dissolved	mg/l	10400	10400	9110	9070	9970	10200	8590	10500	9590	9900	9880	10200	9730	9870	10200	10300	10300	10100	10500	11000	11000
Strontium, Dissolved	µg/l	7670	7670	7180	6930	7100	7290	7150	7250	7000	7250	7610	7210	7040	7350	7300	7460	7450	6780	7310	6770	7720
Sulphate, Dissolved as SO4	mg/l	2670	2670	2270	2470	2480	2630	2890	2690	2530	2540	2560	2680	2570	2540	2630	2650	2730	2440	2700	2440	2720
Barium	µg/l	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Boron	µg/l	3730	3730	4370	3980	4140	4150	4130	4510	4000	4540	4000	4240	3950	4450	4320	4380	4810	4240	4350	3770	4150
Calcium	mg/l	368	368	411	375	389	386	388	426	381	421	394	430	377	405	395	413	448	389	403	387	433
Iron	µg/l	2150	2150	226	184	408	582	243	304	1280	1910	1610	4380	641	727	365	2110	2060	513	503	1110	2500

Table 48 SZ3 water chemistry results for other metals 2

Analyte	*Unit*	*Apr-14*	*May-14*	*Jun-14*	*Jul-14*	*Aug-14*	*Sep-14*	*Oct-14*	*Nov-14*	*Dec-14*	*Jan-15*	*Feb-15*	*Mar-15*	*Apr-15*	*May-15*	*Jun-15*	*Jul-15*	*Aug-15*	*Sep-15*	*Oct-15*	*Nov-15*	*Dec-15*
Magnesium	mg/l	1190	1190	1270	1090	1120	1270	1070	1300	1260	1260	1210	1240	1250	1280	1270	1250	1310	1250	1310	1290	1300
Potassium	mg/l	375	375	488	339	351	413	463	397	393	380	367	398	419	392	383	389	412	376	412	398	413
Strontium	µg/l	6380	6380	7250	6800	7100	6850	6940	7750	6840	7640	6870	7270	6780	7470	7230	7310	7220	7160	7370	7150	7830
Mercury	µg/l	0.0219	0.0219	<0.01	<0.01	<0.01	<0.01	0.0116	0.0128	<0.01	<0.01	<0.01	0.0287	0.0162	0.0128	<0.01	0.0187	0.0143	0.063	0.0222	<0.01	0.0864
Chromium	µg/l	3.08	3.08	<0.5	<0.5	0.86	0.87	<0.5	0.9	1.5	2.25	1.91	4.76	0.975	0.84	<0.5	1.51	3.02	0.68	0.64	1.67	2.1

Table 49 SZ3 water chemistry results for other metals 3

Analyte	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
Arsenic	2.86	2.86	1.06	NA	1.67	2.14	NA	2.01	3.11	NA	4.45	4.4	1.89	1.05	1.12	1.97	2.06	2.83	1.67	2.96	3.8
Selenium Dissolved	<1	<1	<1	NA	<1	<1	NA	<1	<1	NA	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Selenium	<1	<1	<1	NA	<1	<1	NA	<1	<1	NA	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Aluminium, Dissolved	<40	<40	<40	NA	<40	<40	NA	<40	<40	NA	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40
Cobalt, Dissolved	<10	<10	<10	NA	<10	<10	NA	<10	<10	NA	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Molybdenum, Dissolved	<30	<30	<30	NA	<30	<30	NA	<30	<30	NA	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30
Cobalt	<10	<10	<10	NA	<10	<10	NA	<10	<10	NA	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Molybdenum	<30	<30	<30	NA	<30	<30	NA	<30	<30	NA	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30
Cadmium	<0.03	<0.03	0.121	NA	<0.03	0.055	NA	0.039	0.032	NA	<0.03	0.059	0.065	<0.03	0.061	<0.03	<0.03	<0.03	0.102	0.031	<0.03
Copper	2.83	2.83	2.5	NA	2.52	2.74	NA	4.02	2.33	NA	1.53	2.68	2.21	1.48	2.48	1.32	2.04	2.35	5.76	4.23	2.13
Lead	2.58	2.58	0.734	NA	1.24	1.64	NA	1.67	3.35	NA	3.36	3.36	1.39	0.718	0.554	1.14	1.23	2.64	1.36	2.13	2.63
Nickel	1.75	1.75	0.798	NA	1.11	1.57	NA	1.57	1.86	NA	2.05	2.31	1.94	0.999	1.46	1.15	1.34	1.82	1.21	1.97	2.14
Zinc	10.9	10.9	11.9	NA	13.6	20.8	NA	20.8	61.2	NA	8.63	21.6	12	26.5	13.1	7.64	14.4	32.7	22.7	22.3	14.5

Table 50 Sizewell C intake/outfall water chemistry results for other metals 1, units are in µg/l

Analyte	***Unit***	***Apr-14***	***May-14***	***Jun-14***	***Jul-14***	***Aug-14***	***Sep-14***	***Oct-14***	***Nov-14***	***Dec-14***	***Jan-15***	***Feb-15***	***Mar-15***	***Apr-15***	***May-15***	***Jun-15***	***Jul-15***	***Aug-15***	***Sep-15***	***Oct-15***	***Nov-15***	***Dec-15***
Boron, Dissolved	µg/l	3980	3980	4280	NA	3990	4050	NA	4210	4160	NA	4580	4420	3890	4270	4320	4370	4330	4250	4550	3680	4170
Calcium, Dissolved	mg/l	386	386	418	NA	389	396	NA	388	383	NA	437	418	365	402	403	414	392	383	431	370	426
Magnesium, Dissolved	mg/l	1290	1290	1110	NA	1220	1300	NA	1230	1230	NA	1260	1240	1190	1250	1260	1250	1270	1280	1290	1320	1330
Manganese, Dissolved	µg/l	<20	<20	<20	NA	<20	<20	NA	<20	<20	NA	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Potassium, Dissolved	mg/l	416	416	366	NA	395	430	NA	375	382	NA	389	396	357	389	385	385	395	382	403	405	426
Sodium, Dissolved	mg/l	10300	10300	9430	NA	9880	10500	NA	9880	9990	NA	10200	10200	9560	10200	10100	10200	10400	10400	10300	10700	11000
Strontium, Dissolved	µg/l	6960	6960	7310	NA	7050	6970	NA	7090	7000	NA	7740	7320	6780	7360	7290	7460	7330	7030	7420	6760	7640
Sulphate, Dissolved as SO4	mg/l	2580	2580	2270	NA	2520	2480	NA	2570	2550	NA	2600	2610	2480	2610	2630	2600	2640	2440	2620	2460	2730
Barium	µg/l	<100	<100	<100	NA	<100	<100	NA	<100	<100	NA	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Boron	µg/l	3890	3890	4340	NA	4200	4210	NA	4950	4100	NA	4180	4180	4020	4410	4240	4590	4910	4210	4530	3890	4170
Calcium	mg/l	374	374	415	NA	388	394	NA	470	395	NA	414	413	383	406	396	426	455	389	415	393	437
Iron	µg/l	1450	1450	185	NA	517	1180	NA	905	1910	NA	3300	2570	721	554	188	1380	1060	1960	984	1560	2930

Table 51 Sizewell C intake/outfall water chemistry results for other metals 2

Analyte	***Unit***	***Apr-14***	***May-14***	***Jun-14***	***Jul-14***	***Aug-14***	***Sep-14***	***Oct-14***	***Nov-14***	***Dec-14***	***Jan-15***	***Feb-15***	***Mar-15***	***Apr-15***	***May-15***	***Jun-15***	***Jul-15***	***Aug-15***	***Sep-15***	***Oct-15***	***Nov-15***	***Dec-15***
Magnesium	mg/l	1250	1250	1310	NA	1040	1290	NA	1240	1290	NA	1240	1230	1270	1260	1310	1290	1290	1220	1320	1260	1290
Potassium	mg/l	385	385	497	NA	321	414	NA	385	395	NA	389	396	445	383	393	394	401	372	417	401	406
Strontium	µg/l	6560	6560	7320	NA	7110	6950	NA	8550	7110	NA	7150	7030	6870	7530	7220	7540	7510	7130	7600	7260	7880
Mercury	µg/l	<0.01	<0.01	0.0131	NA	<0.01	<0.01	NA	0.013	<0.01	NA	0.0157	0.021	<0.01	0.0139	<0.01	<0.01	<0.01	0.0129	0.064	0.0161	0.0422
Chromium	µg/l	1.97	1.97	<0.5	NA	<0.5	1.74	NA	1.09	2.26	NA	3.18	5.37	1.35	1.34	<0.5	0.799	1.07	2.41	1.01	1.89	2.94

Table 52 Sizewell C intake/outfall water chemistry results for other metals 3

Analyte	***Apr-14***	***May-14***	***Jun-14***	***Jul-14***	***Aug-14***	***Sep-14***	***Oct-14***	***Nov-14***	***Dec-14***	***Jan-15***	***Feb-15***	***Mar-15***	***Apr-15***	***May-15***	***Jun-15***	***Jul-15***	***Aug-15***	***Sep-15***	***Oct-15***	***Nov-15***	***Dec-15***
Arsenic	6.66	6.66	2.04	<1	2.09	2.69	1.38	2.2	3.58	NA	5.15	5.37	NA	1.82	1.73	2.49	3.4	2.18	NA	4.71	3.58
Selenium Dissolved	<1	<1	<1	<1	<1	<1	<1	<1	<1	NA	<1	<1	NA	<1	<1	<1	<1	<1	NA	<1	<1
Selenium	<1	<1	<1	<1	<1	<1	<1	<1	<1	NA	<1	<1	NA	<1	<1	<1	<1	<1	NA	<1	<1
Aluminium, Dissolved	<40	<40	<40	<40	<40	<40	<40	<40	<40	NA	<40	<40	NA	<40	<40	<40	<40	48.6	NA	<40	<40
Cobalt, Dissolved	<10	<10	<10	<10	<10	<10	<10	<10	<10	NA	<10	<10	NA	<10	<10	<10	<10	<10	NA	<10	<10
Molybdenum, Dissolved	<30	<30	<30	<30	<30	<30	<30	<30	<30	NA	<30	<30	NA	<30	<30	<30	<30	<30	NA	<30	33.8
Cobalt	<10	<10	<10	<10	<10	<10	<10	<10	<10	NA	<10	<10	NA	<10	<10	<10	<10	<10	NA	<10	<10
Molybdenum	<30	<30	<30	<30	<30	<30	<30	<30	<30	NA	<30	<30	NA	<30	<30	<30	<30	<30	NA	<30	<30
Cadmium	<0.06	<0.06	0.081	0.387	0.046	0.17	0.036	0.047	0.036	NA	<0.03	<0.03	NA	0.085	0.051	<0.03	0.03	<0.03	NA	0.111	<0.03
Copper	3.87	3.87	1.28	2.16	1.76	8.27	2.49	3.55	1.85	NA	1.59	2.98	NA	3.63	12.4	2.35	2.32	2.02	NA	7.7	2.1
Lead	7.21	7.21	1.4	1.46	1.96	3.31	1.08	1.61	3.32	NA	3.97	3.92	NA	1.5	1.72	1.75	2.42	1.83	NA	3.5	2.59
Nickel	3.82	3.82	1.21	0.764	1.48	2.22	1.04	1.54	1.79	NA	2.27	2.8	NA	1.69	3.28	1.6	1.82	1.39	NA	3.23	2.21
Zinc	39	39	6.57	22.9	20.3	61.4	15.1	21.1	21.6	NA	9.09	23.2	NA	48.2	32.1	20.4	13.8	19	NA	42.1	11.3

Table 53 Sizewell B outfall water chemistry results for other metals 1, units are in µg/l

Analyte	Unit	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15
Boron, Dissolved	µg/l	4180	4180	4070	4220	4090	4320	4340	4170	4220	NA	4450	4170	NA	4430	4160	4360	4430	4170	NA	3790	4150
Calcium, Dissolved	mg/l	396	396	394	396	395	416	405	388	391	NA	439	407	NA	406	399	406	402	380	NA	382	427
Magnesium, Dissolved	mg/l	1280	1280	1060	1110	1200	1400	1140	1200	1230	NA	1200	1210	NA	1250	1270	1280	1260	1260	NA	1330	1320
Manganese, Dissolved	µg/l	<20	<20	<20	<20	<20	<20	<20	<20	<20	NA	<20	<20	NA	27.2	<20	<20	<20	<20	NA	20.5	<20
Potassium, Dissolved	mg/l	410	410	349	352	383	460	426	369	378	NA	378	386	NA	394	393	392	386	373	NA	406	416
Sodium, Dissolved	mg/l	10300	10300	9000	9130	9720	11300	9010	9600	9970	NA	9750	10000	NA	10300	10200	10400	10200	10200	NA	10800	10900
Strontium, Dissolved	µg/l	7280	7280	6900	7150	7140	7310	7180	7080	7160	NA	7780	7170	NA	7390	7220	7310	7490	6990	NA	6960	7620
Sulphate, Dissolved as SO4	mg/l	2650	2650	2290	2310	2420	2950	2970	2400	2550	NA	2520	2620	NA	2620	2630	2650	2680	2460	NA	2480	2760
Barium	µg/l	<100	<100	<100	<100	<100	<100	<100	<100	<100	NA	<100	<100	NA	<100	<100	<100	<100	<100	NA	<100	<100
Boron	µg/l	3970	3970	4340	3990	4210	4250	4140	4460	4220	NA	3920	4140	NA	4340	4180	4510	4840	4320	NA	3910	4070
Calcium	mg/l	398	398	414	380	387	404	392	419	406	NA	397	421	NA	402	391	419	453	397	NA	400	428
Iron	µg/l	4450	4450	796	266	977	1670	567	865	2350	NA	3500	3400	NA	946	751	2020	2450	961	NA	2910	2900

Table 54 Sizewell B outfall water chemistry results for other metals 2

Analyte	*Unit*	*Apr-14*	*May-14*	*Jun-14*	*Jul-14*	*Aug-14*	*Sep-14*	*Oct-14*	*Nov-14*	*Dec-14*	*Jan-15*	*Feb-15*	*Mar-15*	*Apr-15*	*May-15*	*Jun-15*	*Jul-15*	*Aug-15*	*Sep-15*	*Oct-15*	*Nov-15*	*Dec-15*
Magnesium	mg/l	1190	1190	1320	1120	1090	1320	1110	1170	1220	NA	1210	1230	NA	1270	1290	1290	1320	1250	NA	1300	1260
Potassium	mg/l	371	371	403	352	340	420	409	369	378	NA	371	394	NA	392	388	391	413	379	NA	411	393
Strontium	µg/l	6810	6810	7260	6870	7080	7120	7010	7630	7230	NA	6830	7180	NA	7460	7130	7400	7280	7340	NA	7300	7680
Mercury	µg/l	0.0339	0.0339	0.0136	<0.01	<0.01	0.0149	0.0102	<0.01	0.0148	NA	0.0121	0.0318	NA	0.0367	0.0131	0.0624	<0.01	<0.01	NA	0.0341	0.877
Chromium	µg/l	5.16	5.16	1.15	0.55	1.28	2.61	<0.5	1.06	2.25	NA	4.61	5.36	NA	1.32	2.63	1.37	2.21	1.25	NA	3.54	2.75

Table 55 Sizewell B outfall water chemistry results for other metals 3

7 Appendix C

7.1 Nutrient chemistry

Table 56 Nutrient concentrations Sizewell B Intake, March – June 2014

Survey	***Sample Date***	**NH_4-N µg l^{-1}**	**NH_4 µmol**	**DIN-N µg l^{-1}**	**DIN-N µmol**	**PO_4-P µg l^{-1}**	**PO_4-P µmol**	**N:P ratio**
SIZE01/14	13/03/2014	-	<0.1	468	33	71	2.3	15
SIZE01/14	13/03/2014	-	<0.1	441	32	61	2.0	16
SIZE01/14	13/03/2014	-	<0.1	441	32	121	3.9	8
SIZE02/14	09/04/2014	-	<0.1	367	26	33	1.1	24
SIZE02/14	09/04/2014	-	<0.1	358	26	110	3.5	7
SIZE02/14	09/04/2014	-	<0.1	379	27	27	0.9	31
SIZE03/14	13/05/2014	-	<0.1	349	25	19	0.6	42
SIZE03/14	13/05/2014	2.80	0.2	322	23	19	0.6	37
SIZE03/14	13/05/2014	-	<0.1	287	21	17	0.6	37
SIZE04/14	08/06/2014	19.60	1.4	213	15	1	0.0	-
SIZE04/14	08/06/2014	4.20	0.3	190	14	6	0.2	68
SIZE04/14	08/06/2014	-	<0.1	179	13	9	0.3	46

Table 57 Nutrient concentrations Sizewell B Intake July 2014 to December 2014 with additional data from February 2015. Shaded cells are those considered to represent winter values used to make various nutrients assessments

Survey	***Sample Date***	**NH_4-N $\mu g\ l^{-1}$**	**NH_4 µmol**	**DIN-N $\mu g\ l^{-1}$**	**DIN-N µmol**	**PO_4-P $\mu g\ l^{-1}$**	**PO_4-P µmol**	**N:P ratio**
SIZE05/14	07/07/2014	9.80	0.7	57	4	42	1.4	3
SIZE05/14	07/07/2014	2.80	0.2	29	2	210	6.8	0
SIZE06/14	05/08/2014	51.80	3.7	106	8	30	1.0	8
SIZE06/14	05/08/2014	25.20	1.8	81	6	79	2.5	2
SIZE06/14	05/08/2014	16.80	1.2	78	6	13	0.4	13
SIZE07/14	04/09/2014	5.60	0.4	116	8	19	0.6	14
SIZE07/14	04/09/2014	1.40	0.1	120	9	17	0.6	15
SIZE07/14	04/09/2014	4.20	0.3	118	8	17	0.6	15
SIZE09/14	03/10/2014	11.20	0.8	91	7	18	0.6	11
SIZE09/14	03/10/2014	7.00	0.5	71	5	13	0.4	12
SIZE09/14	03/10/2014	7.00	0.5	76	5	13	0.4	13
SIZE10/14	04/11/2014	16.80	1.2	200	14	22	0.7	20
SIZE10/14	04/11/2014	12.60	0.9	213	15	19	0.6	25
SIZE10/14	04/11/2014	12.60	0.9	217	16	22	0.7	22
SIZE11/14	05/12/2014	15.40	1.1	337	24	24	0.8	31
SIZE11/14	05/12/2014	14.00	1.0	358	26	26	0.9	30
SIZE11/14	05/12/2014	15.40	1.1	339	24	26	0.9	28
SIZE02/15	04/02/2015	14.00	1.0	419	30	28	0.9	33

Table 58 Nutrient concentrations Sizewell B Outfall, March – June 2014

Survey	***Sample Date***	**NH_4-N µg l^{-1}**	**NH_4 µmol**	**DIN-N µg l^{-1}**	**DIN-N µmol**	**PO_4-P µg l^{-1}**	**PO_4-P µmol**	**N:P ratio**
SIZE01/14	13/03/2014	<0.1	-	463	33	99	3.2	10
SIZE01/14	13/03/2014	<0.1	-	462	33	60	2.0	17
SIZE01/14	13/03/2014	<0.1	-	462	33	56	1.8	18
SIZE01/14	13/03/2014	<0.1	-	427	31	71	2.3	13
SIZE02/14	09/04/2014	<0.1	-	385	28	28	0.9	31
SIZE02/14	09/04/2014	<0.1	-	357	26	27	0.9	29
SIZE02/14	09/04/2014	<0.1	-	357	26	25	0.8	31
SIZE03/14	13/05/2014	<0.1	-	316	23	23	0.7	31
SIZE03/14	13/05/2014	<0.1	-	312	22	21	0.7	33
SIZE03/14	13/05/2014	0.3	4.20	287	21	20	0.6	32
SIZE04/14	08/06/2014	1.2	16.80	211	15	4	0.1	126
SIZE04/14	08/06/2014	0.1	1.40	188	13	11	0.3	39
SIZE04/14	08/06/2014	0.1	1.40	182	13	10	0.3	39

Table 60 Nutrient concentrations Sizewell B Outfall, July 2014 – December 2014, and including data from February 2015–shaded cells are those considered to represent winter values used to make various nutrients assessments

Survey	***Sample Date***	**NH_4-N µg l^{-1}**	**NH_4 µmol**	**DIN-N µg l^{-1}**	**DIN-N µmol**	**PO_4-P µg l^{-1}**	**PO_4-P µmol**	**N:P ratio**
SIZE05/14	07/07/2014	5.60	0.4	64	5	64	2.1	2
SIZE05/14	07/07/2014	8.40	0.6	43	3	36	1.2	3
SIZE05/14	07/07/2014	2.80	0.2	42	3	4	0.1	25
SIZE06/14	05/08/2014	23.80	1.7	85	6	44	1.4	4
SIZE06/14	05/08/2014	28.00	2.0	88	6	39	1.3	5
SIZE06/14	05/08/2014	26.60	1.9	92	7	17	0.6	12
SIZE07/14	04/09/2014	25.20	1.8	134	10	21	0.7	14
SIZE07/14	04/09/2014	4.20	0.3	130	9	21	0.7	13
SIZE07/14	04/09/2014	18.20	1.3	134	10	20	0.7	15
SIZE09/14	03/10/2014	8.40	0.6	94	7	16	0.5	13
SIZE09/14	03/10/2014	12.60	0.9	95	7	14	0.5	15
SIZE09/14	03/10/2014	15.40	1.1	90	6	17	0.6	11
SIZE10/14	04/11/2014	5.60	0.4	190	14	25	0.8	17
SIZE10/14	04/11/2014	12.60	0.9	218	16	23	0.7	21
SIZE10/14	04/11/2014	11.20	0.8	217	16	23	0.7	21
SIZE11/14	05/12/2014	18.20	1.3	364	26	26	0.8	31
SIZE11/14	05/12/2014	14.00	1.0	363	26	26	0.9	30
SIZE11/14	05/12/2014	16.80	1.2	340	24	27	0.9	28
SIZE02/15	04/02/2015	4.20	0.3	409	29	27	0.9	33

Table 61 Nutrient concentrations Sizewell C Intake/Outfall, March – June 2014

Survey	***Sample Date***	**NH_4-N** **µg l^{-1}**	**NH_4** **µmol**	**DIN-N** **µg l^{-1}**	**DIN-N** **µmol**	**PO_4-P** **µg l^{-1}**	**PO_4-P** **µmol**	**N:P ratio**
SIZE01/14	13/03/2014	<0.1	-	447	32	46	1.5	22
SIZE01/14	13/03/2014	<0.1	-	440	31	42	1.4	23
SIZE02/14	09/04/2014	<0.1	-	349	25	29	0.9	27
SIZE02/14	09/04/2014	<0.1	-	346	25	38	1.2	20
SIZE02/14	09/04/2014	<0.1	-	364	26	26	0.8	31
SIZE03/14	13/05/2014	<0.1	-	280	20	20	0.6	32
SIZE03/14	13/05/2014	<0.1	-	307	22	20	0.7	33
SIZE03/14	13/05/2014	<0.1	-	307	22	18	0.6	37
SIZE04/14	08/06/2014	0.4	5.60	199	14	-	-	
SIZE04/14	08/06/2014	2.5	35.00	227	16	4	0.1	116
SIZE04/14	08/06/2014	0.8	11.20	192	14	8	0.3	51

Table 62 Nutrient concentrations Sizewell B Outfall, July 2014 – December 2014, and including data from February 2015–shaded cells are those considered to represent winter values used to make various nutrients assessments

Survey	***Sample Date***	**NH_4-N** **µg l^{-1}**	**NH_4** **µmol**	**DIN-N** **µg l^{-1}**	**DIN-N** **µmol**	**PO_4-P** **µg l^{-1}**	**PO_4-P** **µmol**	**N:P ratio**
SIZE05/14	07/07/2014	18.20	1.3	53	4	37	1.2	3
SIZE05/14	07/07/2014	8.40	0.6	34	2	33	1.1	2
SIZE06/14	05/08/2014	23.80	1.7	77	6	116	3.7	1
SIZE06/14	05/08/2014	22.40	1.6	76	5	13	0.4	13
SIZE06/14	05/08/2014	19.60	1.4	70	5	12	0.4	13
SIZE07/14	04/09/2014	2.80	0.2	120	9	33	1.1	8
SIZE07/14	04/09/2014		<0.1	116	8	18	0.6	15
SIZE07/14	04/09/2014		<0.1	113	8	17	0.6	15
SIZE09/14	03/10/2014	11.20	0.8	87	6	17	0.5	11
SIZE09/14	03/10/2014	11.20	0.8	78	6	12	0.4	15
SIZE09/14	03/10/2014	7.00	0.5	63	5	11	0.4	13
SIZE10/14	04/11/2014	4.20	0.3	183	13	24	0.8	17
SIZE10/14	04/11/2014	2.80	0.2	183	13	22	0.7	18
SIZE10/14	04/11/2014	21.00	1.5	185	13	23	0.7	18
SIZE11/14	05/12/2014	22.40	1.6	337	24	26	0.9	28
SIZE11/14	05/12/2014	15.40	1.1	316	23	25	0.8	28
SIZE11/14	05/12/2014	5.60	0.4	312	22	25	0.8	28
SIZE02/15	04/02/2015	7.00	0.5	399	29	26	0.9	34

Table 63 Nutrient concentrations SZ3 site, March – June 2014

Survey	***Sample Date***	**NH_4-N** **µg l^{-1}**	**NH_4** **µmol**	**DIN-N** **µg l^{-1}**	**DIN-N** **µmol**	**PO_4-P** **µg l^{-1}**	**PO_4-P** **µmol**	**N:P ratio**
SIZE01/14	13/03/2014	2.80	0.2	483	35	47	1.5	23
SIZE02/14	09/04/2014		<0.1	399	29	32	1.0	28
SIZE03/14	13/05/2014	1.40	0.1	321	23	22	0.7	32
SIZE04/14	08/06/2014	1.40	0.1	183	13	11	0.4	35

Table 64 Nutrient concentrations SZ3 site, July 2014 – December 2014, and including data from February 2015–shaded cells are those considered to represent winter values used to make various nutrients assessments

Survey	***Sample Date***	**NH_4-N µg l^{-1}**	**NH_4 µmol**	**DIN-N µg l^{-1}**	**DIN-N µmol**	**PO_4-P µg l^{-1}**	**PO_4-P µmol**	**N:P ratio**
SIZE05/14	07/07/2014	18.20	1.3	85	6	127	4.1	1
SIZE06/14	05/08/2014	26.60	1.9	109	8	100	3.2	2
SIZE07/14	04/09/2014	7.00	0.5	99	7	18	0.6	12
SIZE07/14	04/09/2014	16.80	1.2	111	8	20	0.6	13
SIZE09/14	03/10/2014	8.40	0.6	95	7	17	0.6	12
SIZE09/14	03/10/2014	5.60	0.4	88	6	15	0.5	13
SIZE10/14	04/11/2014	12.60	0.9	214	15	27	0.9	17
SIZE10/14	04/11/2014	7.00	0.5	206	15	25	0.8	18
SIZE11/14	05/12/2014	16.80	1.2	367	26	189	6.1	4
SIZE11/14	05/12/2014	23.80	1.7	371	27	38	1.2	22
SIZE01/15	08/01/2015	4.20	0.3	298	21	24	0.8	27
SIZE01/15	08/01/2015	11.20	0.8	312	22	25	0.8	28
SIZE02/15	04/02/2015	8.40	0.6	427	31	29	0.9	33

VOLUME 2 APPENDIX 21D

SIZEWELL MARINE SEDIMENT QUALITY.

2019. BEEMS TECHNICAL REPORT TR305.

TR305 Sizewell Marine Sediment Quality Report

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List of Figures and Tables

Tables

Please note that the red line boundary was amended after this document was finalised, therefore figures in this document do not reflect the boundaries in respect of which development consent has been sought in this application. However, amendments to the red line boundary does not have any impact on the findings set out in this document and all other information remains correct.

Figures

Executive summary

EDF Energy is planning to construct a new nuclear power station (new nuclear build, or NNB) to the north of the existing Sizewell B station on the Suffolk coast. The new station, Sizewell C, will be of a once-through design, using water abstracted from, and returned to the local marine environment to cool the condensers. As part of the planning/consent process, EDF is required to undertake an environmental impact assessment (EIA) that will identify and assess all potential impacts of the build and station operation on the local marine ecology. Activities that have the potential to impact on marine communities include activities that will disturb the seabed.

The proposed seabed disturbance activities during the construction and operational phases of the NNB at Sizewell include dredging, piling installation, anchoring of vessels, vessel movements and scour. The proposed approximate total dredge volume from these activities are set out in BEEMS Technical Report TR311.

Sediments act as a net sink for anthropogenic contaminants in marine ecosystems and contaminated sediments may have a range of toxicological effects on benthic fauna and associated species (Roberts, 2012). There are no statutory thresholds available in order to assess the quality of marine sediment in the UK, however the levels of contamination in dredged sediment are assessed against Cefas Action Levels in order to help reduce any impacts (OSPAR, 2010). The Canadian Sediment Quality Guidelines (ISQGs), although not specific to the UK are commonly used to assess sediment quality.

As part of the Sizewell C 2015 geotechnical survey (Fugro, 2015), samples were taken from 14 vibrocores and were analysed for organic chemical and heavy metal contaminants; 5 of those cores were also sampled for radionuclide composition. Sediment samples were analysed by various laboratories (methods and analytical methods described) for the following contaminants:

- Heavy metals and insecticides – Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), Zinc (Zn), DDT and Dieldrin.
- Organotin and Particle size – Monobutyl-tin (MBT), Dibutyl-tin (DBT), Tributyl-tin (TBT) and Particle Size Analysis (PSA).
- Organic and chlorinated compounds – Polyaromatic Hydrocarbons (PAHs), Total Hydrocarbon Content (THC) and Polychlorinated biphenyls (PCBs).
- Radionuclides.

The results from the sediment quality data analysis, show that the material is acceptable for disposal to sea based on the Cefas Action Levels for each determinand. The results also show based on the Canadian ISQGs that there are areas where the sediment is in the probable effect range within which adverse effects frequently occur on biota from arsenic (VC 18 at 2.00 – 2.20 m and VC 30 at 5.00 – 5.20 m) and dimethyl naphthalenes (in eleven samples). There are some areas that are in the possible effect range within which adverse effects occasionally occur on biota from various determinands. However, as these levels are not above Cefas Action Level 2 and the SQG is a conservative value, there is not a concern in relation to contamination. The radionuclide results show that radionuclide concentrations in marine sediment at Sizewell are low (with many values below the level of detection) and consistent with routine local radionuclide monitoring (Environment Agency *et al*., 2015). The PSA results show that the majority of the samples (79 %) are comprised mainly of sand (approximately 65 – 99 % sand). The Sizewell results are consistent with the results of the UK National Marine Monitoring Programme (Cefas, 2004), which did not identify any areas off the Suffolk coast that had high levels of contamination.

Therefore, due to the low risk of contaminants being bioavailable, the proposed seabed disturbance activities associated with the construction and operational phases of the NNB at Sizewell are not likely to cause any effects due to the sediment quality.

1 Context

1.1 Purpose of the report

EDF Energy proposes to construct and operate a new nuclear power station (new nuclear build, or NNB) immediately to the north of the existing Sizewell B operational station at Sizewell on the Suffolk coast. Under the Planning Act 2008, this development, as with other nationally-significant infrastructure projects, requires a Development Consent Order (including, in the case of conservation areas, a Habitats Regulations Assessment) to be granted by the UK Government's Planning Inspectorate. The marine aspects of the development will also require regulatory permits for, amongst other activities, activities that disturb the seabed. Decisions on permissions will be taken on the basis of a marine environmental impact assessment (EIA) encompassing the key ecological features of the site and including all marine activities associated with the development.

The potential effects of the Sizewell C development on the marine environment are dependent upon the engineering designs of specific coastal infrastructure. EDF Energy have not finalised the design of this infrastructure; this is particularly the case for the proposed jetty and beach landing facility. This report reflects engineering designs as at **1st August 2015.** The proposed activities that will disturb the seabed associated with the proposed construction and operational phases of the NNB at Sizewell include (BEEMS Technical Report TR311):

Construction Phase

- Dredging – For the operation of the Beach Landing Facility (BLF), the cooling water intake and outfall heads and the Fish Recovery and Return (FRR) head.
- Piling installation – For the BLF.
- Anchoring of vessels – For the BLF, the cooling water intake and outfall heads and the FRR head.
- Vessel movements – For the BLF and cooling water outfall head.

Operational Phase

- Dredging – For the beach landing facility access channel.
- Scour – From the cooling water intake and outfall heads and the FRR head.
- Anchoring of vessels – For the beach landing facility.
- Vessel movements – For the beach landing facility.

The proposed dredge volumes are set out in BEEMS Technical Report TR311:

This report presents the analysis of the marine sediment quality data for sediment samples collected at Sizewell. It describes the contaminant levels present in the sediment with respect to relevant thresholds of concern and the activities that are likely to disturb the seabed in the construction and operation of the NNB at Sizewell.

1.2 Contaminants in Marine Sediment

Chemicals released into the marine environment as a result of human activities can be persistent, toxic to flora and fauna, and can bioaccumulate up the food chain (Entec UK Limited, 2011). Contaminants enter the marine environment from a range of sources.

Heavy metals occur naturally in the marine environment, however human activities such as combustion of fossil fuels, mining, smelting, manufacturing, solid waste combustion, agricultural fertilisers and industrial wastewater disposal, increase the heavy metal concentrations in marine sediment. Heavy metals bioaccumulate in marine organisms and cause physiological effects and histopathological effects on the kidney, respiratory and other tissues, cancer development and reproductive failure.

Organotins are man-made organic substances used as pesticides and biocides in marine antifouling paints and in wood preservatives and they are not very soluble in water. Releases of organotin compounds to the environment occur primarily by gradual leaching from antifouling paints, wood preservatives and potentially from their manufacture, transport and storage. Tributyltin compounds are highly toxic to many species of aquatic organisms such as mussels, clams, and oysters, and at low levels, may cause structural changes, growth retardation, and mortality.

Polyaromatic hydrocarbons (PAHs) can be classed as naturally occurring or man-made chemicals. PAHs are formed when certain fuels and wastes are incompletely burnt. They are often absorbed onto particles of soot emitted from combustion sources. The majority of PAHs are released by combustion processes, evaporation from treated materials, wash off from bitumen roads etc. Some PAHs are known to cause cancer, birth defects and genetic mutations in animals.

Polychlorinated biphenyls (PCBs) are man-made compounds used in electrical applications they are long-lasting in the environment, accumulate in the food chain and are classed as persistent organic pollutants (POPs). There are no natural sources of PCBs. Sources include disposal of waste products containing PCBs and emissions from industrial processes and power stations, iron and steel and sewage sludge applications to land. PCBs are toxic to fish and other aquatic organisms causing reproductive and developmental problems.

DDT (dichlorodiphenyltrichloroethane) and Dieldrin (an organochloride) are both insecticides, found in agricultural runoff, which can be taken up by aquatic organisms and adsorbed on suspended particles. Both substances are toxic to aquatic organisms. DDT can cause cancer and further up the food chain, egg-shell thinning in birds (Vos *et al.* 2000). Dieldrin can cause endocrine disruption in fish, seabirds and marine mammals. DDT’s breakdown products and metabolites, DDE and DDD, are also highly persistent and have similar chemical and physical properties (Harris *et al.* 2002).

Radionuclides may enter the marine environment through several pathways;

- direct discharge of liquid effluent;
- atmospheric deposition;
- riverine discharges; and
- leachate from solid waste disposal.

Some radionuclides will behave conservatively and stay in the water in soluble form, whereas others will be insoluble or adhere to particles and thus, sooner or later, be transferred to marine sediments (IAEA, 2005). Radionuclides can cause reproductive failure and mutations in aquatic organisms.

Sediments act as a net sink for anthropogenic contaminants in marine ecosystems and contaminated sediments may have a range of toxicological effects on benthic fauna and associated species (Roberts, 2012). This applies particularly to fine grained bottom sediments which tend to accumulate contaminants due to their sorptive nature (Grimwood & McGhee, 1979). Resuspension and mixing of sediments from bioturbation, the action of currents or human disturbance alter metal sediment–water partitioning and metal speciation in the dissolved phase, i.e., pore waters and overlying waters (Riedel *et al.* 1997; Kristensen, 2000; Simpson *et al.* 2002). The fate (speciation) of metals either already in the water column or following release from sediments is affected by overlying water conditions, in particular the pH, salinity, dissolved oxygen concentration and amount of suspended solids and dissolved organic carbon content (Eggleton & Thomas, 2004).

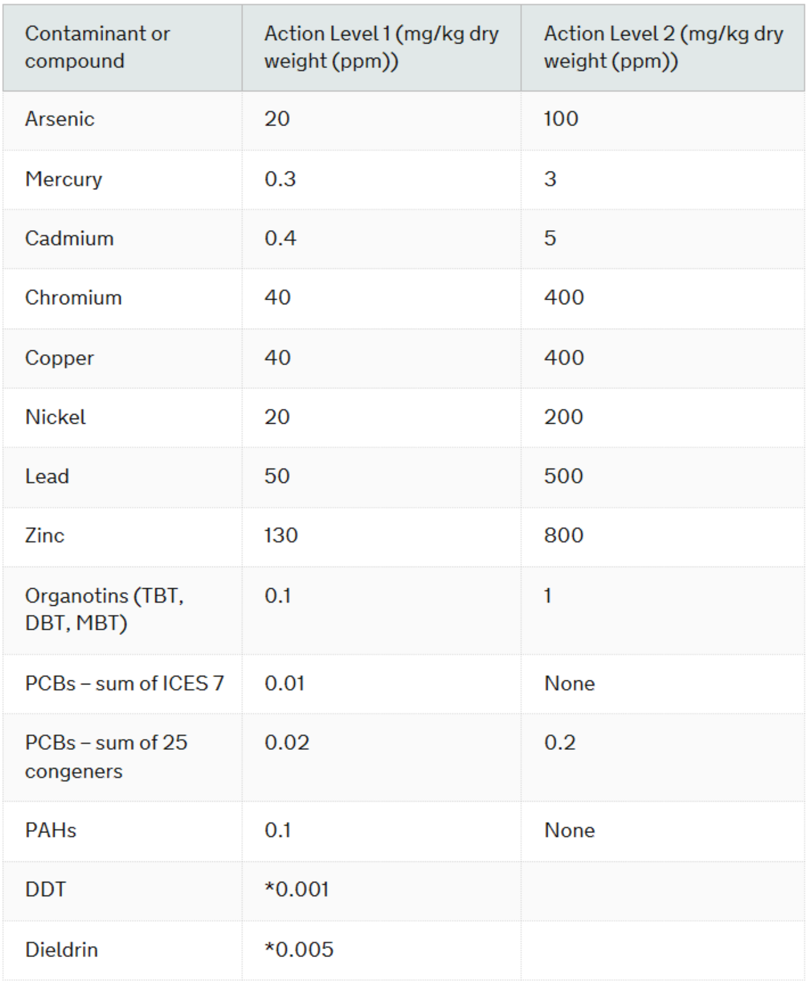
2 Assessment of Contamination in Marine Sediments

2.1 Cefas Action Levels

There are no statutory thresholds to assess the quality of marine sediment in the UK. However, there are upper threshold limits of sediment which are acceptable for disposal to sea. These contaminant disposal limits are regulated in England by the Marine Management Organisation under the Marine and Coastal Access Act 2009[1]. The aim of these limits is to prevent accumulation of high levels of contamination in offshore sediments and to avoid direct toxic effects on marine flora and fauna.

Levels of contamination in dredged sediment are assessed against Cefas Action Levels in order to help reduce any impacts (OSPAR, 2010). Cefas Action Levels are used as part of a ‘weight of evidence’ approach to assessing dredged material and its suitability for disposal to sea. These values are used in conjunction with a range of other assessment methods e.g. bioassays, as well as historical data and knowledge regarding the dredging site, the material's physical characteristics, the disposal site characteristics and other relevant data, to make management decisions regarding the fate of dredged material. The Cefas Action Level limits for contaminants are shown in Table 1, these were set in 1994.

Table 1 – Cefas Action Levels in sediments (MMO, 2015a)



Contaminant or compound	Action Level 1 (mg/kg dry weight (ppm))	Action Level 2 (mg/kg dry weight (ppm))
Arsenic	20	100
Mercury	0.3	3
Cadmium	0.4	5
Chromium	40	400
Copper	40	400
Nickel	20	200
Lead	50	500
Zinc	130	800
Organotins (TBT, DBT, MBT)	0.1	1
PCBs – sum of ICES 7	0.01	None
PCBs – sum of 25 congeners	0.02	0.2
PAHs	0.1	None
DDT	*0.001	
Dieldrin	*0.005	

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[1] Available from: http://www.legislation.gov.uk/ukpga/2009/23/contents

- Below Cefas Action Level 1 limit - In general, contaminant levels in dredged material below Cefas Action Level 1 are of no concern and are unlikely to influence the licensing decision.
- Between Cefas Action Level 1 and Cefas Action Level 2 limits - Dredged material with contaminant levels between Cefas Action Levels 1 and 2 requires further consideration and testing (where appropriate) before a decision can be made.
- Above Cefas Action Level 2 limit - Dredged material with contaminant levels above Cefas Action Level 2 is generally considered unsuitable for sea disposal.

The MMO commissioned a high level review of current Action Level guidance applied by the MMO to the licensing of the disposal of dredged material to sea (MMO, 2015b). The report recommended that the UK approach to action levels would benefit from a further, more detailed review of the action levels and guidance to establish whether they are fit for purpose given current policy and regulatory requirements. However, there are no current studies or reviews into the existing Action Levels and guidance.

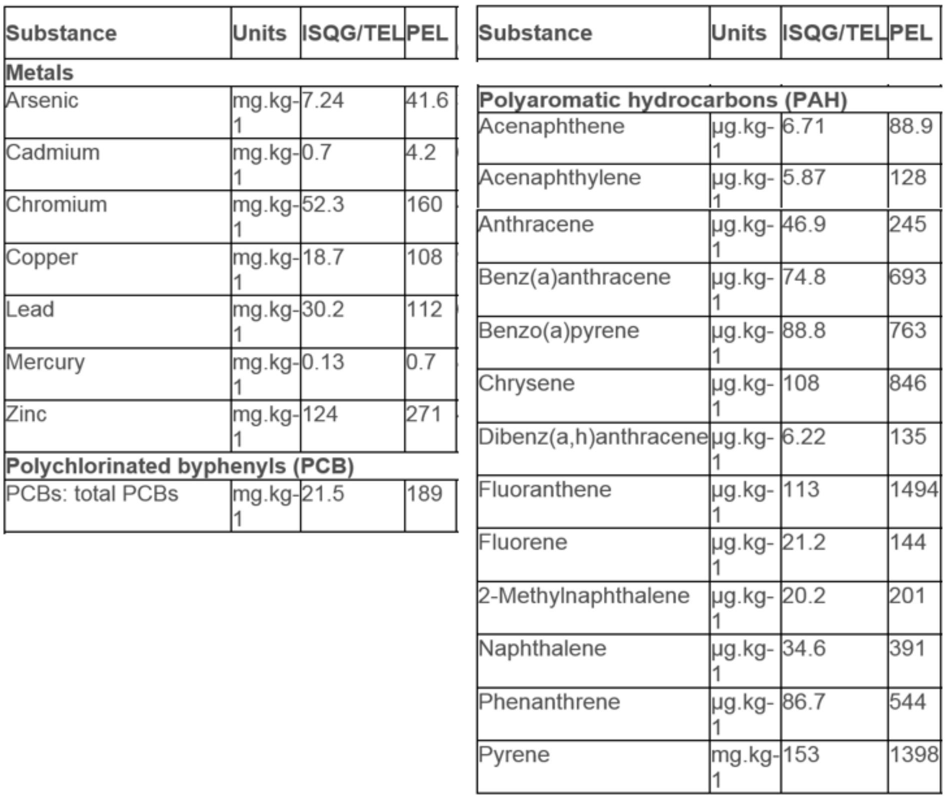
2.2 Canadian Sediment Quality Guidelines

The Interim Canadian Sediment Quality Guidelines (ISQGs), although not specific to the UK are commonly used to assess sediment quality. The guidelines were developed by the Canadian Council of Ministers of the Environment as broadly protective tools to support the functioning of healthy aquatic ecosystems (CCME, 2001). They are based on field research programmes that have demonstrated associations between chemicals and biological effects by establishing cause and effect relationships in particular organisms.

The guidelines consist of threshold effect levels (TELs) and probable effect levels (PELs), these are shown in Table 2. The TELs and PELs are used to identify the following three ranges of chemical concentrations with regard to biological effects:

- Below TEL - Minimal effect range within which adverse effects rarely occur.
- Between TEL and PEL - Possible effect range within which adverse effects occasionally occur.
- Above PEL - Probable effect range within which adverse effects frequently occur.

Table 2 – Canadian Sediment Quality Guidelines (CCME, 2001)



Substance	Units	ISQG/TEL	PEL
Metals			
Arsenic	mg.kg-1	7.24	41.6
Cadmium	mg.kg-1	0.7	4.2
Chromium	mg.kg-1	52.3	160
Copper	mg.kg-1	18.7	108
Lead	mg.kg-1	30.2	112
Mercury	mg.kg-1	0.13	0.7
Zinc	mg.kg-1	124	271
Polychlorinated byphenyls (PCB)			
PCBs: total PCBs	mg.kg-1	21.5	189
Polyaromatic hydrocarbons (PAH)			
Acenaphthene	µg.kg-1	6.71	88.9
Acenaphthylene	µg.kg-1	5.87	128
Anthracene	µg.kg-1	46.9	245
Benz(a)anthracene	µg.kg-1	74.8	693
Benzo(a)pyrene	µg.kg-1	88.8	763
Chrysene	µg.kg-1	108	846
Dibenz(a,h)anthracene	µg.kg-1	6.22	135
Fluoranthene	µg.kg-1	113	1494
Fluorene	µg.kg-1	21.2	144
2-Methylnaphthalene	µg.kg-1	20.2	201
Naphthalene	µg.kg-1	34.6	391
Phenanthrene	µg.kg-1	86.7	544
Pyrene	mg.kg-1	153	1398

2.3 Radionuclide Dose Assessment

The UK government is a signatory to the London Convention (1972)[2] that prohibits the disposal of radioactive material at sea unless it fulfils exemption criteria developed by the International Atomic Energy Agency (IAEA). If both the following radiological criteria are satisfied:

- The effective dose expected to be incurred by any member of the public or ship's crew is of the order of 10 μSv or less in a year.
- The collective effective dose to the public or ship's crew is not more than 1 man Sv per annum

Then the material is deemed to contain *de minimis* levels of radioactivity and may be disposed at sea pursuant to it fulfilling all the other provisions under the Convention. The individual dose criteria are placed in perspective (i.e. very low), given that the average background dose to the UK population is ~2700 μSv/a (Cefas, 2006).

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[2] Available from: http://www.imo.org/en/OurWork/Environment/LCLP/Documents/LC1972.pdf

3 Methods

3.1 Sizewell geotechnical survey

NNB Generation Company Ltd commissioned a survey in 2015 in order to acquire seabed and subseabed data, to provide sediment data relating to the defined site areas intended for construction of the BLF 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 (Fugro, 2015).

As part of the geotechnical survey carried out between 02/02/2015 and 30/04/2015, 30 Vibrocores (VC) were acquired. The VC were carried out using Fugro's High Performance Corer (HPC). The corer has a 6 m barrel and uses a motor to generate optimum excitation frequency and vibration amplitude. Immediately after recovery, the vibrocores were cut into 1 m 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 0.62 m to 6.22 m and an average recovery ratio of 92%. Insufficient water depth prevented cores at the proposed locations VC20 and VC25.

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 1 m 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.

The marine sediment at Sizewell has been characterised with respect to sediment quality in keeping with OSPAR requirements for dredged material of 7 – 15 stations required for dredge volumes of 100,000 – 500,000 m^3 (OSPAR, 1998).

Figure 1 shows the position of vibrocore stations sampled at Sizewell between 24/03/2015 and 28/04/2015. Sediment samples from the vibrocores shown in pink were analysed for the following contaminants between 25/05/2015 and 23/07/2015:

- National Laboratory Service – Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), Zinc (Zn), DDT and Dieldrin.
- FAOL – Monobutyl-tin (MBT), Dibutyl-tin (DBT), Tributyl-tin (TBT) and Particle Size Analysis (PSA).
- Cefas – Polyaromatic Hydrocarbons (PAHs), Total Hydrocarbon Content (THC) and Polychlorinated biphenyls (PCBs).
- Cefas – Radionuclides.

3.2 Analytical methods

The metal analysis method for As, Cd, Cr, Cu, Pb, Ni, and Zn was sediment microwave aqua regia digest, determined by inductively coupled plasma mass spectrometry (ICP-MS). Samples were sieved to 2000 µm. The metal analysis method for Hg was sediment microwave aqua regia digested, acidic SnC_{12} reduced determined by cold vapour atomic fluorescence spectroscopy (CV-AFS). Samples were sieved to 2000 µm.

The organotin analysis method for MBT, DBT and TBT was acidic solvent extraction of the sample followed by analysis by gas chromatography mass spectrometry (GC-MS).

The PAH analysis method was sulphur removal followed by analysis by gas chromatography mass spectrometry (GC-MS). The THC analysis method was solvent extraction followed by analysis by gas chromatography flame ionisation detector (GC-FID). THC includes all dichloromethane extractable hydrocarbons between nC_{10} to nC_{40}.

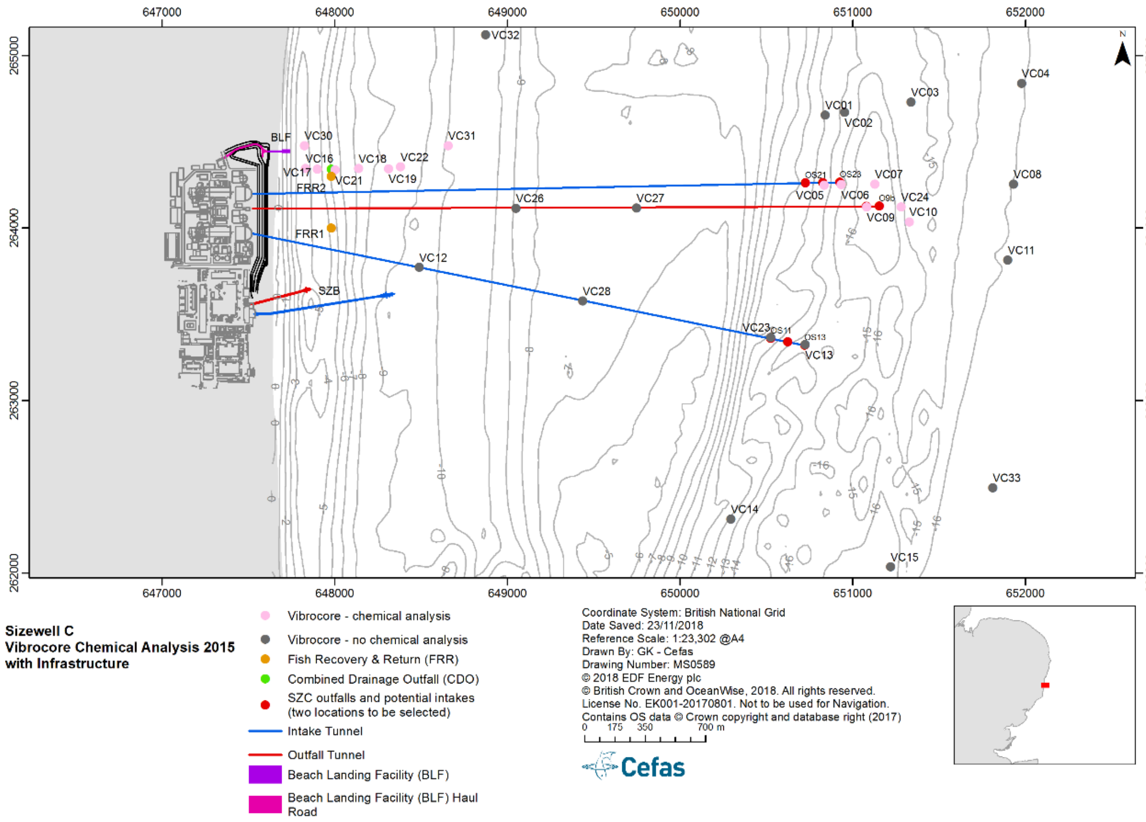

Figure 1 – Position of Sizewell C 2015 vibrocore sampling stations from the geotechnical survey and selected cores from which samples were taken for chemical analysis in relation to Sizewell C infrastructure.

The PCB analysis method was sulphur removal followed by analysis by gas chromatography mass spectrometry (GC-MS). 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 DDT and Dieldrin analysis method was solvent extraction followed by analysis by gas chromatography mass spectrometry (GC-MS).

The PSA analysis method was by dry sieving (63000 – 1000 µm) at 0.5 Phi intervals and laser diffraction (<1000 - <3.91 µm) 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 UKAS accredited.

3.3 Sizewell Marine Water Quality Monitoring

A marine water quality monitoring programme was established off the Suffolk coast in the vicinity of Sizewell B power station from February 2010 to February 2011. A spatial survey was conducted at twelve sampling stations. The sampling was centred upon the existing cooling water outfall for Sizewell B. A tidal-cycle survey was carried out during which water samples were acquired at hourly intervals over an ebb/flood tidal cycle during spring tide conditions. A seasonal survey was also carried out by acquiring water samples near slack water at two stations on 21 occasions throughout the programme. In addition to water sampling a limited program of benthic sediment samples were acquired and chemically analysed. Triplicate benthic samples were acquired from the cooling water outfall and a reference site further offshore. Samples were acquired in June 2010 (BEEMS, TR189).

4 Sizewell Sediment Quality Results

Metal and organotin results

Table 5 in Appendix A, shows the metal and organotin results compared to the Cefas Action Levels for each contaminant. The results show elevated levels above Cefas Action Level 1 for arsenic in six samples, chromium in eight samples and nickel in eight samples. All other determinands were below both Cefas Action Level limits. There are no distinct spatial or depth profile patterns with regard to the samples which contained elevated levels above Cefas Action Level 1 for metals as these samples were found at vibrocore stations across the sampling area both horizontally and vertically.

Table 6 in Appendix A, shows the metal and organotin results compared to the Canadian ISQGs (TELs and PELs) for each contaminant. The results show elevated levels above the TEL for arsenic in twenty five samples and chromium in six samples. The results show elevated levels above the PEL for arsenic in two samples. All other determinands were below both the TEL and PEL limits. The two samples which show elevated levels above the PEL for arsenic are both from inshore vibrocore stations (see Figure 1) at depth (VC 18 at 2.00 – 2.20 m and VC 30 at 5.00 – 5.20 m). There are no distinct spatial or depth profile patterns for the other samples which show elevated levels above the TEL for arsenic and chromium as these samples were found at vibrocore stations across the sampling area both horizontally and vertically.

4.1 Polyaromatic Hydrocarbon (PAH) and Total Hydrocarbon Content (THC) Results

Table 7 in Appendix A, shows the PAH (1-10) and THC results compared to the Cefas Action Levels for each contaminant. Table 8 in Appendix A, shows the PAH (11-22) PAH results compared to Cefas Action Levels for each contaminant. The results show elevated levels above Cefas Action Level 1 for THC in thirteen samples. The results show elevated levels above Cefas Action Level 1 for various PAH determinands in a range of samples. All other determinands were below the Cefas Action Level 1 limit (there is no Cefas Action Level 2 for PAHs). These results are comparable with what is typically found in this area (see Tables 3 and 4, Great Yarmouth). There are no distinct spatial or depth profile patterns with regard to the samples which contained elevated levels above Cefas Action Level 1 for PAHs and THC as these samples were found at vibrocore stations across the sampling area both horizontally and vertically.

Table 9 in Appendix A, shows the PAH (1-10) and THC results compared to the Canadian ISQGs (TELs and PELs) for each contaminant. Table 10 in Appendix A, shows the PAH (11-22) results compared to the Canadian ISQGs (TELs and PELs) for each contaminant. The results show elevated levels above the TEL for various PAH determinands in six samples on average. The results show elevated levels above the PEL for dimethyl naphthalenes in eleven samples. All other determinands were below both the TEL and PEL limits. There are no distinct spatial or depth profile patterns with regard to the samples which show elevated levels above the TEL and PEL for PAHs as these samples were found at vibrocore stations across the sampling area both horizontally and vertically.

Table 3 – Dredgings PAH summary 1998 – 2001 (Kelly *et al.* 2002)

Location	N	C1-N	C2-N	C3-N	Athylene	Athene	Fluorene	P	A	C1-P	Fl
Heysham	426	904	1060	2160	ND	ND	ND	1720	330	1570	2600
Anglesey	410	697	1080	1790	ND	ND	ND	862	325	956	1291
Tees	27100	22100	50200	3930	ND	ND	ND	7530	2430	5030	7500
Great Yarmouth	69	259	287	608	17	24	35	86	89	233	858
Great Yarmouth	932	1410	1670	2970	34	112	89	386	131	731	430
Tilbury	978	2700	8820	9480	15	149	309	1270	329	2330	1450
Sheerness	650	3080	2160	3740	69	116	216	1890	867	2840	4130
Sheerness	92	343	249	402	9.4	33	28	372	158	513	1210
Mersey	1330	1370	1610	1150	85	148	301	942	469	1070	1830
Southampton	135	306	413	459	19	55	36	513	155	521	1360
Cardiff	191	360	463	630	16	67	151	441	129	530	3520
Gosport	40	38	50	150	0.5	20	29	327	39	243	1640
Dover	34	82	203	207	<0.1	13	15	136	35	136	298
Devonport	185	211	259	457	37	44	91	472	249	882	4940
Shoreham	44	82	91	444	<0.1	4.8	56	438	79	654	1110
Milford Haven	93	465	330	312	100	365	209	851	71	292	1030
Solway	198	1500	1710	2830	55	79	139	585	119	1260	620
Humber	621	1820	2130	2610	28	93	181	1080	271	1460	1580
Tyne	2890	13200	13000	28600	150	559	869	4020	669	6120	3620

Table 4 – Dredgings PAH summary 1998 – 2001 (Kelly *et al.* 2002)

Location	Py	BaA	Chrysene	BFs	BeP	BaP	Perylene	I123cdP	BghiP	DahA	ΣPAH	%oil	%combustion
Heysham	2320	837	1130	2060	823	854	224	799	1030	ND	20,800	38	62
Anglesey	1430	565	691	1430	606	667	183	570	735	ND	14,300	41	59
Tees	5530	2930	2350	2620	922	1040	271	324	479	ND	142,000	81	19
Great Yarmouth	683	445	447	1150	362	646	164	308	210	67	7,050	23	77
Great Yarmouth	500	170	145	215	151	118	32	72	68	26	10,400	80	20
Tilbury	1150	598	569	2080	748	738	309	399	309	83	34,800	75	25
Sheerness	3240	1250	2220	2400	963	1370	385	807	632	255	33,300	44	56
Sheerness	1040	782	1000	1530	607	777	225	519	349	171	10,400	20	80
Mersey	877	589	534	1380	607	764	186	603	569	168	16,600	48	52
Southampton	1630	595	619	1860	735	967	401	505	381	116	11,800	21	79
Cardiff	2480	1540	2240	5050	1700	1540	446	1780	1340	461	25,100	11	89
Gosport	1330	428	511	994	304	429	140	284	159	58	7,210	12	88
Dover	262	115	122	339	140	166	61	199	187	43	2,790	30	70
Devonport	5220	2660	2600	5790	1800	3380	921	1490	1190	447	33,300	8	92
Shoreham	953	499	472	8010	2870	7130	1660	2620	2080	984	30,300	6	94
Milford Haven	712	331	422	710	300	305	91	249	236	208	7,680	38	62
Solway	562	2470	4770	638	274	268	100	256	221	72	18,700	44	56
Humber	1340	857	873	1560	662	810	261	552	533	170	19,500	51	49
Tyne	2480	1670	1780	3270	1260	1330	260	549	759	190	87,200	79	21

Key to Tables 3/4:

N, naphthalene; Athylene, acenaphthylene; Athene, acenaphthene; P, phenanthrene; A, anthracene; Fl, fluoranthene;

C1 to C3 denote degrees of alkylation in substituted PAH.

Py, pyrene; BaA, benz[a]anthracene; BFs, benzofluoranthenes;BeP, benzo[e]pyrene; BaP, benzo[a]pyrene; I123cdP, indeno[1,2,3-cd]pyrene; BghiP, benzo[ghi]perylene; DahA, dibenz[a,h]anthracene.

4.2 Polychlorinated Biphenyl (PCB) Results

Table 11 in Appendix A, shows the PCB (1-13) results compared to the Cefas Action Levels and the Canadian ISQGs (TELs and PELs) for each contaminant. Table 12 in Appendix A, shows the PCB (14-27) results compared to the Cefas Action Levels and the Canadian ISQGs (TELs and PELs) for each contaminant. The results show that all determinands were below both Cefas Action Level limits and the TEL and PEL.

4.3 DDT, Dieldrin and PSA Results

Table 13 in Appendix A, shows the DDT, Dieldrin and PSA results compared to the Cefas Action Levels for each contaminant, PSA does not have an associated Cefas Action Level or guideline. There are no Canadian ISQGs (TELs and PELs) for DDT, Dieldrin and PSA. The results show that there are elevated levels above Cefas Action Level 1 for DDT in one sample (VC 24 at 0.00 – 0.20 m). All other determinands were below both Cefas Action Level limits. The PSA results show 79 % of the samples are comprised mainly of sand (approximately 65 – 99 % sand), 12 % of samples are comprised mainly of silt/clay (approximately 65 – 90 % silt/clay) with the other 9 % of samples comprised of a mixture of sand and silt/clay (approximately 50% sand and 50 % silt/clay). The samples that are composed mainly of silt/clay were from inshore vibrocore stations (hatched green area in Figure 1) at various depths. There are no distinct spatial or depth profile patterns with regard to the samples which comprised mainly of sand as these samples were found at vibrocore stations across the sampling area both horizontally and vertically. The samples that are comprised of a mixture of sand and silt/clay were from offshore vibrocore stations (around the red diamond in Figure 1) at various depths.

4.4 Radionuclide Results

Table 14 In Appendix A, shows the radionuclide results. The results show that the concentration of the artificial radionuclides (e.g. ^{137}Cs) in the marine sediment at Sizewell is low (with many values below the level of detection) and consistent with routine local radionuclide monitoring (Environment Agency *et al*. 2015). Apportionment of the effects of these sources is difficult because of the low levels detected (many below the level of detection).

4.5 Marine Water Quality Monitoring Results

Conductivity, temperature and depth sensor (CTD) profiles showed that the waters sampled were well mixed with regard to salinity. Most parameters do not show a tidally-driven pattern of variation. Exceptions to this are turbidity and suspended solids. The concentration of suspended solids was at its lowest shortly after local high and low water, and maxima occurred during the mid-tide periods of peak flow when resuspension of sediments would be expected to be greatest. Natural background suspended sediment concentrations range between 9 – 426 mg l^{-1}. Dissolved oxygen levels ranged from 93 – 119% saturation so oxygenation in the water column remained high and the measured biological oxygen demand and chemical oxygen demand remained low at all sites during the monitoring programme. The organic carbon percentage in sediments was low at 0.08 – 0.1 OC % inshore and 0.58 – 0.82 % further offshore (BEEMS, TR189).

4.6 Results Summary

The results from the sediment quality data analysis of marine sediment samples collected for the NNB geotechnical survey between 24/03/2015 and 28/04/2015, show that the material is acceptable for disposal to sea based on the Cefas Action Levels for each determinand. The results also show based on the Canadian ISQGs that there are areas where the sediment is in the probable effect range within which adverse effects frequently occur on biota from arsenic (VC 18 at 2.00 – 2.20 m and VC 30 at 5.00 – 5.20 m) and dimethyl naphthalenes (in eleven samples). There are some areas that are in the possible effect range within which adverse effects occasionally occur on biota from various determinands. The radionuclide results show that radionuclide concentrations in marine sediment at Sizewell are low (with many values below the level of detection) and consistent with routine local radionuclide monitoring (Environment Agency *et al*. 2015). The PSA results show that the majority of the samples (79 %) are comprised mainly of sand (approximately 65 – 99 % sand). The marine water quality monitoring (BEEMS, TR189) results show that dissolved oxygen levels in the water column are high (93 – 119% saturation) and the organic carbon percentage in sediments was low (0.08 – 0.1 OC % inshore and 0.58 – 0.82 % further offshore).

5 Discussion

The Sizewell sediment quality results show that the marine sediment at Sizewell is predominantly sand and contains relatively low concentrations of contaminants, including radionuclides, when compared against the Cefas Action Levels and Canadian ISQGs. In light of the recommendations from the high level review of UK action levels (MMO, 2015b), if there are any subsequent changes to the action level limits then the Sizewell sediment quality results will need to be compared against the revised action levels. However, there are no current studies or reviews into the existing Action Levels and guidance. ISQGs for the protection of aquatic life are derived from the available toxicological information on the biological effects of sediment-associated chemicals on aquatic organisms. The resulting guidelines provide scientific benchmarks to be used as a basis for the evaluation, protection, and enhancement of sediment quality. The Canadian ISQGs were developed with the intention to be conservative, since they are to be used on a national scale. Although ISQGs are considered to be applicable to a variety of sediment types, they are not intended to define uniform values of sediment quality on a nationwide basis (CCME, 2001). However, they may be employed as nationally consistent screening tools. Therefore, despite areas where the sediment at Sizewell is above the PEL for arsenic (VC 18 at 2.00 – 2.20 m and VC 30 at 5.00 – 5.20 m) and dimethyl naphthalenes (in eleven samples), as these levels are not above Cefas Action Level 2 and the SQG is a conservative value, there is not a concern in relation to contamination.

To put these results into context with the larger scale area of the North Sea, a report by Cefas (1998) found that contaminant levels in the southern North Sea offshore sediment were relatively low compared to other areas around the UK. The results of the national monitoring programme conducted between 1995 and 1996 compared with the contaminant levels found at Sizewell are as follows:

- Chromium - <42 mg kg^{-1} compared to an average concentration of 21.33 mg kg^{-1} found at Sizewell.
- Lead – 8.6 mg kg^{-1} compared to an average concentration of 8.47 mg kg^{-1} found at Sizewell.
- Nickel – approximately 12.0 mg kg^{-1} compared to an average concentration of 11.21 mg kg^{-1} found at Sizewell.
- PCB ICES 7 - <0.00004 mg kg^{-1} compared to an average concentration of <0.0007 mg kg^{-1} found at Sizewell.
- Dieldrin - 0.58 mg kg^{-1} compared to an average concentration of <0.0005 mg kg^{-1} found at Sizewell.

This shows that for the contaminants compared, the concentrations at Sizewell are typically lower than those found offshore in the southern North Sea, apart from PCB concentrations. However, the average PCB Sum of 25 congeners of 0.0025 mg kg^{-1} at Sizewell is consistent with the coastal PCB concentration of 0.002 mg kg^{-1} recorded by Cefas (2001). The Sizewell results are also consistent with the results of the UK National Marine Monitoring Programme (Cefas, 2004), which did not identify any areas off the Suffolk coast that had high levels of contamination.

Bioavailability and bioaccumulation of contaminants in an aquatic environment is mainly dependent on the partitioning behaviour or binding strength of the contaminant to sediment (Di Toro *et al.* 1990). Sediment disturbance events such as dredging allows the mixing of anoxic sediments with biologically active surface sediments, leading to the release of sediment- and pore water-associated contaminants such as mercury (Eggleton & Thomas, 2004). Dredge-related bioavailability is mainly site-specific and dependent on the degree of contamination, the amount of suspended sediment, the duration of the disturbance and the organism (Su *et al.* 2002). The resuspension of sediment, which can occur through vessel movements stirring up bottom sediment, has been shown to accelerate desorption, partitioning, bacterial degradation and oxidation of organic contaminants (Latimer *et al.* 1999). However, the chemical fate and bioavailability of sediment-associated chemicals are directly affected by grain size. In general, chemicals are found in higher concentrations in fine grained material, but are less available for bio-uptake than from sandier sediments (Bray, 2008). The marine water quality monitoring (BEEMS, TR189) results have shown that there are high dissolved oxygen levels in the water column at Sizewell, despite high levels of suspended sediment occurring naturally. Also, the organic carbon content in the sediment at Sizewell is low, therefore, additional suspension of the sediments through disturbance activities at Sizewell is unlikely to result in a significant reduction in dissolved oxygen levels in the water column.

In summary, due to the low risk of contaminants being bioavailable, the proposed seabed disturbance activities associated with the construction and operational phases of the NNB at Sizewell are not likely to cause any effects due to the sediment quality...

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Appendix A - Sizewell Marine Sediment Vibrocore Contaminant Analysis Data

Table 5 – Results of metal and organotin analysis of marine sediment samples collected for the NNB geotechnical survey between 24/03/2015 and 28/04/2015 compared against Cefas Action Levels.

Sample	Depth (m)	As	Hg	Cd	Cr	Cu	Ni	Pb	Zn	MBT	DBT	TBT
		mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}
Cefas AL1		20	0.3	0.4	40	40	20	50	130	0.1	0.1	0.1
Cefas AL2		100	3	5	400	400	200	500	800	1	1	1
VC05	0.00 - 0.20	9.9	0.0216	0.041	24.3	6.44	11.8	10.6	33.6	<0.0004	<0.0004	<0.0004
VC05	1.00 - 1.20	6.35	0.00611	0.016	7.73	2.2	4.52	3.57	11.5	<0.0004	<0.0004	<0.0004
VC05	2.00 - 2.20	8.87	0.0125	0.034	21.6	6.26	11.2	6.52	28.3	<0.0004	<0.0004	<0.0004
VC05	3.00 - 3.20	14.2	0.0172	0.062	35.6	7.47	18	9.46	40.6	<0.0004	<0.0004	<0.0004
VC06	0.00 - 0.20	13.1	0.0276	0.029	19.1	6.05	9.57	12.5	32	<0.0004	<0.0004	<0.00044
VC06	1.00 - 1.20	6.08	0.00914	0.021	8.24	2.16	4.44	3.45	13.2	<0.0004	<0.0004	<0.0004
VC06	2.00 - 2.20	6	0.00826	0.01	13.3	1.75	4.95	6.08	18.2	<0.0004	<0.0004	<0.0004
VC07	0.00 - 0.20	14.6	0.058	0.067	37.4	10.7	18.6	20.9	55.1	0.00152	0.00066	0.00105
VC07	1.00 - 1.20	16.9	0.0256	0.263	69.5	18.6	40.1	15.7	76.3	<0.0004	<0.0004	<0.0004
VC07	2.00 - 2.20	6.25	0.01	0.046	12.6	2.92	8.02	5.66	21.2	<0.0004	<0.0004	<0.0004
VC09	0.00 - 0.20	13.7	0.03	0.038	22.3	6.89	10.2	13.9	37.2	<0.0004	<0.0004	0.00079
VC09	1.00 - 1.20	19.1	0.0215	0.238	34	13.2	20.5	7.56	38.2	<0.0004	<0.0004	<0.0004
VC09	2.00 - 2.20	5.51	0.00199	0.009	10.4	3.26	5.54	3.04	9.87	<0.0004	<0.0004	<0.0004
VC10	0.00 - 0.20	13.2	0.0955	0.062	30.5	8.82	13.6	24.1	52.3	<0.0004	<0.0004	<0.0004
VC10	1.00 - 1.20	6.29	0.0069	0.024	8.33	3.09	4.06	7.35	16.6	<0.0004	<0.0004	<0.0004
VC10	2.00 - 2.20	6.71	0.0253	0.032	13.4	2.91	5.52	10.9	22.4	<0.0004	<0.0004	<0.0004
VC10	3.00 - 3.20	8.84	0.0332	0.047	18.1	4.63	7.98	14	29	<0.0004	<0.0004	<0.0004
VC16	0.00 - 0.20	4.91	<0.0005	<0.005	3.06	0.85	1.56	2.43	6.22	<0.0004	<0.0004	<0.0004
VC16	0.91 - 1.11	7.13	0.00337	0.014	5.3	1.42	3.04	3.72	9.29	<0.0004	<0.0004	<0.0004
VC16	1.91 - 2.11	4.8	0.00173	0.015	6.7	2.63	3.71	3.53	9.84	<0.0004	<0.0004	<0.0004
VC16	2.91 - 3.11	19.6	0.0149	0.095	77.1	16.5	40.6	20.5	86.2	<0.0004	<0.0004	<0.0004
VC16	3.91 - 4.11	19.1	0.014	0.036	7.23	2.57	4.53	0.78	19.4	<0.0004	<0.0004	<0.0004
VC17	0.00 - 0.20	8.38	<0.0005	0.023	3.83	1.1	2.59	2.73	10.4	<0.0004	<0.0004	<0.0004
VC17	1.00 - 1.20	4.32	<0.0005	0.007	3.41	1.13	1.95	2.47	6.87	<0.0004	<0.0004	<0.0004
VC17	2.00 - 2.20	6.43	0.0102	0.009	10.2	2.93	4.53	6.65	16.1	<0.0004	0.00154	0.00353
VC18	0.00 - 0.20	6.98	<0.0005	0.007	4.82	1.12	2.25	2.14	6.91	<0.0004	<0.0004	<0.0004
VC18	1.00 - 1.20	9.93	0.00919	0.102	49.4	10.6	25.8	12.2	53.6	<0.0004	<0.0004	<0.0004
VC18	2.00 - 2.20	84.7	0.00891	0.022	6.25	2.01	4.03	1.49	8.58	<0.0004	<0.0004	<0.0004
VC19	0.00 - 0.20	7.35	0.00232	0.016	8.61	3.64	4.83	4.55	15.1	<0.0004	<0.0004	<0.0004
VC19	1.00 - 1.20	6.25	0.00182	0.013	7.63	3.59	4.16	4.72	14.5	<0.0004	<0.0004	<0.0004
VC21	0.00 - 0.20	4.56	<0.0005	0.008	2.91	1.14	1.64	2.34	6.63	<0.0004	<0.0004	<0.0004
VC21	1.00 - 1.20	22.6	0.00767	0.038	20.9	5.79	12.1	12.1	32	<0.0004	<0.0004	<0.0004
VC21	2.00 - 2.20	24.2	0.0151	0.095	92.3	18.6	45.5	19.5	92.2	<0.0004	<0.0004	<0.0004
VC21	3.00 - 3.20	6.23	0.00683	0.029	2.28	2.66	2.12	0.617	11.2	<0.0004	<0.0004	<0.0004
VC22	0.00 - 0.20	7.86	0.00223	0.012	6.59	2.14	3.75	4.29	12.8	<0.0004	<0.0004	<0.0004
VC22	1.00 - 1.20	21.1	0.0114	0.07	53.6	11.8	28.3	13.5	59.6	<0.0004	<0.0004	<0.0004
VC24	0.00 - 0.20	16.8	0.0879	0.086	42.3	11.4	18	26.3	62.4	0.00098	0.00046	0.00202
VC24	0.90 - 1.10	9.91	0.0205	0.031	12.5	3.38	6.52	11.2	26	<0.0004	<0.0004	<0.0004
VC24	1.90 - 2.10	7.05	0.00711	0.03	12.2	3.82	5.35	8.47	21.2	<0.0004	<0.0004	<0.0004
VC30	0.00 - 0.20	4.25	<0.0005	0.005	2.52	0.74	1.43	1.9	5.62	<0.0004	<0.0004	<0.0004
VC30	1.00 - 1.20	8.57	0.000955	0.015	6.57	1.89	4.02	3.7	11.3	<0.0004	<0.0004	<0.0004
VC30	2.00 - 2.20	4.6	<0.0005	0.007	3.42	1.28	2.37	2.25	6.63	<0.0004	<0.0004	<0.0004
VC30	3.00 - 3.20	24.7	0.016	0.081	74.9	16.8	41.6	18.4	84	<0.0004	<0.0004	<0.0004
VC30	4.00 - 4.20	19.8	0.0127	0.089	59.6	13.2	33.1	13.7	60.6	<0.0004	<0.0004	<0.0004
VC30	5.00 - 5.20	91.5	0.0111	0.029	5.01	3.37	7.72	0.46	7.82	<0.0004	<0.0004	<0.0004
VC31	0.00 - 0.20	10.2	0.00592	0.02	9.36	3.01	4.76	9.06	16	<0.0004	<0.0004	<0.0004
VC31	1.00 - 1.20	12	0.0116	0.046	28.3	7.31	14	12.2	35.3	<0.0004	<0.0004	<0.0004
VC31	2.10 - 2.40	3.57	0.0013	0.01	8.58	2.45	3.4	3.32	10.7	<0.0004	<0.0004	<0.0004

Table 6 - Results of metal and organotin analysis of marine sediment samples collected for the NNB geotechnical survey between 24/03/2015 and 28/04/2015 compared against Canadian sediment quality guidelines (TELs and PELs).

Sample	Depth (m)	As	Hg	Cd	Cr	Cu	Ni	Pb	Zn	MBT	DBT	TBT
		mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}
Canadian TEL		7.24	0.13	0.7	52.3	18.7		30.2	124			
Canadian PEL		41.6	0.7	4.2	160	108		112	271			
VC05	0.00 - 0.20	9.9	0.0216	0.041	24.3	6.44	11.8	10.6	33.6	<0.0004	<0.0004	<0.0004
VC05	1.00 - 1.20	6.35	0.00611	0.016	7.73	2.2	4.52	3.57	11.5	<0.0004	<0.0004	<0.0004
VC05	2.00 - 2.20	8.87	0.0125	0.034	21.6	6.26	11.2	6.52	28.3	<0.0004	<0.0004	<0.0004
VC05	3.00 - 3.20	14.2	0.0172	0.062	35.6	7.47	18	9.46	40.6	<0.0004	<0.0004	<0.0004
VC06	0.00 - 0.20	13.1	0.0276	0.029	19.1	6.05	9.57	12.5	32	<0.0004	<0.0004	<0.00044
VC06	1.00 - 1.20	6.08	0.00914	0.021	8.24	2.16	4.44	3.45	13.2	<0.0004	<0.0004	<0.0004
VC06	2.00 - 2.20	6	0.00826	0.01	13.3	1.75	4.95	6.08	18.2	<0.0004	<0.0004	<0.0004
VC07	0.00 - 0.20	14.6	0.058	0.067	37.4	10.7	18.6	20.9	55.1	0.00152	0.00066	0.00105
VC07	1.00 - 1.20	16.9	0.0256	0.263	69.5	18.6	40.1	15.7	76.3	<0.0004	<0.0004	<0.0004
VC07	2.00 - 2.20	6.25	0.01	0.046	12.6	2.92	8.02	5.66	21.2	<0.0004	<0.0004	<0.0004
VC09	0.00 - 0.20	13.7	0.03	0.038	22.3	6.89	10.2	13.9	37.2	<0.0004	<0.0004	0.00079
VC09	1.00 - 1.20	19.1	0.0215	0.238	34	13.2	20.5	7.56	38.2	<0.0004	<0.0004	<0.0004
VC09	2.00 - 2.20	5.51	0.00199	0.009	10.4	3.26	5.54	3.04	9.87	<0.0004	<0.0004	<0.0004
VC10	0.00 - 0.20	13.2	0.0955	0.062	30.5	8.82	13.6	24.1	52.3	<0.0004	<0.0004	<0.0004
VC10	1.00 - 1.20	6.29	0.0069	0.024	8.33	3.09	4.06	7.35	16.6	<0.0004	<0.0004	<0.0004
VC10	2.00 - 2.20	6.71	0.0253	0.032	13.4	2.91	5.52	10.9	22.4	<0.0004	<0.0004	<0.0004
VC10	3.00 - 3.20	8.84	0.0332	0.047	18.1	4.63	7.98	14	29	<0.0004	<0.0004	<0.0004
VC16	0.00 - 0.20	4.91	<0.0005	<0.005	3.06	0.85	1.56	2.43	6.22	<0.0004	<0.0004	<0.0004
VC16	0.91 - 1.11	7.13	0.00337	0.014	5.3	1.42	3.04	3.72	9.29	<0.0004	<0.0004	<0.0004
VC16	1.91 - 2.11	4.8	0.00173	0.015	6.7	2.63	3.71	3.53	9.84	<0.0004	<0.0004	<0.0004
VC16	2.91 - 3.11	19.6	0.0149	0.095	77.1	16.5	40.6	20.5	86.2	<0.0004	<0.0004	<0.0004
VC16	3.91 - 4.11	19.1	0.014	0.036	7.23	2.57	4.53	0.78	19.4	<0.0004	<0.0004	<0.0004
VC17	0.00 - 0.20	8.38	<0.0005	0.023	3.83	1.1	2.59	2.73	10.4	<0.0004	<0.0004	<0.0004
VC17	1.00 - 1.20	4.32	<0.0005	0.007	3.41	1.13	1.95	2.47	6.87	<0.0004	<0.0004	<0.0004
VC17	2.00 - 2.20	6.43	0.0102	0.009	10.2	2.93	4.53	6.65	16.1	<0.0004	0.00154	0.00353
VC18	0.00 - 0.20	6.98	<0.0005	0.007	4.82	1.12	2.25	2.14	6.91	<0.0004	<0.0004	<0.0004
VC18	1.00 - 1.20	9.93	0.00919	0.102	49.4	10.6	25.8	12.2	53.6	<0.0004	<0.0004	<0.0004
VC18	2.00 - 2.20	84.7	0.00891	0.022	6.25	2.01	4.03	1.49	8.58	<0.0004	<0.0004	<0.0004
VC19	0.00 - 0.20	7.35	0.00232	0.016	8.61	3.64	4.83	4.55	15.1	<0.0004	<0.0004	<0.0004
VC19	1.00 - 1.20	6.25	0.00182	0.013	7.63	3.59	4.16	4.72	14.5	<0.0004	<0.0004	<0.0004
VC21	0.00 - 0.20	4.56	<0.0005	0.008	2.91	1.14	1.64	2.34	6.63	<0.0004	<0.0004	<0.0004
VC21	1.00 - 1.20	22.6	0.00767	0.038	20.9	5.79	12.1	12.1	32	<0.0004	<0.0004	<0.0004
VC21	2.00 - 2.20	24.2	0.0151	0.095	92.3	18.6	45.5	19.5	92.2	<0.0004	<0.0004	<0.0004
VC21	3.00 - 3.20	6.23	0.00683	0.029	2.28	2.66	2.12	0.617	11.2	<0.0004	<0.0004	<0.0004
VC22	0.00 - 0.20	7.86	0.00223	0.012	6.59	2.14	3.75	4.29	12.8	<0.0004	<0.0004	<0.0004
VC22	1.00 - 1.20	21.1	0.0114	0.07	53.6	11.8	28.3	13.5	59.6	<0.0004	<0.0004	<0.0004
VC24	0.00 - 0.20	16.8	0.0879	0.086	42.3	11.4	18	26.3	62.4	0.00098	0.00046	0.00202
VC24	0.90 - 1.10	9.91	0.0205	0.031	12.5	3.38	6.52	11.2	26	<0.0004	<0.0004	<0.0004
VC24	1.90 - 2.10	7.05	0.00711	0.03	12.2	3.82	5.35	8.47	21.2	<0.0004	<0.0004	<0.0004
VC30	0.00 - 0.20	4.25	<0.0005	0.005	2.52	0.74	1.43	1.9	5.62	<0.0004	<0.0004	<0.0004
VC30	1.00 - 1.20	8.57	0.000955	0.015	6.57	1.89	4.02	3.7	11.3	<0.0004	<0.0004	<0.0004
VC30	2.00 - 2.20	4.6	<0.0005	0.007	3.42	1.28	2.37	2.25	6.63	<0.0004	<0.0004	<0.0004
VC30	3.00 - 3.20	24.7	0.016	0.081	74.9	16.8	41.6	18.4	84	<0.0004	<0.0004	<0.0004
VC30	4.00 - 4.20	19.8	0.0127	0.089	59.6	13.2	33.1	13.7	60.6	<0.0004	<0.0004	<0.0004
VC30	5.00 - 5.20	91.5	0.0111	0.029	5.01	3.37	7.72	0.46	7.82	<0.0004	<0.0004	<0.0004
VC31	0.00 - 0.20	10.2	0.00592	0.02	9.36	3.01	4.76	9.06	16	<0.0004	<0.0004	<0.0004
VC31	1.00 - 1.20	12	0.0116	0.046	28.3	7.31	14	12.2	35.3	<0.0004	<0.0004	<0.0004
VC31	2.10 - 2.40	3.57	0.0013	0.01	8.58	2.45	3.4	3.32	10.7	<0.0004	<0.0004	<0.0004

Table 7 - Results of THC and PAH (1-10) analysis of marine sediment samples collected for the NNB geotechnical survey between 24/03/2015 and 28/04/2015 compared against Cefas Action Levels.

Sample	**Depth (m)**	**THC**	**Naphthalene***	**methyl naphthalenes***	**dimethyl naphthalenes***	**trimethyl naphthalenes***	**Acenaphthylene***	**Acenapthene***	**Fluorene***	**Phenanthrene***	**Anthracene***	**methyl phenanthrene***
		mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}
Cefas AL1		100	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cefas AL2												
VC05	0.00 - 0.20	68	0.0377	0.148	0.227	0.313	0.00112	0.00346	0.00871	0.0488	0.00725	0.119
VC05	1.00 - 1.20	24	0.00668	0.0297	0.0496	0.0712	<0.0001	0.0005	0.00181	0.0136	0.00052	0.0344
VC05	2.00 - 2.20	62	0.0107	0.0543	0.095	0.148	0.00012	0.00111	0.00425	0.0275	0.00115	0.0758
VC05	3.00 - 3.20	172	0.0234	0.131	0.224	0.354	0.00016	0.00241	0.00981	0.0648	0.00321	0.18
VC06	0.00 - 0.20	86	0.0263	0.106	0.145	0.214	0.00073	0.00225	0.00646	0.0343	0.00489	0.0848
VC06	1.00 - 1.20	36	0.00732	0.0276	0.0446	0.0693	<0.0001	0.00053	0.00197	0.0142	0.00093	0.0364
VC06	2.00 - 2.20	<0.1	<0.00086	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00052	<0.0001	<0.0001
VC07	0.00 - 0.20	200	0.0699	0.263	0.39	0.472	0.00265	0.00795	0.0175	0.115	0.0182	0.227
VC07	1.00 - 1.20	10	0.00345	0.00284	<0.0001	0.0103	0.00058	0.00522	0.00091	0.00723	0.0016	0.00866
VC07	2.00 - 2.20	14	<0.00086	0.00216	0.00362	0.00664	<0.0001	<0.0001	0.00012	0.00123	0.00012	0.00537
VC09	0.00 - 0.20	158	0.0486	0.194	0.274	0.394	0.0019	0.00434	0.0125	0.0687	0.00923	0.167
VC09	1.00 - 1.20	22	0.0107	0.00838	0.0221	0.0133	0.00181	0.00495	0.00429	0.0252	0.00465	0.0252
VC09	2.00 - 2.20	0.7	<0.00132	0.00044	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00141	<0.0001	0.0035
VC10	0.00 - 0.20	321	0.0841	0.232	0.369	0.513	0.0122	0.0257	0.048	0.26	0.063	0.364
VC10	1.00 - 1.20	26	0.00894	0.0257	0.0459	0.0688	0.00124	0.00251	0.00351	0.0266	0.00564	0.036
VC10	2.00 - 2.20	183	0.0492	0.201	0.342	0.516	0.00716	0.014	0.0248	0.193	0.0415	0.299
VC10	3.00 - 3.20	84	0.0248	0.101	0.164	0.251	0.00204	0.00232	0.00604	0.0549	0.00839	0.128
VC16	0.00 - 0.20	2	0.0014	0.00438	0.00841	0.0118	<0.0001	<0.0001	0.00025	0.00225	0.00043	0.00483
VC16	0.91 - 1.11	6.8	0.00211	0.00754	0.0125	0.0157	0.0001	0.00016	0.00066	0.00345	0.00044	0.00853
VC16	1.91 - 2.11	50	0.00729	0.0365	0.0629	0.0951	0.00019	0.0012	0.00463	0.0195	0.00212	0.048
VC16	2.91 - 3.11	204	0.0198	0.113	0.195	0.302	0.00037	0.00319	0.0203	0.0716	0.00618	0.182
VC16	3.91 - 4.11	92	0.0365	0.0242	0.0378	0.0345	0.0112	0.00827	0.0422	0.143	0.0218	0.125
VC17	0.00 - 0.20	0.2	0.00018	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00051	<0.0001	<0.0001
VC17	1.00 - 1.20	0.3	<0.00068	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00126	<0.0001	<0.0001
VC17	2.00 - 2.20	105	0.0435	0.19	0.263	0.383	0.00218	0.00565	0.0121	0.057	0.00908	0.131
VC18	0.00 - 0.20	<0.1	<0.00068	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00051	<0.0001	<0.0001
VC18	1.00 - 1.20	88	0.014	0.0716	0.177	0.194	0.0003	0.00259	0.0125	0.0411	0.00618	0.112
VC18	2.00 - 2.20	69	0.0175	0.0142	0.0185	0.021	0.00599	0.00336	0.0108	0.072	0.0123	0.0618
VC19	0.00 - 0.20	69	0.0264	0.104	0.14	0.196	0.00096	0.00228	0.00573	0.031	0.00449	0.0711
VC19	1.00 - 1.20	3.7	0.00118	0.00427	0.00591	0.00817	<0.0001	0.0001	0.00016	0.00157	0.0001	0.00398
VC21	0.00 - 0.20	0.6	<0.00054	0.0001	<0.0001	0.00079	<0.0001	<0.0001	<0.0001	<0.00111	0.00016	0.00095
VC21	1.00 - 1.20	58	0.00761	0.039	0.0707	0.105	0.0001	0.00079	0.00326	0.0194	0.00166	0.047
VC21	2.00 - 2.20	190	0.0231	0.122	0.252	0.344	<0.0001	0.00442	0.0213	0.086	0.00503	0.203
VC21	3.00 - 3.20	43	0.00467	0.00569	0.0884	0.021	0.00222	0.00076	0.00403	0.0134	0.00227	0.02
VC22	0.00 - 0.20	35	0.0172	0.0657	0.106	0.132	0.00058	0.00182	0.00405	0.0203	0.00361	0.0525
VC22	1.00 - 1.20	126	0.0245	0.128	0.198	0.275	0.00025	0.00227	0.0106	0.0557	0.00286	0.142
VC24	0.00 - 0.20	285	0.0956	0.355	0.631	0.919	0.00793	0.0185	0.0416	0.217	0.0575	0.434
VC24	0.90 - 1.10	45.3	0.0173	0.0657	0.126	0.172	0.00336	0.00285	0.00692	0.0733	0.00917	0.0964
VC24	1.90 - 2.10	44	0.0131	0.0413	0.0677	0.101	0.00186	0.00227	0.00405	0.0316	0.00725	0.0517
VC30	0.00 - 0.20	0.4	<0.00034	0.00021	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00083	<0.0001	0.00053
VC30	1.00 - 1.20	4	0.00168	0.00484	0.00735	0.00978	<0.0001	0.00014	0.00027	0.00262	0.00036	0.00405
VC30	2.00 - 2.20	1.4	0.00062	0.00196	0.00286	0.00419	<0.0001	<0.0001	0.00013	<0.00083	0.00016	0.00169
VC30	3.00 - 3.20	245	0.026	0.127	0.22	0.313	<0.0001	0.00438	0.0184	0.0731	0.00744	0.169
VC30	4.00 - 4.20	204	0.0221	0.13	0.237	0.336	0.00049	0.00426	0.0222	0.0758	0.00741	0.199
VC30	5.00 - 5.20	429	0.0215	0.0107	<0.0001	<0.0001	0.00643	0.00388	0.0269	0.0982	0.0134	0.061
VC31	0.00 - 0.20	9.1	0.00235	0.00773	0.0131	0.0176	0.00016	0.00032	0.0007	0.0048	0.00056	0.0102
VC31	1.00 - 1.20	86	0.086	0.102	0.176	0.257	<0.0001	0.0016	0.00625	0.0424	0.00162	0.119
VC31	2.10 - 2.40	<0.1	<0.0001	0.00043	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00084	<0.0001	<0.0001

Table 8 - Results of PAH (11 - 22) analysis of marine sediment samples collected for the NNB geotechnical survey between 24/03/2015 and 28/04/2015 compared against Cefas Action Levels.

Sample	**Depth (m)**	**Fluoranthene***	**Pyrene***	**Benz[a] anthracene***	**Chrysene***	**Benzo[b] fluoranthene***	**Benzo[k] fluoranthene***	**Benzo[e] pyrene***	**Benzo[a] pyrene***	**Perylene***	**Indeno[1,2,3-cd] pyrene***	**Benzo[g,h,i] perylene***	**Dibenz[a,h] anthracene***
		$mgkg^{-1}$	$mgkg^{-1}$	$mgkg^{-1}$	$mgkg^{-1}$	$mgkg^{-1}$	$mgkg^{-1}$	$mgkg^{-1}$	$mgkg^{-1}$	$mgkg^{-1}$	$mgkg^{-1}$	$mgkg^{-1}$	$mgkg^{-1}$
Cefas AL1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.01
Cefas AL2													
VC05	0.00 - 0.20	0.0378	0.0364	0.0281	0.0224	0.0267	0.0121	0.0263	0.0229	0.0107	0.0256	0.0307	0.00525
VC05	1.00 - 1.20	0.00489	0.00657	0.00253	0.00297	0.00396	0.00144	0.00571	0.0036	0.00474	0.00351	0.00771	0.0009
VC05	2.00 - 2.20	0.00839	0.0108	0.00664	0.007	0.00915	0.003	0.0146	0.00967	0.0124	0.00772	0.0229	0.00247
VC05	3.00 - 3.20	0.0207	0.025	0.0221	0.0162	0.0218	0.00653	0.0338	0.0227	0.0312	0.0167	0.0527	0.00589
VC06	0.00 - 0.20	0.0271	0.0236	0.0205	0.016	0.02	0.00836	0.0182	0.0176	0.00979	0.0196	0.0248	0.004
VC06	1.00 - 1.20	0.00425	0.00539	0.00393	0.00342	0.0043	0.00129	0.00641	0.00458	0.00574	0.00363	0.00977	0.00114
VC06	2.00 - 2.20	<0.00016	<0.00013	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001
VC07	0.00 - 0.20	0.0988	0.0968	0.0602	0.0541	0.0499	0.0283	0.0616	0.0569	0.0263	0.0591	0.0706	0.0129
VC07	1.00 - 1.20	0.00288	0.00214	<0.0001	0.00099	0.00223	0.00054	0.00135	0.00043	1.25	0.00136	0.00225	0.0003
VC07	2.00 - 2.20	0.00057	0.00065	0.00072	0.0012	0.00203	0.00073	0.00197	0.00132	0.0242	0.00154	0.00278	0.00052
VC09	0.00 - 0.20	0.0646	0.0545	0.037	0.0315	0.0406	0.0183	0.0373	0.0387	0.0168	0.0403	0.0466	0.00852
VC09	1.00 - 1.20	0.0206	0.0145	0.00375	0.00679	0.00796	0.00194	0.00507	0.00257	7.98	0.00496	0.00494	0.00075
VC09	2.00 - 2.20	0.00041	0.00027	<0.0001	<0.0001	<0.0001	<0.0001	0.00012	<0.0001	0.0104	<0.0001	0.00017	<0.0001
VC10	0.00 - 0.20	0.391	0.324	0.177	0.18	0.208	0.108	0.167	0.206	0.0649	0.206	0.185	0.0399
VC10	1.00 - 1.20	0.03	0.0354	0.0294	0.0142	0.0182	0.00999	0.0159	0.0192	0.00625	0.0183	0.017	0.00346
VC10	2.00 - 2.20	0.25	0.23	0.135	0.104	0.127	0.064	0.113	0.116	0.04	0.112	0.114	0.0237
VC10	3.00 - 3.20	0.0457	0.0608	0.0397	0.0238	0.0405	0.0175	0.0369	0.0369	0.0144	0.0352	0.0406	0.00697
VC16	0.00 - 0.20	0.00212	0.00223	<0.0001	0.00145	0.00108	0.00065	0.0012	0.00154	0.00041	0.00101	0.00142	0.00029
VC16	0.91 - 1.11	0.00232	0.0026	0.00226	0.00119	0.00244	0.00116	0.0021	0.00224	0.00093	0.00281	0.00295	0.00054
VC16	1.91 - 2.11	0.0116	0.0124	0.01	0.00589	0.00854	0.00332	0.0115	0.00872	0.0445	0.00786	0.0195	0.00219
VC16	2.91 - 3.11	0.0397	0.0394	0.0262	0.018	0.0334	0.00734	0.0423	0.0263	0.185	0.0237	0.0729	0.00755
VC16	3.91 - 4.11	0.177	0.0919	0.0224	0.0292	0.0508	0.0163	0.0261	0.0126	2.46	0.0273	<0.0001	0.00319
VC17	0.00 - 0.20	0.00014	0.00033	<0.0001	<0.0001	<0.0001	<0.0001	0.00025	0.00041	<0.00086	<0.0001	<0.0001	<0.0001
VC17	1.00 - 1.20	<0.00012	<0.00017	<0.0001	<0.0001	<0.0001	<0.0001	0.00011	<0.0001	<0.00086	<0.0001	<0.0001	<0.0001
VC17	2.00 - 2.20	0.0585	0.0525	0.0353	0.0235	0.0333	0.0152	0.0306	0.0338	0.014	0.032	0.0392	0.00656
VC18	0.00 - 0.20	<0.00012	<0.00017	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00086	<0.0001	<0.0001	<0.0001
VC18	1.00 - 1.20	0.0186	0.019	0.0116	0.00774	0.017	0.00413	0.021	0.0152	0.0697	0.0136	0.0421	0.00419
VC18	2.00 - 2.20	0.114	0.0752	0.0151	0.0201	0.0296	0.0125	0.0191	0.0135	0.0805	0.0226	0.0223	0.00325
VC19	0.00 - 0.20	0.0288	0.0268	0.0208	0.0139	0.0212	0.0088	0.0189	0.0187	0.00849	0.02	0.0244	0.00428
VC19	1.00 - 1.20	0.00042	0.00067	0.00116	0.00046	0.00044	0.00019	0.00058	0.00054	0.00058	0.00039	0.00105	<0.00035
VC21	0.00 - 0.20	0.00093	0.00083	0.00049	0.00043	0.00032	0.00019	0.00024	0.00037	0.00014	0.00025	0.00026	<0.00035
VC21	1.00 - 1.20	0.0113	0.0132	0.00738	0.00517	0.00965	0.00403	0.0115	0.00746	0.0093	0.00904	0.016	0.0021
VC21	2.00 - 2.20	0.0371	0.0414	0.0392	0.031	0.03	0.0123	0.058	0.0335	0.164	0.0291	0.0749	0.00996
VC21	3.00 - 3.20	0.015	0.0134	<0.0001	0.0016	0.0054	0.00184	0.00251	0.00464	0.214	0.00718	0.00971	0.00079
VC22	0.00 - 0.20	0.0184	0.0172	0.0123	0.0108	0.013	0.0063	0.0124	0.013	0.0062	0.0132	0.0163	0.00284
VC22	1.00 - 1.20	0.0231	0.0278	0.0185	0.0139	0.0203	0.00558	0.0301	0.0185	0.0728	0.0151	0.0427	0.00473
VC24	0.00 - 0.20	0.273	0.255	0.17	0.129	0.118	0.0666	0.111	0.124	0.0407	0.104	0.11	0.0238
VC24	0.90 - 1.10	0.112	0.103	0.0471	0.0407	0.0476	0.023	0.0364	0.0467	0.0118	0.0354	0.033	0.00675
VC24	1.90 - 2.10	0.0476	0.0552	0.0334	0.0203	0.0349	0.0153	0.0254	0.0321	0.00959	0.0302	0.0278	0.00561
VC30	0.00 - 0.20	<0.00035	0.00025	<0.0001	0.00011	0.00011	<0.0001	<0.0001	0.00013	<0.00019	<0.00062	<0.00076	<0.00085
VC30	1.00 - 1.20	0.00289	0.00276	0.00214	0.00128	0.00106	0.00058	0.00104	0.00149	0.00047	0.00121	0.00114	<0.00085
VC30	2.00 - 2.20	0.0006	0.00073	<0.0001	0.0003	0.00032	0.00016	0.0003	0.00049	<0.00019	<0.00062	<0.00076	<0.00085
VC30	3.00 - 3.20	0.0376	0.0457	0.0264	0.0281	0.0287	0.00974	0.0498	0.0282	0.279	0.0222	0.0705	0.00712
VC30	4.00 - 4.20	0.0405	0.0443	0.0286	0.021	0.0311	0.00799	0.0438	0.0289	0.228	0.0254	0.0775	0.00817
VC30	5.00 - 5.20	0.0866	0.0505	0.0178	0.0265	0.0257	0.0109	0.0157	0.0131	2.09	0.0186	0.0138	<0.0001
VC31	0.00 - 0.20	0.00291	0.0033	0.00536	0.00179	0.00184	0.00107	0.00251	0.0025	0.00154	0.00302	0.00354	0.00058
VC31	1.00 - 1.20	0.0141	0.0184	0.0136	0.012	0.0111	0.00324	0.0166	0.0112	0.0162	0.00878	0.0235	0.00277
VC31	2.10 - 2.40	<0.00038	<0.00025	<0.0001	0.0001	0.00011	<0.0001	0.00021	<0.0001	<0.0001	0.00019	0.00051	<0.0001

Table 9 - Results of THC and PAH (1-10) analysis of marine sediment samples collected for the NNB geotechnical survey between 24/03/2015 and 28/04/2015 compared against Canadian sediment quality guidelines (TELs and PELs).

Sample	**Depth (m)**	**THC**	**Naphthalene***	**methyl naphthalenes***	**dimethyl naphthalenes***	**trimethyl naphthalenes***	**Acenaphthylene***	**Acenapthene***	**Fluorene***	**Phenanthrene***	**Anthracene***	**methyl phenanthrene***
		mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}
Canadian TEL			0.0346		0.0202		0.00587	0.00671	0.0212	0.0867	0.0469	
Canadian PEL			0.391		0.201		0.128	0.0889	0.144	0.544	0.245	
VC05	0.00 - 0.20	68	0.0377	0.148	0.227	0.313	0.00112	0.00346	0.00871	0.0488	0.00725	0.119
VC05	1.00 - 1.20	24	0.00668	0.0297	0.0496	0.0712	<0.0001	0.0005	0.00181	0.0136	0.00052	0.0344
VC05	2.00 - 2.20	62	0.0107	0.0543	0.095	0.148	0.00012	0.00111	0.00425	0.0275	0.00115	0.0758
VC05	3.00 - 3.20	172	0.0234	0.131	0.224	0.354	0.00016	0.00241	0.00981	0.0648	0.00321	0.18
VC06	0.00 - 0.20	86	0.0263	0.106	0.145	0.214	0.00073	0.00225	0.00646	0.0343	0.00489	0.0848
VC06	1.00 - 1.20	36	0.00732	0.0276	0.0446	0.0693	<0.0001	0.00053	0.00197	0.0142	0.00093	0.0364
VC06	2.00 - 2.20	<0.1	<0.00086	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00052	<0.0001	<0.0001
VC07	0.00 - 0.20	200	0.0699	0.263	0.39	0.472	0.00265	0.00795	0.0175	0.115	0.0182	0.227
VC07	1.00 - 1.20	10	0.00345	0.00284	<0.0001	0.0103	0.00058	0.00522	0.00091	0.00723	0.0016	0.00866
VC07	2.00 - 2.20	14	<0.00086	0.00216	0.00362	0.00664	<0.0001	<0.0001	0.00012	0.00123	0.00012	0.00537
VC09	0.00 - 0.20	158	0.0486	0.194	0.274	0.394	0.0019	0.00434	0.0125	0.0687	0.00923	0.167
VC09	1.00 - 1.20	22	0.0107	0.00838	0.0221	0.0133	0.00181	0.00495	0.00429	0.0252	0.00465	0.0252
VC09	2.00 - 2.20	0.7	<0.00132	0.00044	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00141	<0.0001	0.0035
VC10	0.00 - 0.20	321	0.0841	0.232	0.369	0.513	0.0122	0.0257	0.048	0.26	0.063	0.364
VC10	1.00 - 1.20	26	0.00894	0.0257	0.0459	0.0688	0.00124	0.00251	0.00351	0.0266	0.00564	0.036
VC10	2.00 - 2.20	183	0.0492	0.201	0.342	0.516	0.00716	0.014	0.0248	0.193	0.0415	0.299
VC10	3.00 - 3.20	84	0.0248	0.101	0.164	0.251	0.00204	0.00232	0.00604	0.0549	0.00839	0.128
VC16	0.00 - 0.20	2	0.0014	0.00438	0.00841	0.0118	<0.0001	<0.0001	0.00025	0.00225	0.00043	0.00483
VC16	0.91 - 1.11	6.8	0.00211	0.00754	0.0125	0.0157	0.0001	0.00016	0.00066	0.00345	0.00044	0.00853
VC16	1.91 - 2.11	50	0.00729	0.0365	0.0629	0.0951	0.00019	0.0012	0.00463	0.0195	0.00212	0.048
VC16	2.91 - 3.11	204	0.0198	0.113	0.195	0.302	0.00037	0.00319	0.0203	0.0716	0.00618	0.182
VC16	3.91 - 4.11	92	0.0365	0.0242	0.0378	0.0345	0.0112	0.00827	0.0422	0.143	0.0218	0.125
VC17	0.00 - 0.20	0.2	0.00018	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00051	<0.0001	<0.0001
VC17	1.00 - 1.20	0.3	<0.00068	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00126	<0.0001	<0.0001
VC17	2.00 - 2.20	105	0.0435	0.19	0.263	0.383	0.00218	0.00565	0.0121	0.057	0.00908	0.131
VC18	0.00 - 0.20	<0.1	<0.00068	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00051	<0.0001	<0.0001
VC18	1.00 - 1.20	88	0.014	0.0716	0.177	0.194	0.0003	0.00259	0.0125	0.0411	0.00618	0.112
VC18	2.00 - 2.20	69	0.0175	0.0142	0.0185	0.021	0.00599	0.00336	0.0108	0.072	0.0123	0.0618
VC19	0.00 - 0.20	69	0.0264	0.104	0.14	0.196	0.00096	0.00228	0.00573	0.031	0.00449	0.0711
VC19	1.00 - 1.20	3.7	0.00118	0.00427	0.00591	0.00817	<0.0001	0.0001	0.00016	0.00157	0.0001	0.00398
VC21	0.00 - 0.20	0.6	<0.00054	0.0001	<0.0001	0.00079	<0.0001	<0.0001	<0.0001	<0.00111	0.00016	0.00095
VC21	1.00 - 1.20	58	0.00761	0.039	0.0707	0.105	0.0001	0.00079	0.00326	0.0194	0.00166	0.047
VC21	2.00 - 2.20	190	0.0231	0.122	0.252	0.344	<0.0001	0.00442	0.0213	0.086	0.00503	0.203
VC21	3.00 - 3.20	43	0.00467	0.00569	0.0884	0.021	0.00222	0.00076	0.00403	0.0134	0.00227	0.02
VC22	0.00 - 0.20	35	0.0172	0.0657	0.106	0.132	0.00058	0.00182	0.00405	0.0203	0.00361	0.0525
VC22	1.00 - 1.20	126	0.0245	0.128	0.198	0.275	0.00025	0.00227	0.0106	0.0557	0.00286	0.142
VC24	0.00 - 0.20	285	0.0956	0.355	0.631	0.919	0.00793	0.0185	0.0416	0.217	0.0575	0.434
VC24	0.90 - 1.10	45.3	0.0173	0.0657	0.126	0.172	0.00336	0.00285	0.00692	0.0733	0.00917	0.0964
VC24	1.90 - 2.10	44	0.0131	0.0413	0.0677	0.101	0.00186	0.00227	0.00405	0.0316	0.00725	0.0517
VC30	0.00 - 0.20	0.4	<0.00034	0.00021	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00083	<0.0001	0.00053
VC30	1.00 - 1.20	4	0.00168	0.00484	0.00735	0.00978	<0.0001	0.00014	0.00027	0.00262	0.00036	0.00405
VC30	2.00 - 2.20	1.4	0.00062	0.00196	0.00286	0.00419	<0.0001	<0.0001	0.00013	<0.00083	0.00016	0.00169
VC30	3.00 - 3.20	245	0.026	0.127	0.22	0.313	<0.0001	0.00438	0.0184	0.0731	0.00744	0.169
VC30	4.00 - 4.20	204	0.0221	0.13	0.237	0.336	0.00049	0.00426	0.0222	0.0758	0.00741	0.199
VC30	5.00 - 5.20	429	0.0215	0.0107	<0.0001	<0.0001	0.00643	0.00388	0.0269	0.0982	0.0134	0.061
VC31	0.00 - 0.20	9.1	0.00235	0.00773	0.0131	0.0176	0.00016	0.00032	0.0007	0.0048	0.00056	0.0102
VC31	1.00 - 1.20	86	0.086	0.102	0.176	0.257	<0.0001	0.0016	0.00625	0.0424	0.00162	0.119
VC31	2.10 - 2.40	<0.1	<0.0001	0.00043	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00084	<0.0001	<0.0001

Table 10 - Results of THC and PAH (11-22) analysis of marine sediment samples collected for the NNB geotechnical survey between 24/03/2015 and 28/04/2015 compared against Canadian sediment quality guidelines (TELs and PELs).

Sample	**Depth (m)**	**Fluoranthene***	**Pyrene***	**Benz[a] anthracene***	**Chrysene***	**Benzo[b] fluoranthene***	**Benzo[k] fluoranthene***	**Benzo[e] pyrene***	**Benzo[a] pyrene***	**Perylene***	**Indeno[1,2,3-cd] pyrene***	**Benzo[g,h,i] perylene***	**Dibenz[a,h] anthracene***
		mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}
Canadian TEL		0.113	0.153	0.0748	0.108				0.0888				0.00622
Canadian PEL		1.494	1.398	0.693	0.846				0.763				0.135
VC05	0.00 - 0.20	0.0378	0.0364	0.0281	0.0224	0.0267	0.0121	0.0263	0.0229	0.0107	0.0256	0.0307	0.00525
VC05	1.00 - 1.20	0.00489	0.00657	0.00253	0.00297	0.00396	0.00144	0.00571	0.0036	0.00474	0.00351	0.00771	0.0009
VC05	2.00 - 2.20	0.00839	0.0108	0.00664	0.007	0.00915	0.003	0.0146	0.00967	0.0124	0.00772	0.0229	0.00247
VC05	3.00 - 3.20	0.0207	0.025	0.0221	0.0162	0.0218	0.00653	0.0338	0.0227	0.0312	0.0167	0.0527	0.00589
VC06	0.00 - 0.20	0.0271	0.0236	0.0205	0.016	0.02	0.00836	0.0182	0.0176	0.00979	0.0196	0.0248	0.004
VC06	1.00 - 1.20	0.00425	0.00539	0.00393	0.00342	0.0043	0.00129	0.00641	0.00458	0.00574	0.00363	0.00977	0.00114
VC06	2.00 - 2.20	<0.00016	<0.00013	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001
VC07	0.00 - 0.20	0.0988	0.0968	0.0602	0.0541	0.0499	0.0283	0.0616	0.0569	0.0263	0.0591	0.0706	0.0129
VC07	1.00 - 1.20	0.00288	0.00214	<0.0001	0.00099	0.00223	0.00054	0.00135	0.00043	1.25	0.00136	0.00225	0.0003
VC07	2.00 - 2.20	0.00057	0.00065	0.00072	0.0012	0.00203	0.00073	0.00197	0.00132	0.0242	0.00154	0.00278	0.00052
VC09	0.00 - 0.20	0.0646	0.0545	0.037	0.0315	0.0406	0.0183	0.0373	0.0387	0.0168	0.0403	0.0466	0.00852
VC09	1.00 - 1.20	0.0206	0.0145	0.00375	0.00679	0.00796	0.00194	0.00507	0.00257	7.98	0.00496	0.00494	0.00075
VC09	2.00 - 2.20	0.00041	0.00027	<0.0001	<0.0001	<0.0001	<0.0001	0.00012	<0.0001	0.0104	<0.0001	0.00017	<0.0001
VC10	0.00 - 0.20	0.391	0.324	0.177	0.18	0.208	0.108	0.167	0.206	0.0649	0.206	0.185	0.0399
VC10	1.00 - 1.20	0.03	0.0354	0.0294	0.0142	0.0182	0.00999	0.0159	0.0192	0.00625	0.0183	0.017	0.00346
VC10	2.00 - 2.20	0.25	0.23	0.135	0.104	0.127	0.064	0.113	0.116	0.04	0.112	0.114	0.0237
VC10	3.00 - 3.20	0.0457	0.0608	0.0397	0.0238	0.0405	0.0175	0.0369	0.0369	0.0144	0.0352	0.0406	0.00697
VC16	0.00 - 0.20	0.00212	0.00223	<0.0001	0.00145	0.00108	0.00065	0.0012	0.00154	0.00041	0.00101	0.00142	0.00029
VC16	0.91 - 1.11	0.00232	0.0026	0.00226	0.00119	0.00244	0.00116	0.0021	0.00224	0.00093	0.00281	0.00295	0.00054
VC16	1.91 - 2.11	0.0116	0.0124	0.01	0.00589	0.00854	0.00332	0.0115	0.00872	0.0445	0.00786	0.0195	0.00219
VC16	2.91 - 3.11	0.0397	0.0394	0.0262	0.018	0.0334	0.00734	0.0423	0.0263	0.185	0.0237	0.0729	0.00755
VC16	3.91 - 4.11	0.177	0.0919	0.0224	0.0292	0.0508	0.0163	0.0261	0.0126	2.46	0.0273	<0.0001	0.00319
VC17	0.00 - 0.20	0.00014	0.00033	<0.0001	<0.0001	<0.0001	<0.0001	0.00025	0.00041	<0.00086	<0.0001	<0.0001	<0.0001
VC17	1.00 - 1.20	<0.00012	<0.00017	<0.0001	<0.0001	<0.0001	<0.0001	0.00011	<0.0001	<0.00086	<0.0001	<0.0001	<0.0001
VC17	2.00 - 2.20	0.0585	0.0525	0.0353	0.0235	0.0333	0.0152	0.0306	0.0338	0.014	0.032	0.0392	0.00656
VC18	0.00 - 0.20	<0.00012	<0.00017	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00086	<0.0001	<0.0001	<0.0001
VC18	1.00 - 1.20	0.0186	0.019	0.0116	0.00774	0.017	0.00413	0.021	0.0152	0.0697	0.0136	0.0421	0.00419
VC18	2.00 - 2.20	0.114	0.0752	0.0151	0.0201	0.0296	0.0125	0.0191	0.0135	0.0805	0.0226	0.0223	0.00325
VC19	0.00 - 0.20	0.0288	0.0268	0.0208	0.0139	0.0212	0.0088	0.0189	0.0187	0.00849	0.02	0.0244	0.00428
VC19	1.00 - 1.20	0.00042	0.00067	0.00116	0.00046	0.00044	0.00019	0.00058	0.00054	0.00058	0.00039	0.00105	<0.00035
VC21	0.00 - 0.20	0.00093	0.00083	0.00049	0.00043	0.00032	0.00019	0.00024	0.00037	0.00014	0.00025	0.00026	<0.00035
VC21	1.00 - 1.20	0.0113	0.0132	0.00738	0.00517	0.00965	0.00403	0.0115	0.00746	0.0093	0.00904	0.016	0.0021
VC21	2.00 - 2.20	0.0371	0.0414	0.0392	0.031	0.03	0.0123	0.058	0.0335	0.164	0.0291	0.0749	0.00996
VC21	3.00 - 3.20	0.015	0.0134	<0.0001	0.0016	0.0054	0.00184	0.00251	0.00464	0.214	0.00718	0.00971	0.00079
VC22	0.00 - 0.20	0.0184	0.0172	0.0123	0.0108	0.013	0.0063	0.0124	0.013	0.0062	0.0132	0.0163	0.00284
VC22	1.00 - 1.20	0.0231	0.0278	0.0185	0.0139	0.0203	0.00558	0.0301	0.0185	0.0728	0.0151	0.0427	0.00473
VC24	0.00 - 0.20	0.273	0.255	0.17	0.129	0.118	0.0666	0.111	0.124	0.0407	0.104	0.11	0.0238
VC24	0.90 - 1.10	0.112	0.103	0.0471	0.0407	0.0476	0.023	0.0364	0.0467	0.0118	0.0354	0.033	0.00675
VC24	1.90 - 2.10	0.0476	0.0552	0.0334	0.0203	0.0349	0.0153	0.0254	0.0321	0.00959	0.0302	0.0278	0.00561
VC30	0.00 - 0.20	<0.00035	0.00025	<0.0001	0.00011	0.00011	<0.0001	<0.0001	0.00013	<0.00019	<0.00062	<0.00076	<0.00085
VC30	1.00 - 1.20	0.00289	0.00276	0.00214	0.00128	0.00106	0.00058	0.00104	0.00149	0.00047	0.00121	0.00114	<0.00085
VC30	2.00 - 2.20	0.0006	0.00073	<0.0001	0.0003	0.00032	0.00016	0.0003	0.00049	<0.00019	<0.00062	<0.00076	<0.00085
VC30	3.00 - 3.20	0.0376	0.0457	0.0264	0.0281	0.0287	0.00974	0.0498	0.0282	0.279	0.0222	0.0705	0.00712
VC30	4.00 - 4.20	0.0405	0.0443	0.0286	0.021	0.0311	0.00799	0.0438	0.0289	0.228	0.0254	0.0775	0.00817
VC30	5.00 - 5.20	0.0866	0.0505	0.0178	0.0265	0.0257	0.0109	0.0157	0.0131	2.09	0.0186	0.0138	<0.0001
VC31	0.00 - 0.20	0.00291	0.0033	0.00536	0.00179	0.00184	0.00107	0.00251	0.0025	0.00154	0.00302	0.00354	0.00058
VC31	1.00 - 1.20	0.0141	0.0184	0.0136	0.012	0.0111	0.00324	0.0166	0.0112	0.0162	0.00878	0.0235	0.00277
VC31	2.10 - 2.40	<0.00038	<0.00025	<0.0001	0.0001	0.00011	<0.0001	0.00021	<0.0001	<0.0001	0.00019	0.00051	<0.0001

Table 11 - Results of PCB (1-13) analysis of marine sediment samples collected for the NNB geotechnical survey between 24/03/2015 and 28/04/2015 compared against Cefas Action Level and Canadian sediment quality guidelines (TELs and PELs) .

Sample	**Depth (m)**	**PCB#28**	**PCB#52**	**PCB#101**	**PCB#118**	**PCB#153**	**PCB#138**	**PCB#180**	**PCB#31**	**PCB#105**	**PCB#128**	**PCB#149**	**PCB#170**	**PCB#183**
		mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}
Cefas AL1														
Cefas AL2														
Canadian TEL														
Canadian PEL														
VC05	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC05	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC05	2.00 - 2.20	<0.0001	<0.0001	<0.0001	0.00048	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC05	3.00 - 3.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC06	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC06	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC06	2.00 - 2.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC07	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	0.00014	0.00011	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC07	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC07	2.00 - 2.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC09	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00012	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC09	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC09	2.00 - 2.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC10	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC10	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC10	2.00 - 2.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC10	3.00 - 3.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC16	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC16	0.91 - 1.11	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC16	1.91 - 2.11	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC16	2.91 - 3.11	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC16	3.91 - 4.11	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC17	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC17	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC17	2.00 - 2.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00013	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC18	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC18	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC18	2.00 - 2.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC19	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC19	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC21	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC21	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC21	2.00 - 2.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC21	3.00 - 3.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC22	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC22	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC24	0.00 - 0.20	0.00018	<0.0001	0.0002	0.00022	0.00026	0.00031	0.00018	0.00013	0.00012	<0.0001	0.0002	<0.0001	0.00016
VC24	0.90 - 1.10	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC24	1.90 - 2.10	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC30	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC30	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC30	2.00 - 2.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC30	3.00 - 3.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC30	4.00 - 4.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC30	5.00 - 5.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC31	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC31	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
VC31	2.10 - 2.40	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Table 12 - Results of PCB (14-27) analysis of marine sediment samples collected for the NNB geotechnical survey between 24/03/2015 and 28/04/2015 compared against Cefas Action Levels and Canadian sediment quality guidelines (TELs and PELs).

Sample	Depth (m)	PCB#187	PCB#18	PCB#44	PCB#47	PCB#49	PCB#66	PCB#110	PCB#158	PCB#141	PCB#151	PCB#156	PCB#194	PCB Ices 7	PCB 25 congeners
		mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}	mgkg^{-1}
Cefas AL1														0.01	0.02
Cefas AL2															0.2
Canadian TEL															21.5
Canadian PEL															189
VC05	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC05	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC05	2.00 - 2.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00108	0.00288
VC05	3.00 - 3.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC06	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC06	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC06	2.00 - 2.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC07	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00075	0.00255
VC07	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00011	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	0.00251
VC07	2.00 - 2.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC09	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00072	0.00252
VC09	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC09	2.00 - 2.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC10	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC10	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC10	2.00 - 2.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC10	3.00 - 3.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC16	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC16	0.91 - 1.11	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC16	1.91 - 2.11	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC16	2.91 - 3.11	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC16	3.91 - 4.11	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00011	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	0.00251
VC17	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC17	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC17	2.00 - 2.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00011	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00073	0.00254
VC18	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC18	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC18	2.00 - 2.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC19	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC19	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC21	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC21	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC21	2.00 - 2.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC21	3.00 - 3.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC22	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC22	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC24	0.00 - 0.20	0.00011	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00027	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00145	0.00704
VC24	0.90 - 1.10	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC24	1.90 - 2.10	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC30	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC30	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC30	2.00 - 2.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC30	3.00 - 3.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC30	4.00 - 4.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC30	5.00 - 5.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC31	0.00 - 0.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC31	1.00 - 1.20	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025
VC31	2.10 - 2.40	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0007	<0.0025

Table 13 - Results of DDT, Dieldrin and PSA analysis of marine sediment samples collected for the NNB geotechnical survey between 24/03/2015 and 28/04/2015 compared against Cefas Action Levels.

Sample	Depth (m)	DDT	Dieldrin	Silt/Clay	Sand
		$mgkg^{-1}$	$mgkg^{-1}$	%	%
Cefas AL1		0.001	0.005		
Cefas AL2					
VC05	0.00 - 0.20	<0.0001	<0.0005	26	74
VC05	1.00 - 1.20	<0.0001	<0.0005	6.69	93.31
VC05	2.00 - 2.20	<0.0001	<0.0005	29.9	70.1
VC05	3.00 - 3.20	<0.0001	<0.0005	49.1	50.9
VC06	0.00 - 0.20	<0.0001	<0.0005	25.5	74.5
VC06	1.00 - 1.20	<0.0001	<0.0005	21.9	78.1
VC06	2.00 - 2.20	<0.0001	<0.0005	4.71	95.29
VC07	0.00 - 0.20	<0.0001	<0.0005	42.4	57.6
VC07	1.00 - 1.20	<0.0001	<0.0005	56.3	43.7
VC07	2.00 - 2.20	<0.0001	<0.0005	7.35	92.65
VC09	0.00 - 0.20	<0.0001	<0.0005	10.6	89.4
VC09	1.00 - 1.20	<0.0001	<0.0005	36.1	63.9
VC09	2.00 - 2.20	<0.0001	<0.0005	1.62	98.38
VC10	0.00 - 0.20	0.000852	<0.0005	36.1	63.9
VC10	1.00 - 1.20	<0.0001	<0.0005	3.62	96.38
VC10	2.00 - 2.20	<0.0001	<0.0005	14.5	85.5
VC10	3.00 - 3.20	<0.0001	<0.0005	15.3	84.7
VC16	0.00 - 0.20	<0.0001	<0.0005	0.59	99.41
VC16	0.91 - 1.11	<0.0001	<0.0005	2.14	97.86
VC16	1.91 - 2.11	<0.0001	<0.0005	1.36	98.64
VC16	2.91 - 3.11	<0.0001	<0.0005	91.7	8.3
VC16	3.91 - 4.11	<0.0002	<0.001	21.1	78.9
VC17	0.00 - 0.20	<0.0001	<0.0005	<0.01	>99.99
VC17	1.00 - 1.20	<0.0001	<0.0005	<0.01	>99.99
VC17	2.00 - 2.20	<0.0001	<0.0005	6.89	93.11
VC18	0.00 - 0.20	<0.0001	<0.0005	<0.01	>99.99
VC18	1.00 - 1.20	<0.0001	<0.0005	66.3	33.7
VC18	2.00 - 2.20	<0.0001	<0.0005	21	79
VC19	0.00 - 0.20	<0.0001	<0.0005	3.28	96.72
VC19	1.00 - 1.20	<0.0001	<0.0005	11.5	88.5
VC21	0.00 - 0.20	<0.0001	<0.0005	<0.01	>99.99
VC21	1.00 - 1.20	<0.0001	<0.0005	21.5	78.5
VC21	2.00 - 2.20	<0.0001	<0.0005	82.8	17.2
VC21	3.00 - 3.20	<0.0001	<0.0005	22	78
VC22	0.00 - 0.20	<0.0001	<0.0005	7.59	92.41
VC22	1.00 - 1.20	<0.0001	<0.0005	67.2	32.8
VC24	0.00 - 0.20	0.00108	<0.0005	44.1	55.9
VC24	0.90 - 1.10	<0.0001	<0.0005	8.13	91.87
VC24	1.90 - 2.10	<0.0001	<0.0005	13	87
VC30	0.00 - 0.20	<0.0001	<0.0005	<0.01	>99.99
VC30	1.00 - 1.20	<0.0001	<0.0005	1.39	98.61
VC30	2.00 - 2.20	<0.0001	<0.0005	<0.01	>99.99
VC30	3.00 - 3.20	<0.0001	<0.0005	88	12
VC30	4.00 - 4.20	<0.0001	<0.0005	68.3	31.7
VC30	5.00 - 5.20	<0.0002	<0.001	15.2	84.8
VC31	0.00 - 0.20	<0.0001	<0.0005	11.1	88.9
VC31	1.00 - 1.20	<0.0001	<0.0005	35.5	64.5
VC31	2.10 - 2.40	<0.0001	<0.0005	1.93	98.07

Table 14 - Results of radionuclide analysis of marine sediment samples collected for the NNB geotechnical survey between 24/03/2015 and 28/04/2015.

Collection Date	**Sample**	**Depth (m)**	**Co-60 Bq/kg dry ± error**	**Cs-137 Bq/kg dry ± error**	**Ra-226 (Pb-214) Bq/kg dry ± error**	**Th-232 (Ac-228) Bq/kg dry ± error**	**U-238 (Th-234) Bq/kg dry ± error**	**Am-241 Bq/kg dry ± error**
23/04/2015	VC06	0.00 - 0.20	< 0.16	1.03 ± 8.54%	9.50 ± 5.92%	10.98 ± 5.73%	18.46 ± 8.55%	< 0.31
23/04/2015	VC06	4.74 - 4.85	< 0.10	< 0.10	18.51 ± 5.57%	7.54 ± 5.60%	25.26 ± 6.13%	< 0.23
24/04/2015	VC09	0.00 - 0.20	< 0.18	2.30 ± 6.20%	11.23 ± 5.90%	14.65 ± 5.37%	24.97 ± 7.09%	< 0.28
24/04/2015	VC09	5.29 - 5.39	< 0.13	< 0.11	6.02 ± 6.27%	5.08 ± 6.96%	9.62 ± 13.55%	< 0.23
23/04/2015	VC13	0.00 - 0.20	< 0.12	0.21 ± 25.38%	8.05 ± 6.01%	5.07 ± 6.85%	8.39 ± 12.62%	< 0.23
23/04/2015	VC13	5.88 - 6.08	< 0.09	< 0.09	5.94 ± 6.06%	2.39 ± 9.19%	6.67 ± 11.66%	< 0.16
24/04/2015	VC22	0.00 - 0.20	< 0.13	1.33 ± 6.90%	6.72 ± 6.21%	6.96 ± 6.35%	11.69 ± 10.39%	< 0.25
24/04/2015	VC22	5.65 - 5.75	< 0.12	< 0.12	9.32 ± 5.92%	6.95 ± 6.46%	10.91 ± 11.94%	< 0.25
25/04/2015	VC31	0.00 - 0.20	< 0.10	0.20 ± 19.87%	6.07 ± 6.04%	4.90 ± 6.33%	10.74 ± 11.32%	< 0.19
25/04/2015	VC31	2.15 - 2.45	< 0.13	< 0.13	8.61 ± 5.96%	9.23 ± 5.67%	14.70 ± 9.35%	< 0.28

VOLUME 2 APPENDIX 21E

SIZEWELL C- MARINE WATER AND SEDIMENT QUALITY SYNTHESIS (MSR2/6).

2019. BEEMS TECHNICAL REPORT TR306 EDITION.5.

TR306 Sizewell Marine Water and Sediment Quality Synthesis Report MSR2/5

BEEMS Technical Report TR306 Edition 5

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List of Tables and Figures

Tables

Please note that the red line boundary used in the figures within this document was amended after this document was finalised, and therefore does not reflect the boundaries in respect of which development consent has been sought in this application. However, the amendment to the red line boundary does not have any impact on the findings set out in this document and all other information remains correct.

Figures

Executive summary

The Centre for Environment, Fisheries and Aquaculture science (Cefas) supported by a network of subcontractors has been contracted by SZC Co to undertake the necessary marine studies to provide the evidence base for the Sizewell C project Development Consent Order (DCO) application via a comprehensive set of studies known collectively as the BEEMS programme for Sizewell C. This report provides a synthesis of the marine water and sediment quality evidence relevant to the Environmental Impact (EIA) and Water Discharge Activity (WDA) Environmental Permit assessments. Specific evidence for the Sizewell C Water Framework Directive (WFD) assessment and the shadow Habitat Regulations Assessment (HRA) is presented in BEEMS Technical Report TR483 and is referenced in this report. Further detail can be found in the cited BEEMS Technical Reports that underpin this document.

The Sizewell C EIA scoping report (SZC Co, 2014a) lists the elements of the Main Development Site that could impact on marine water and sediment quality as follows:

During construction and commissioning

- Changes in water turbidity (cloudiness) and quality (contaminant mobilisation) due to the re-suspension of marine sediments into the water column during the construction of the cooling water intake and outfall vertical shafts and head structures, the construction drainage outfall (CDO), the fish recovery and return system (FRR) and the beach landing facility (BLF);
- Discharges to surface waters that enter the marine environment that include surface water drainage, and groundwater containing suspended sediment and contaminants. Added to these discharges at different rates at different times may be treated sewage effluent, chemicals used in tunnelling. All such discharges would be subject to permit and would have an appropriate level of treatment before discharge to the marine environment to meet permitted levels; and
- Potential changes to marine water quality because of chemicals that are used in the cold commissioning of Sizewell C and discharged via the CDO before there is a fully functional cooling water system.

During operation

- Discharge of treated sewage effluent to sea would occur via the cooling water system;
- The elevated temperature of the cooling water effluent would alter the thermal regime in the vicinity of the discharge point;
- Potential changes may occur to marine water quality because of process chemicals that will be used in the operation of the main development site and that are discharged in the cooling water effluent;
- Chemical and physical changes that may occur due to decay of any fish discharged from the Fish Recovery and Return system that do not survive passage through the system; and
- The occasional need to access the beach landing facility to receive deliveries of Abnormal Indivisible Loads (AILs) by sea during the operational life of the power station may result in localised changes in water turbidity (cloudiness) and quality (contaminant mobilisation) due to the re-suspension of marine sediments into the water column from dredging operations and vessel movements.

This report describes the potential effects of each of these elements and is set out as follows:

- Description of the area of assessment for the EIA;
- Description of relevant water and sediment quality standards
- Description of the water and sediment quality of the greater Sizewell Bay;
- Description of the marine components of the proposed Sizewell C development;
- Potential effects of the development on marine water and sediment quality;

- Effects of the proposed Sizewell C development activities acting in-combination;

Some of the potential effects of the main development site on marine water and sediment quality are dependent upon the engineering designs of specific coastal infrastructure. SZC Co have not finalised the detailed design of this infrastructure and will not be able to do so until engineering contractors have been selected to build the station. Some of the detailed analyses contained in this report are therefore subject to change. This report reflects engineering designs and proposed construction sequencing as at **March 2020** and where necessary adopts a Rochdale Envelope approach to bracket engineering uncertainties.

There are three main areas of activity for the proposed new build power station Sizewell C that are assessed for the potential to affect marine water and sediment quality:

I. Construction activities in the marine environment;
II. On site construction activities including cold commissioning for which there may be chemical discharge (these are considered for different Cases or examples of the combined discharges for groundwater, sewage and other construction inputs that vary across the construction period);
III. On site operation activities for which there may be a thermal inputs and chemical discharge

Tables A1 to A10 summarise the key assessments and significance of effects described to marine water quality and sediment that could be associated with the Proposed Development.

Changes to this Report

Changes in Edition 5 dated 4/3/20202

Dredging activities are considered separately and in combination. Hydrazine cold commissioning discharge level has been revised to better reflect expected discharge level for permitting. An additional load assessment for trace metal contamination (cadmium and mercury) of raw materials used for water treatment has been added. A section has been added on inter relationship effects of discharges from the CDO and those from Sizewell B cooling water outfall (section 5.14). An inter-relationships section has also been added to consider interaction of discharge sources in the cooling water discharge for Sizewell C and interaction with temperature. Corrections have been made to some of the loading values for operational chemicals as more information has become available none of the changes has had significant implications for predicted impacts.

Changes in Edition 4. 17/10/2019

The sediment plume data has been updated and individual dredging campaigns are considered separately for modelling to more accurately reflect sequence and overlap of activities. This report includes an assessment of tunnelling and commissioning discharges. Phytoplankton modelling is included to assess the combined influence of nutrients from construction and cold commissioning. A section has been added on the potential influence of climate change on thermal effects of the cooling water plume. The potential influence of dead fish from the Fish recovery and return system is also included and an assessment made. Corrections have been made to some of the loading values for operational chemicals as more information has become available none of the changes has had significant implications for predicted impacts.

Changes in Edition 3. 7/06/2019

The report has been restructured so that construction description and assessment sections follow each other as do those for commissioning and for operation. These changes are to improve readability in response to regulator comments on the previous draft of this report and from the MTF in March 2019.

The methodology for screening and assessment of large cooling water discharges has been fully adopted for the operational assessment and the results of screening assessments updated accordingly.

A further modelling assessment was conducted to assess nutrient inputs and the results are included. Further work is underway to provide an assessment of potential discharges from tunnelling and from commissioning. The sediment plume assessment will also be updated with assessments that separate out individual dredging campaigns for modelling to more accurately reflect sequence and overlap of activities. This is not expected to increase the impact indicated in the present assessment.

Changes in Edition 2. 8/03/2019

The model runs for Sizewell B for chlorination (Total residual oxidants, TRO) and for bromoform have been repeated due to some inconsistencies in calculation of areas affected for initial runs and are provided in this report. This is has led to small changes in the predicted areas affected for the Sizewell B only run. Small differences in the prediction for Sizewell C area affected also resulted and have been corrected.

Section 6.2.3 ammonia in groundwater and sewage during construction - ammonia source data there are some small changes in derived values due to the use of 50%ile rather than mean values for pH and salinity. This change made to ensure consistency of approach throughout. Resultant changes to derived un-ionised ammonia are insignificant. The small change in the percentage mixing of construction discharge with seawater upon discharge that result has led to small revisions of distance to achieve dilution below the un-ionised ammonia EQS.

In section 6.2.1 a fuller explanation of the thermal elevation of different component sources that make up the cooling water discharge is provided.

Table 18 ammonia source data there are some small changes in derived values. This change resulted from a correction to use a 50%ile pH value rather than a 95%ile in the un-ionised ammonia calculation.

Section 6.2.4.1 localised effect of DIN the case E volume discharges were incorrect in the text although the correct values were used to derive relevant load figures.

Section 6.2.4.4 the assessment of BOD has been made consistent across construction and operation and with previous assessments and more detail is provided.

Table A1 Scale of construction activities in the marine environment with potential to influence sediment and water quality.

Structure	Activity	Influence of activity
Sediment	Disturbance	The sandy nature of the material and levels of contamination below Cefas Action Level 2 found in the marine sediment at Sizewell, there is a low risk of bioavailable contaminants. Sediments associated with dredging for the Planned Development are therefore considered to be uncontaminated and the effects of resuspension of contaminants on marine water quality and ecology receptors is not considered further.
Beach Landing Facility	Dredging	Capital dredging of the BLF would remove a total dredge volume of 4,600m^3. Modelling indicates sediment only settles on the bed over a relatively small area close inshore. Depth average location maximum SSC of more than 100mgl^{-1} above daily maximum background extend approximately 5 km north and south of the dredge site over an area of up to 108ha at the sea surface and 83ha as a depth averaged plume. Plume quickly disperses after dredge – low concentrations 20mgl^{-1} above background over three days. For maintenance dredging plumes of SSC of 100mg/l would affect an area of 108ha at the surface and 28ha at the bed but this elevation in SSC would relatively short-lived. Changes in SSC are not of sufficient duration and magnitude to alter the SSC status of the Suffolk Coastal Waterbody
Cooling water intake	Dredging	For intakes elongate area 13km north, 22km south ~2 km east-west affected by increases in SSC >100mgl^{-1}, depth averaged peak at >1,000mgl^{-1} above background. Elevated concentrations are short lived, with more typical SSC of 100mgl^{-1}. Following dredging, the plume quickly dissipates –ca., two days until at background. Changes in SSC not significant for marine water quality. Dredging for outfall similar SSC elevation and time to return to background.
	Drilling and shaft insertion	During the drilling of the bedrock at the intake structures, a very diffuse plume with SSC of around 5mgl^{-1} relative to background may occur– Changes in SSC not significant for marine water quality
	Installation head	Head is lowered into place, not cast in-situ so no predicted foreign material release effects to the water and sediment quality of the local area
Cooling water outfall	All activities	As for intake
FRR and CDO	Dredging	No areas are subjected to increased surface SSC of more than 50mg/l for more than 6 hours.
	Drilling	Tunnel approximately 0.8m diameter directionally drilled from onshore with drill cuttings returned to land no predicted sediment resuspension effects to the water. There are no details available for chemical selection and quantities required for tunnelling but conservative values for products assessed for use at HPC are evaluated for Sizewell. Changes in SSC not significant for marine water quality
	Installation of head	Head lowered into place, not being cast in-situ so negligible predicted foreign material release effects to the water and sediment

Table A2 Construction discharges via the CDO with potential to influence marine sediment and water quality.

Determinand	Influence of discharge
Metals load	Combined discharges for groundwater were assessed for contribution against the annual load limits for the priority hazardous substances cadmium and mercury of 5kg and 1kg cumulative loads. These values are not exceeded by the discharges during any phases of construction. Consideration also made of potential additional inputs from trace metal contamination of water teatment chemicals used for demineralisation of water and these combined additions did not exceed annual load limits.
Metals thresholds	Several metals are present in groundwater. Chromium and zinc fail screening and were modelled. Chromium plume is below EQS at<25m and zinc is undetectable above background at<3m from the CDO outfall. Not significant.
Ammonia	Maximum ammoniacal nitrogen contributions from groundwater and sewage for the construction period were evaluated. Exceedance of the EQS for un-ionised ammonia (21µgl^{-1}) maximum only occurs within 6.3m of the point of discharge. Not significant
Nutrients DIN and phosphorus	Maximum dissolved inorganic nitrogen and phosphorus contributions from groundwater and sewage were combined with the nitrogen and phosphorus loading used during commissioning. These loadings provided source terms for input to a combined phytoplankton and macroalgae model. Run over an annual cycle the model showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.13% for maximum construction and commissioning inputs of DIN and phosphorus. Not Significant
BOD	Using 13.3ls^{-1} and BOD of 40mgl^{-1} and taking account of groundwater contributions a maximum daily BOD of 121kg was calculated. This represents an oxygen requirement of 40.6kg/day. This amount of oxygen would be transferred across 1.2ha in a day and reaeration at the sea surface would also contribute. There is therefore considered negligible impact on the well mixed and well oxygenated waters off Sizewell from this discharge. Not Significant
Microbiological	*E.coli* meets bathing water standards <1m of the outfall with UV treatment and intestinal enterococci are ≤200 cfu/100ml at discharge the nearest Bathing water is 10k North of the discharge. No impact.
Tunnelling wastewater and chemicals	The offshore cooling water infrastructure consists of two subterranean intake tunnels and one outfall tunnel. Tunnels would be excavated by tunnel boring machines (TBMs) from land. Three chemicals used to facilitate tunnelling and that might be discharged at Sizewell were evaluated in terms of significance of discharge concentration. Conservative scenarios were modelled for a clay mineral (bentonite) that may be required at Sizewell and based on Hinkley Point information for two surfactant chemicals. The low toxicity of bentonite, the small areas affected (concentrations of 10µgl^{-1} restricted to sea surface areas of mean 1.35ha and a 95th percentile area of 10.8ha) and the low discharge concentrations are likely to have negligible effects on water quality. For both surfactants assessed no exceedance of the EQS occurred at the seabed and the maximum area of exceedance at the surface was small with highest mean exceedance of 3.14 ha and 25ha as a 95th percentile. Not significant for marine water quality.

Table A3 Commissioning discharges via the CDO with potential to influence marine sediment and water quality.

Determinand	Influence of discharge
Commissioning discharges	For commissioning the predicted discharge concentrations of phosphate were already assessed in combination with construction discharges. The circuit conditioning chemical ethanolamine passed the H1 test 5 dilution screening test and hydrazine and un-ionised ammonia were evaluated using GETM discharge modelling via the CDO. Hydrazine would be treated to achieve a maximum discharge concentration of 30μgl^{-1}. This discharge was assessed in terms of areas of exceedance for the acute and chronic hydrazine PNEC and intersection with the Minsmere sluice, the Coralline Crag and the foraging area for three SPA breeding colonies of birds. Hydrazine only intersects the sluice on the ebbing tide when it is likely to be closed. Passage of species like Eel that move to and from the saltmarsh via the sluice are not expected to have a significant affect as the peak concentrations are 800,000-fold less than levels shown to cause sublethal effects in fish. Peak hydrazine concentrations over the coralline crag do not exceed the precautionary chronic PNEC. The hydrazine plume never intersects foraging areas for two of the three SPA breeding colonies of birds. The hydrazine plume does intersect foraging areas for the Minsmere Little Tern colony. Whilst the plume intersection with 15μgl^{-1} release concentration regularly exceeds 1% of the foraging range, the duration of the plume is short, with concentrations exceeding the acute PNEC for no longer than 4 hours a day. These changes are evaluated not significant for marine water quality, but further assessment is relevant for specific receptors. The un-ionised ammonia discharge during commissioning is rapidly reduced by the changing pH and salinity as well as by dilution as it mixes with seawater. Exceedance of the annual average EQS for un-ionised ammonia is predicted to only to occur in the direct vicinity of the discharge point and to be below the EQS 25m from the point of discharge. This change is not considered significant for marine water quality. As for the construction discharge assessment the total ammonium concentration at the point of mixing described above is at background for total ammonia and well below levels of concern.

Table A4 Inter-relationship effects during the construction period

Determinand	Influence of discharge
Overview	This section provides a description of the identified inter-relationships that have the potential to affect marine water quality and sediment from construction and cold commissioning of the proposed development. Activities include potential for overlapping dredging for different infrastructure. Assessment of the construction discharges have already accounted for maximum potential inputs of the same substances from different phases of construction and cold commissioning. Here the interaction of the effects of the discharge from the CDO and the Sizewell B cooling water discharge plume are also considered.
Dredging activity	Simultaneous dredging activities may occur for some elements of the development. The suspended sediment plumes from the BLF maintenance dredge and the cooling water infrastructure do not interact, forming two discrete plumes. Therefore, the concurrent activities result in a greater spatial area of impacts rather than interactive effects. Increases in the total size of the instantaneous SSC plume are minimal. The suspended sediment plume from the BLF maintenance dredge and the FRR dredge plume do interact. At the sea surface the maximum instantaneous area exceeding 100mg/l increases to 111ha. The plume is highly transient and the total duration of increases in SSC would be reduced due to the temporal overlap. Simultaneous overlap of BLF maintenance, CWS intake and FRR outfalls would represent an area equivalent to 5% of the Suffolk Coastal waterbody this area of exceedance would occur for <5% of the year assuming e.g. monthly maintenance dredging and dredging of six CWS intakes and outfalls.
CDO chemical discharge and thermal elevation Sizewell B	CDO chemical discharges have a small area of exceedance at EQS levels <25m so the influence of thermal elevation at ca. 5°C above background would be very limited and insignificant.
Chlorinated discharge Sizewell B and ammonia input CDO	Chlorine and ammonia at similar molar concentrations and at low concentration can react in full strength seawater to form, predominantly, dibromamine which has higher toxicity than TRO alone. However, TRO typically at ca 20µg/l and ammonia NH4-N rapidly decreases to ca., 11µg/l at around 25 metres of the discharge meaning that the concentration of any combination products would be at very low concentrations and within a limited area around the CDO.

Table A5 Operation activities and discharges (cooling water thermal input) with potential to influence marine temperature and dissolved oxygen saturation.

Type of discharge	Influence of discharge
Cooling water – Thermal SPA	The absolute areas of exceedance for each thermal standard that applies to the SPA were assessed: For the 2˚C uplift threshold based on a maximum excess (100th percentile) the absolute areas of exceedance range between a minimum area of 5,219ha at the seabed for Sizewell B to 22,464ha at the surface for Sizewell B + Sizewell C. The second criteria for SPAs concern the 98th percentile of the absolute temperature. The predicted absolute areas where the plume temperatures exceed 28˚C are all below 1ha based on a calculated mean excess of >8.6˚C added to the 98%ile for Sizewell. In some cases, large areas are influenced by the thermal change but the magnitude is not evaluated as significant for marine water quality, but individual receptor assessments are further considered in the Marine Ecology Environmental Statement Chapter 21.
Cooling Water Thermal WFD	The absolute areas of exceedance for each thermal standard that applies to the WFD waterbodies was assessed: For the 2˚C uplift threshold based on a 98th percentile of >23˚C the absolute areas of exceedance range between a minimum area of 8.75ha at the seabed for Sizewell B to 89.6ha at the surface for Sizewell B + Sizewell C. For excess temperatures of 2˚C as a 98th percentile this was exceeded for a minimum of 2126.71ha at the seabed for Sizewell B and 7899.17ha at the surface for Sizewell B +Sizewell C In some cases, large areas are influenced by the thermal change but the magnitude is not evaluated as significant for marine water quality but individual receptor assessments are warranted.
Cooling water – Thermal effect on Oxygen WFD	The effect of the thermal discharge on the oxygen saturation of the surrounding area has been derived using modelling. GETM runs show the area calculated that is beneath various DO concentrations for the entire model domain. The derived average DO concentration for the model domain for both Sizewell B and Sizewell C and Sizewell B alone is>5.77mgl^{-1} as a 5th percentile which is at or above the WFD threshold for High Status of 5.7mgl^{-1}. The influence of this change on marine water quality is not evaluated as significant
Cooling water – Thermal effect on percentage un-ionised ammonia WFD	The calculated mean ammonia discharge concentration was added to either the mean or 95 percentile un-ionised ammonia regional background value derived using the temperature fields generated by GETM and the relevant physicochemical data and total ammonia concentration for each scenario to derive the un-ionised ammonia calculation. The predicted mean increase in un-ionised ammonia was at maximum 13 times below the EQS of 21µgl^{-1}. The influence of this change on marine water quality is not evaluated as significant

Table A6 Operation activities and discharges (cooling water chemical input, TRO, CBP and hydrazine) with potential to influence marine sediment and water quality.

Type of discharge	Influence of discharge
Cooling water - TRO	For the Sizewell C discharge plume there is a small area of 2.13ha that exceeds the TRO EQS 95th percentile of 10µgl^{-1} for Sizewell C at the seabed and over ~337ha at the sea surface. The Sizewell C plume does not mix with the Sizewell B plume. (The absolute values for Sizewell B and Sizewell C in combination exceed the TRO EQS 95th percentile of 10µgl^{-1} over 726ha at the surface and 167ha at the seabed. In some cases, large areas are influenced by TRO concentrations above the EQS but as TRO is not persistent the effects are not evaluated as significant for marine water quality, but individual receptor assessments are further considered in the Marine Ecology Environmental Statement Chapter 21.
FRR - TRO	An initial assessment of discharge of chlorinated seawater from this system was made in BEEMS TR333 and all the potential tunnel locations passed the assessment. However, intakes and tunnels will not be chlorinated.
Cooling water – CBP's	The Bromoform discharge was modelled for 132m^{3}s^{-1}. The Bromoform plume area that exceeds the applied EQS (PNEC 5µgl^{-1} as a 95th percentile) for Sizewell C only at the seabed is ca., 0.15ha and ca.,52ha at the sea surface. The Sizewell C plume does not mix with the Sizewell B plume. The combined plumes for Sizewell B and Sizewell C result in an area of ca., 357ha at the surface and ca.,130ha at the seabed. In some cases, large areas are influenced by bromoform concentrations above the EQS but based on toxicity and persistence the effects are not evaluated as significant for marine water quality, but individual receptor assessments are further considered in the Marine Ecology Environmental Statement Chapter 21.
Cooling water - Hydrazine	Hydrazine discharges exceed the acute and chronic quality standard (PNEC) values for discharge concentrations derived from both 24-hour and annual loadings. The chronic PNEC 0.4ngl^{-1} is exceeded at the surface and at the seabed, although in the latter case, an area of less than 1ha is affected for both discharge scenarios. The acute PNEC 4ngl^{-1} is exceeded at the surface (for less than 18ha) and at the seabed, but only in the case of the 69ngl^{-1} release for an area of 0.13ha. Relatively small areas are influenced by hydrazine concentrations above the acute or chronic EQS. These values are precautionary and so the effects are evaluated as not significant for marine water quality, but individual receptor assessments are further considered in the Marine Ecology Environmental Statement Chapter 21.
Various substances screened out	Various substances (copper, zinc, chromium) exceeded the 24 hour or annual discharge assessment but this resulted from high background concentrations and predicted discharge concentration for these substances would be below detection limits, so they were screened out. Other substances that have no PNEC and reference site background cannot be effectively assessed but again most are below detection limits so again are screened out of further assessment

Table A7 Operation activities and discharges (Un-ionised ammonia, dissolved inorganic nitrogen, phosphorus and microbiological parameters) with potential to influence marine sediment and water quality.

Type of discharge	Influence of discharge
Un-ionised ammonia	During operation the concentration of ammonia predicted in the discharge has been added to the site background and predictions of un-ionised ammonia concentrations derived for the discharge to Sizewell Bay. All cases (including worst cases) for un-ionised ammonia show that no areas exceed the EQS of $21 \mu g l^{-1}$ NH_3-N as an annual mean. Evaluated as not significant for marine water quality.
DIN	The predicted DIN loading during operation 332kg represents ca., 2% of the exchange per day in summer between Sizewell Bay, the outer tidal excursion and the wider area. Based on these values and combined with PO_4-P a phytoplankton and macroalgal growth Box model run over an annual cycle showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.11%. Evaluated as not significant for marine water quality but further receptor evaluation evaluations are considered in the Marine Ecology Environmental Statement Chapter 21.
Phosphorus	The predicted phosphorus loading during operation PO_4-P gives a value of 114.8kg. This loading represents ca., 5% of the PO_4-P exchange per day in summer between Sizewell Bay, the outer tidal excursion and the wider area. Based on these values and combined with DIN a phytoplankton growth Box model run over an annual cycle showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.11%. Evaluated as not significant for marine water quality but further receptor evaluation evaluations are considered in the Marine Ecology Environmental Statement Chapter 21.
Microbiological parameters	During operation the maximum number of staff on site is estimated at 1900 based on HPC. If UV treatment is applied to the predicted sewage effluent volume discharge and assuming a 5.4 log reduction in specific microorganisms compliance would be achieved at the point of discharge. Evaluated as not significant for marine water quality.

Table A8: Discharges of moribund fish from the FRR with potential to influence marine sediment and water quality.

Type of discharge	Influence of discharge
FRR moribund fish influence on nutrient status	Nitrogen and phosphorus concentrations from decaying fish biomass predicted to be discharged from the unmitigated FRR and based on annual average fish loadings were assessed in a model run in combination with operational inputs using a Combined Phytoplankton and Macroalgae Model. A model run over an annual cycle predicts a less than 0.29% difference in annual gross production of carbon and this level of change would not be discriminated above natural background variation. Evaluated as not significant for marine water quality but evaluations for marine ecology receptors are considered in the Marine Ecology Environmental Statement Chapter 21.
FRR moribund fish influence on un-ionised ammonia	The un-ionised ammonia input from decaying biomass from the unmitigated FRR was derived for the maximum annual biomass loading. Relevant seasonal pH and temperature which influence the proportion of un-ionised ammonia were also accounted for an equivalent area of 6.7ha would potentially exceed the un-ionised ammonia annual average EQS. This area of exceedance is considered to be low relative to the potential for mixing and exchange of water across the GSB. Evaluated as not significant for marine water quality but further considered in the Marine Ecology Environmental Statement Chapter 21.
FRR moribund fish influence on dissolved oxygen	The effect of biomass decay on dissolved oxygen was also derived. The calculated annual mean daily biomass oxygen demand represents 0.2% of the oxygen available in the volume of water exchange across the Greater Sizewell Bay. Reaeration at the surface would also resupply oxygen with typical values of surface exchange for this area providing an equivalent loading to that consumed by the biomass discharge over an area of ca., 14ha. For the maximum predicted discharge of biomass during March oxygen demand would increase to 0.6% of that available from daily exchange and would be equivalent to reaeration over 45.2ha. Evaluated as not significant for marine water quality but further considered in the Marine Ecology Environmental Statement Chapter 21.

Table A9: Influence of climate change on Operational discharges.

Type of discharge	**Influence of discharge**
Cooling water – Thermal	Thermal uplifts above ambient are predicted to be largely independent of the background sea temperature. Therefore, thermal uplift areas are predicted to remain largely unchanged under future climate scenarios. The results indicate that future climate change is not predicted to significantly increase the absolute areas in exceedance of 28ºC, which remain under 1ha for all scenarios tested. Following the decommissioning of Sizewell B, 28ºC as an absolute temperature is not predicted to be exceeded as a 98th percentile even under the extreme climate case of the proposed development operating in 2110. Therefore, thermal effects in the receiving waters are predicted to remain minimal. Whilst climate change would act in-combination with the proposed development to increase areas of exceedance, receptors exposed would be acclimated to a modified thermal baseline. Furthermore, changes in species composition may have occurred independently of the proposed development. For species exposed to the thermal plume, effects would be like those predicted for the current baseline.
Cooling water - TRO	TRO decay will increase at elevated temperatures, but dosing is adjusted to ensure that the target TRO of 0.2mgl^{-1} is achieved in critical sections of the CW plant. The residual oxidant level at the point of discharge is therefore unlikely to be reduced under climate change. The ratio of oxidant chemicals formed upon chlorination of seawater is influenced by pH. Lowering pH could in theory reduce toxicity but the pH change and influence on ratio of hypobromous and hypochlorous acid is not considered significant so the assessment remains the same as for current conditions.
Cooling water – CBP's	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
Cooling water - Hydrazine	Hydrazine half-life 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.

Table A10: Inter relationship effects Operation

Type of discharge	Influence of discharge
Synergistic effects chlorinated discharge and treated sewage effluent	Seasonal chlorination and un-ionised ammonia from treated sewage discharge have the potential to interact in the cooling water discharge. The level of total ammonia discharged including current background levels is low and represents an increase of ca.30% of the present mean background total ammonia. The synergistic effects of chlorination and ammonia discharges may result in the formation of additional combined products. However, the low level of ammonia available to interact with chlorinated seawater would limit the byproduct formation to below levels of significance in terms of change to toxicological influence of the chlorinated seawater alone.
Synergistic effects of temperature and toxicity of chlorinated seawater	Beyond the immediate point of discharge ca 10-20m the residual oxidant exposure would be low at a few 10s of micrograms/litre and the thermal elevation would be a few degrees above background. Beyond this point the low level of thermal elevation and its influence on the toxicity of residual oxidants would be insignificant. The area affected with potential for synergistic effects of temperature on chlorinated seawater toxicity would therefore be very limited.

1 Background

SZC Co proposes to construct and operate a new nuclear power station (new nuclear build, or NNB) immediately to the north of the existing Sizewell B station on the Suffolk coast. Under the Planning Act 2008, this development, as with other nationally-significant infrastructure projects, requires a Development Consent Order (including, in the case of conservation areas, a Habitats Regulations Assessment) to be granted by the UK Government's Planning Inspectorate. The marine aspects of the development will also require regulatory permits for, amongst other activities, cooling water discharges and activities that disturb the seabed. Decisions on permissions will be taken based on an Environmental Impact Assessment (EIA) encompassing the key ecological features of the site and including all marine activities associated with the development.

In 2007, British Energy (now EDF Energy) commissioned Cefas to undertake a programme of marine studies to underpin the Sizewell C development. This programme, termed BEEMS, is tasked with providing authoritative scientific advice encompassing the whole of the marine ecosystem (marine ecology and fisheries, coastal geomorphology and hydrodynamics and marine water and sediment quality), in terms of construction and operation as well as the Development Consent Order and associated permits and licences.

This marine water and sediment quality synthesis is intended to provide detail on the potential impacts of the construction, commissioning, and operational activities of the proposed Sizewell C power station. It is intended to inform the EIA, Water Discharge Activity (WDA) Environmental Permit and Marine Licence assessments for the development. It does not include assessments for the Habitats Directive (HRA) or the Water Framework Directive (WFD) which are considered in BEEMS TR483. Decommissioning will be the subject of a separate environmental assessment when relevant details are known. The Environmental Statement (ES) will assess the potential in-combination (activities associated with Sizewell C) and cumulative effects (activities associated with Sizewell C plus activities from other relevant developments), this will be included in the ES. Zones of Influence (ZoI) are established for these assessments and the Planning Inspectorate guidance will be adhered to.

The marine components of the development site include:

1. Coastal Defence Features (CDFs);
2. Beach Landing Facility (BLF);
3. Cooling Water Infrastructure including Intakes and Outfall heads;
4. Fish Recovery and Return (FRR) systems, and;
5. Combined Drainage Outfall (CDO).

The elements of the Main Development Site that could impact on marine water and sediment quality are as follows:

During construction and commissioning

- Changes in water turbidity (cloudiness) and quality (contaminant mobilisation) due to the re-suspension of marine sediments into the water column during the construction of the cooling water intake and outfall vertical shafts and head structures, the fish recovery and return system, the CDO and the BLF;
- Discharges to surface waters that enter the marine environment that include surface water drainage containing suspended sediment, contaminants and treated sewage effluent. All such discharges would have an appropriate level of treatment before discharge to the marine environment; and
- Potential changes to marine water quality because of chemicals that are used in the commissioning of the Main Development Site.

During operation

- Discharge of treated sewage effluent to sea would occur via the cooling water system;
- The elevated temperature of the cooling water effluent would alter the thermal regime near the discharge point;
- Potential changes may occur to marine water quality because of process chemicals that will be used in the operation of the Main Development Site and that are discharged in the cooling water effluent; and
- The occasional need to access the beach landing facility to receive deliveries of Abnormal Indivisible Loads (AILs) by sea during the operational life of the power station may result in localised changes in water turbidity (cloudiness) and quality (contaminant mobilisation) due to the re-suspension of marine sediments into the water column from dredging operations and vessel movements.

Some of the potential effects of the Main Development Site on marine water and sediment quality are dependent upon the engineering designs of specific coastal infrastructure. SZC Co have not finalised the detailed design of this infrastructure and will not be able to do so until engineering contractors have been selected to build the station. Some of the detailed analyses contained in this report are therefore subject to change. This report reflects engineering designs and proposed construction sequencing as at **March 2020** and where necessary adopts a Rochdale Envelope approach to bracket engineering uncertainties.

1.1 Area of assessment for the EIA

The Greater Sizewell Bay (GSB) is considered as the initial reference area for the study site. 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 on the bank. The landward limit of the marine study area is delineated by Mean High Water Springs (MHWS).

The GSB is not a closed system and water exchanges with the rest of the southern North Sea. The Zone of Influence (ZoI) for development impacts is therefore dependent on hydrodynamic processes. For the EIA, the potential ZoI is dependent on several factors including; the position and duration of the discharge, the behaviour and persistence and/or degradation rates of the discharge components, bathymetry, and the state of the tidal cycle. Construction and 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.

Sizewell B intakes and outfalls are located within the Sizewell-Dunwich Bank (Figure 1) and discharge into the receiving waters of the GSB. Construction discharges from the CDO and operational discharges from the FRRs associated with Sizewell C would also occur within the GSB and would be transported throughout the inner tidal excursion within the Sizewell-Dunwich Bank. This excursion has been determined through particle tracking and is approximately 20.8 km North-South and approximately 3.5 km east-west. More detail on the calculation of the inner tidal excursion is provided in Appendix A.

The Sizewell C cooling water intakes and outfalls are located 3km offshore, beyond the Sizewell-Dunwich Bank, and therefore operational discharges would be within a different and larger tidal excursion.

The proposed tidal excursion associated with the Sizewell C intake locations (BEEMS Technical Report TR385), is approximately 15.9 km, and 1.4 km east – west during spring tides. The trajectory of the tide flows both north and south, thus the tidal volume represents a body of water 31.8 km long and approximately 2.8 km wide. The area and volume based upon the average depth, of the associated ZoIs are shown in **Error! Reference source not found.** (Table 37 and the respective tidal excursions are shown in Figure 15). The calculated data provide similar approximate volume and area estimates to confirm those applied in TR385, to enable model predictions of the effect of Sizewell C on phytoplankton community biomass and these are the values used for this report.

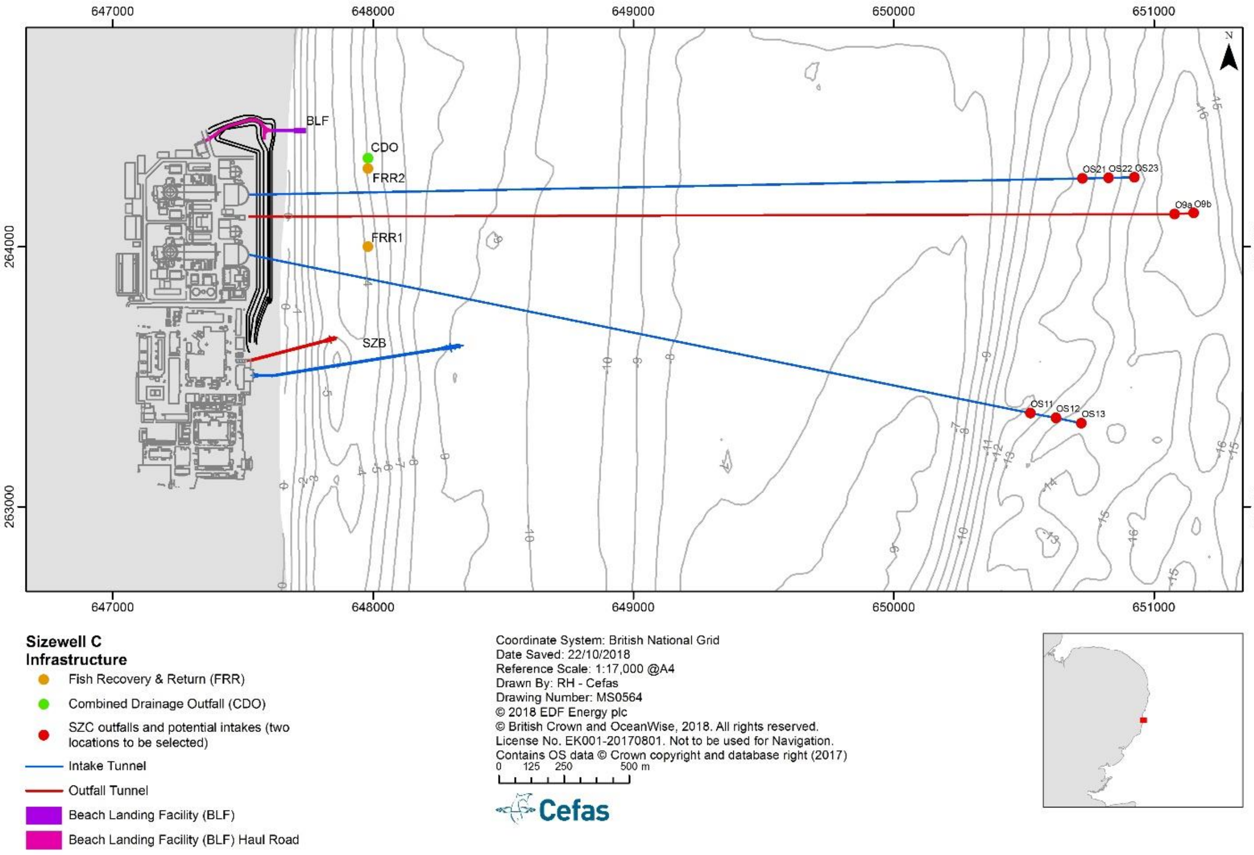


Figure 1: Schematic of development locations in the marine environment overlaid on bathymetry, blue indicates intake tunnels, red indicates outfall.

This report considers the influence of absolute areas of activity or discharge impact that exceed relevant water quality standards or applied values.

To prevent confusion with HRA and WFD assessments, this synthesis determines the absolute area of developmental impacts relative to hydrodynamically-relevant spatial and temporal scales, rather than considering effects within the specific WFD waterbodies or European designated sites. Marine water and sediment quality have no direct conservation value as they are not a designated features within this area. The area has some socioeconomic value as it contains recreational beaches and bathing waters (below MHWS).

The sea adjacent to the Main Development Site (MDS) is part of the Outer Thames Estuary Special Protection Area (SPA) and the Southern North Sea Special Area of Conservation (SAC) for harbour porpoises and the Suffolk Coastal waterbody and supporting elements. The evidence base for marine impacts of the development relative to WFD and Habitats Directive standards is addressed in BEEMS Technical Report TR483.

1.2 Marine water and sediment quality standards

1.2.1 Background

All direct cooled power stations require large quantities of cooling water to remove low grade waste heat resulting from the condensation of the steam used to drive turbo-generators. Where cooling water is abstracted from and discharged to surface waters, it is important that potential impacts on receiving water quality are carefully assessed. Some of the legislation requires that specific standards are not exceeded – these primarily relate to chemical parameters – but in other cases the requirement is that water quality status based on several biological and physical parameters is not negatively influenced by human activities. Good surface water status is one of the principal objectives for surface water bodies not designated as heavily modified or artificial under the Water Framework Directive. Those designated as heavily modified have a target of good ecological potential – that is, to achieve ecological quality that is as good as it can be, taking account of the modifications that give it heavily modified status. The other principal objective is to prevent deterioration of surface water status (UKTAG, Surface Water classification, 2007). In this latter case, particularly in relation to areas that are protected or that have special conservation status, there is greater uncertainty as to what constitutes acceptable levels of chemical and physical change to water quality and how this links to biological quality elements which can only be resolved by a detailed consideration of potential effects.

1.2.2 Thermal effects and standards

Table 1 summarises the legislation associated with thermal discharges. The primary change to cooling water discharged from power stations is increased temperature. The potential effects of a thermal plume are predominantly on sessile and sedentary benthic organisms that cannot avoid the plume. However, due to the plume buoyancy, appropriately designed thermal outfalls do not result in large areas of elevated seabed temperature. Planktonic organisms that drift with the tidal currents are only potentially at risk when they enter the mixing zone where the plume dilutes in the receiving water.

The potential effects of a thermal plume are predominantly:

- Acute effects – lethal effects where temperatures approach critical thresholds for a species (most likely close to parts of the cooling water system where rapid temperature increase occurs)
- Chronic effects – long term effect on biological processes (e.g. growth, reproduction) where the concern is elevation of mean temperatures

In addition, as fish can actively avoid areas of high temperatures, if they so choose, it is necessary to consider:

- Any potential thermal barriers to fish migration and the linked concern about the potential displacement of fish prey out of marine bird foraging ranges.

There is also a potential chronic effect at short ranges from some cross-shore outfall designs due to daily temperature fluctuations caused by the passage of large magnitude thermal fronts over benthic organisms, but this effect would not be expected to occur near the proposed relatively deep-water Sizewell C discharge.

The EU Water Framework Directive (WFD) was transposed into law in England and Wales by the Water Environment (Water Framework Directive) (England and Wales) Regulations 2003. To meet the requirements of the WFD, the competent authority (the Environment Agency) has set Environmental Objectives for each water body. A default objective in all water bodies will be to prevent deterioration in either the ‘Ecological Status’ (for natural water bodies) or the ‘Ecological Potential’ (for heavily modified or artificial water bodies). The ecological status of a surface water body is assessed according to:

a. The condition of relevant biological elements, for example fish, benthic invertebrates, phytoplankton, and other aquatic flora;
b. The condition of supporting physico-chemical elements, for example temperature, pH, oxygenation salinity and concentrations of nutrients;
c. The concentrations of specific pollutants; and

d. The condition of the hydromorphological quality elements, including morphological condition, hydrological regime, and tidal regime (coastal waters only).

The Water Framework Directive (WFD) process has developed water quality standards for temperature suitable for application to UK water bodies. These supersede UK standards based on the European Freshwater Fish Directive (78/659/EEC), which arose from European Inland Fisheries Advisory Commission (EIFAC) water quality criteria first published in the 1960s (Alabaster and Lloyd, 1980). Other relevant thermal criteria are associated with the Shellfish (Directive79/923 Shellfish Waters Directive, Article 22 of the WFD repeals Directive 78/659/EEC and Directive 79/923/EEC,22 December 2013.), for which a guideline value recommends that for shellfish waters, no more than a 2°C rise above natural background should result from a thermal input.

In interim guidance on marine protected sites (WQTAG 160,Guidance on assessing the impact of thermal discharges on European Marine Sites cited in Turnpenny and Liney, 2006) a 2ºC rise was stated as the maximum allowable increase at the edge of a mixing zone for Special Protected Areas and Special Areas of Conservation.

For WFD assessements, guidance issued by UKTAG (2008a and b) recommends that maximum temperatures at the edge of the mixing zone should not exceed 23ºC with maximum uplift of 3ºC. The principal issues for water quality in terms of temperature increase are set out in detail in Table 1 and are summarised as:

- the acceptable maximum temperature and maximum increase/decrease in temperature in relation to the status class of the water body concerned and with respect to specific environmental sensitivities, and the potential for thermal barriers to limit fish movement in the estuary
- the interaction of oxygen concentration and temperature – warmer water at standard air pressure will hold less oxygen than it would at lower temperature – leads to the recommendation in waters where DO is less than 5mg DO l^{-1}, that the maximum allowable water temperatures should be reduced by 4ºC for every 1mg of dissolved oxygen per litre below 5mg DO l^{-1}.
- the interaction of temperature, dissolved oxygen levels, pH change and ammonia toxicity where there is potential for impact upon a protected feature or for the development of water conditions that create barriers to the passage of migrating or juvenile fish
- the effect of temperature increase upon the release and bioavailability of sediment contaminants.

Temperature standards may be applied both temporally and spatially and compliance assessed accordingly:

- temperature may be allowed to exceed a standard value within a given mixing zone from the point of discharge
- temperature may be allowed to exceed a standard value for a given period of time
- temperature may be allowed to exceed a standard value over a fixed area of a water body (this may apply to surface area and cross section).

Guidance on mixing zones that is more readily applied to tidal waters was finalised in 2010 (Common implementation guidance, on setting mixing zones, 2010) with a focus on chemical inputs. The principle of mixing zones acknowledges that a standard for a chemical or a physical parameter may be exceeded in a discharge, providing dilution is sufficiently rapid to avoid an impact upon the biology of the receiving water beyond the point of initial dilution. In this context, the footprint of a discharge for temperature in which a standard is exceeded could be considered equivalent to the mixing zone when the area potentially impacted meets good practice guidance on cross-sectional area, does not result in the failure of standards set in terms of overall temperature increase in a water body, and temperature elevation with respect to particular sensitivities does not impact upon a significant percentage of a given habitat type.

Table 1: Summary of legislation primarily triggered by the direct and indirect impacts of thermal plumes (prolonged elevated temperatures).

POTENTIAL ACTION BY POWER PLANT: Thermal Discharge				
Activity	**Measurement**	**Threshold**	**Consequence**	**Directive**
Thermal plume, increase in temperature	Temperature of surface water	Set against WFD status thresholds not > (defined value) for more than 5% of time	Temperature and DO part of the ecological classification. Potential to directly impact on the health of biological elements. Classification integrated into overall ecology. Failure of temp or DO results in failure of water body	WFD assessment from 2009. Will continue to 2030
Decrease in Dissolved Oxygen (DO)	DO monitoring (high frequency)	DO value no less than 4 mgl^{-1} for more than 5% of time		WFD assessment from 2009. Will continue to 2030
Fish behaviour, fish mortality	Sub-metrics under the fish classification scheme in WFD	Failure of ecological quality ratios (EQR) in the overall sub-metrics	Changes in fish behaviour relating to migration patterns and spawning are identified in the fish classification scheme. Change in fish species composition must relate to a pressure	WFD assessment from 2009. Will continue to 2030
Benthic invertebrates	Temperature effects on benthic invertebrates: Acute effects temperatures near lethal levels; Stress caused by short-term fluctuation; chronic effects exposure for significant period of life cycle BEEMS SAR008 v2		More information needed	
Change in phytoplankton community	Sub-metrics under the phytoplankton tools	Failure of ecological quality ratios (EQR) in the overall sub-metrics	Significant deviation in community composition is part of the normative definitions and will be identified in the phytoplankton classification tools	WFD assessment from 2009. Will continue to 2030
Impact on SAC biological element	Measurable change in a protected species or conservation area	Measurable change in features extent or condition	Measurable change in a species or conservation area could impact on the high conservation species or area by altering the site integrity	Habitats Directive

1.2.2.1 Thermal standards in transitional and coastal waters (TraC)

Under the Habitats Directive and the Water Framework Directive indicative thermal boundaries have to be established to protect the most sensitive taxa, which have been discussed and agreed with the Environment Agency and Natural England. Existing thermal guidelines have mostly been derived from data on fish (Table 2 and Table 3).

The Habitats Directive has no specific temperature requirements but requires that European protected habitats and species be maintained or restored with strict protection of Annex IV species.

In 2006 WQTAG 160,"Guidance on assessing the impact of thermal discharges on European Marine Sites" cited in Turnpenny and Liney, 2006 recommended interim thermal standards for assessing SAC/SPA sites in estuarine and coastal sites under the Habitats Regulations based upon standards contained within the Freshwater Fish Directive (summarised in Table 2). To avoid impacts on migratory species in line with international good practice it is also recommended that the mixing zone should not occupy more than 25% of the cross-sectional area of an estuarine channel as a 95th percentile (BEEMS Science Advisory Report SAR008 v2). Temperature uplifts at the edge of thermal plume mixing zones had been described in the Freshwater Fish Directive, with values of 1.5 – 3.0°C, dependent upon the species being protected. In the review and development of temperature standards for marine and freshwater environments, Turnpenny and Liney (2006) recommend that "for water of high ecological status an uplift of 2°C be applied". This value being consistent with that set as a maximum allowable temperature for the edge of the plume mixing zone for Special Areas of Conservation that include sensitive migratory species such as salmonids (Turnpenny and Liney, 2006).

Table 2: Recommended interim thermal standards in WQTAG 160 (2006), Turnpenny and Liney (2006), SAR 008 (2011) for assessing SAC/SPA sites (when a site is both a SPA and a SAC the most stringent apply).

Designation	**Deviation from ambient**	**Maximum temperature**
Special Protected Area	2°C as a Maximum Allowable Concentration (MAC) at the edge of the mixing zone	28°C as an annual 98 percentile at the edge of the mixing zone
Special Area Conservation (any designated for estuary or embayment habitat and/or salmonid species)	2°C as a MAC at the edge of the mixing zone Cross-sectional guidance ≤2°C 25 % of the estuary for 98% of the time	Not >21.5°C as an annual 98 percentile at the edge of the mixing zone[1]

Recommended thermal thresholds for SACs designated for estuarine or embayment habitat and/or salmonid species, apply absolute temperature thresholds of 21.5°C as a 98th percentile (BEEMS SAR008 v2). These criteria are not applicable to fish assessments for the proposed development as salmonids are not designated features of the EMS within the ZoI of the thermal plume and the Southern North Sea SAC, directly adjacent to the proposed development is designated for harbour porpoise. As such, SPA absolute temperature criteria are applied.

The Water Framework Directive, WFD (2000/60/EC) is intended to provide a mechanism by which disparate regulatory controls on human activities that have the potential to impact on water quality may be managed in an effective and consistent manner. It supercedes the Freshwater fish directive which was repealed in 2013. UK TAG (2008a and b) produced draft standards for rivers that it was suggested could be used on an interim basis for transitional and coastal waters: Under this guidance, in order to achieve good status it is therefore necessary to ensure that maximum temperatures at the edge of the mixing zone do not exceed 23°C and that outside the mixing zone that temperature rises above ambient are limited to 3°C, Table 3.

Table 3: Recommended interim thermal standards in UK TAG 2008a and b for assessing sites under WFD.

Standard	High	**Good**	Moderate	Poor
Maximum temperatues (as an annual 98 percentile) allowed at the edge of the mixing zone	20°C	**23°C**	28°C	30°C
Deviation from ambient outside of mixing zone	2°C	**3°C**	3°C	3°C

1.2.2.2 *Interpretation of thermal standards for TraC waters*

The interim 2006 thermal guidelines for SACs were derived by transposition of thresholds in the Freshwater Fish Directive to marine waters without any substantial evidence base on their suitability. The 21.5°C was set as an absolute limit as a 98th percentile to protect SACs designated for estuarine or embayment habitat and/or migrating salmonid fish. Later recommendations. However, these criteria are not applicable to the Southern North Sea SAC designated for harbour porpoise. Absolute temperature thresholds for marine mammal sensitivity assessments consider SPA thresholds (28ºC as a 98th percentile). Turnpenny and Liney, 2006, based on a comprehensive review of temperature effects recommended that a cross sectional area criteria should be set to prevent thermal barriers to fish migration within river and estuarine channels. For fish species, a conservative thermal uplift of 3°C is considered a more appropriate avoidance threshold (BEEMS Technical Report TR483). Thus, 3°C will be taken into account for indirect effects.

In 2010 The Environment Agency issued “Guidance on Temperature Standards and Environmental Permit Requirments – informal guidance pending UKTAG decisions on TraC temperature standards”. This document, which was intended to guide both EA staff and NNB developers, states that the Environment Agency will use the cold water UKTAG (WFD) standards of 2008 as the basis for determining conditions for environmental permits for cooling water discharges from new nuclear power stations. The document also states that “in addition to the draft WFD standards, other temperature standards may need to be considered in relation to conservation designations and specific conservation objectives”

Unlike chemical standards which normally have a clear evidence link to ecological effects, thermal standards are not always evidence based due to a lack of reliable data (BEEMS Scientific Advisory Report SAR008 v2). In order to be protective of the most sensitive species, thermal standards have, therefore, been set on an indicative basis and, as such, they act as trigger values for further investigation of potential ecological effects.

BEEMS Scientific Advisory Report SAR008 v2 reviewed the available evidence on thermal effects and concludes:

> *“The available data confirms that adverse effects of CW outfalls are restricted to an area close to the plume, that temperature rises up to 3°C appear to be tolerable, and that resulting temperatures of less than 27°C have no clear deleterious impact on species in the receiving waters, but, in the longer term, changes in the local community may result as species with differing tolerances of elevated temperature show differing survival, growth and patterns of reproduction from those expressed under ambient conditions. Furthermore, populations that persist adjacent to a heated CW effluent will acclimate to those new local conditions and evolve in response to them”*

Two threshold values are recommended as trigger assessments for SPAs:

1. Temperature uplift ≤2˚C as a Maximum Allowed Concentration (MAC) at the edge of the mixing zone
2. 98th percentile of the absolute temperature ≤28˚C

The uplift criteria 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 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.

The absolute temperature standard for SPAs of ≤28°C as a 98th percentile does have a better evidence link as it is known than the upper lethal temperature for many benthic organisms is in the range 30-33°C (BEEMS Scientific Advisory Report SAR008 v2).

BEEMS Science Advisory Report SAR008 v2 prepared by the independent BEEMS Expert Panel presented evidence that the UKTAG 2008a and b WFD recommendations should be adopted for TraC waters with the single exception that the maximum temperature for High Status should be set at 23°C not 20°C.

Sizewell C modelling results in this report are assessed against the standards shown in Table 4.

Table 4: Water quality thermal assessment criteria applied in this report[1].

Designated Areas	Thermal thresholds (at the edge of the agreed mixing zone)
For SACs and SPAs	a.2006 WQTAG 160 interim guidleines for absolute and uplift temperatures (28°C[1] and 2°C respectively)
Special Area Conservation (any designated for estuary or embayment habitat and/or salmonid species)	b. the maximum cross sectional area criteria (estuaries should not be subject to temperature increase of >2°C across >25% of a cross section for >5% of the time).[2]
For WFD waterbodies	UKTAG 2008a and b cold water standards to achieve Good status of 23°C absolute[1] and 3°C uplift.

[1] Absolute temperatures from the GETM modelling cannot be reliably used as they produce overestimates. So more reliable prediction of 98th percentile absolute temperature can be derived at any location 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;[2] Recommended thermal thresholds for SACs designated for estuarine or embayment habitat and/or salmonid species, apply absolute temperature thresholds of 21.5ºC as a 98th percentile (BEEMS SAR008 v2). These criteria are not applicable to fish assessments for the proposed development.

1.2.2.3 *Dissolved oxygen*

The presence of dissolved oxygen at sufficient levels in all waterbodies including estuaries and coastal waters is essential to the survival and normal functioning of biological communities.

Oxygen depletion may occur over a number of timescales influenced by both seasonal and anthropogenic factors (Kemp *et al*. 2009). The solubility of oxygen varies with salinity, temperature and pressure (Garcia and Gordon, 1992) and an increase in water temperature will lead to a decrease in oxygen saturation. The other major factor controlling dissolved oxygen concentration is biological activity: photosynthesis producing oxygen while respiration and nitrification consume oxygen. The proposed provisional Water Framework Directives standards for dissolved oxygen shown in Table 5 reflect these issues, while remaining generally compatible with previous recommendations. They are all 5th percentile, i.e. they should be exceeded for 95 % of the time.

The thermal influence of the Sizewell C cooling water discharge on the dissolved oxygen concentration and saturation of the relevant waterbody and habitats will be assessed with reference to the relevant standards that apply.

Table 5: Dissolved oxygen standards for transitional and coastal waters [from UKTAG, 2008a and b].

WFD Status	**Freshwater 5%ile (mg l^{-1})**	**Marine 5%ile (mg l^{-1})**	**Description**
High	7.0	5.7	Protects all life stages of salmonid fish
Good	5.0–7.0	4.0–5.7	Resident salmonid fish
Moderate	3.0–5.0	2.4–4.0	Protects most life stages of non-salmonid adults
Poor	2.0–3.0	1.6–2.4	Resident non-salmonid fish, poor survival of salmonid fish
Bad	2.0	1.6	No salmonid fish. Marginal survival of resident species

1.2.3 Chemical effects and standards

During construction of Sizewell C there will be activities that have the potential to release chemicals to the environment.

- Wastes produced in the early phase of construction when no route for marine discharge is available will be tankered off site for appropriate disposal
- Surface water drainage potentially containing contaminants from construction processes
- Effluent from potable supply and from the treatment of sewage (grey and black water respectively) by the on-site treatment works;
- Water containing trace levels of various contaminants pumped from both groundwater and excavations during construction dewatering activities.
- Wash water from cleaning concrete production equipment.
- Waste water from horizontal cooling water system tunnelling operations (during construction).

In addition, when the cooling water system is commissioned a range of tests will be conducted and conditioning of the entire plant will be undertaken with demineralised water and various chemical additives. This process will generate waste water containing several chemicals that will be discharged through the construction drainage system. Chemicals known to be present in the commissioning discharge effluent will need to be at sufficiently low level so that upon discharge and dilution in the marine environment the mixing zone within which there is exceedance of any EQS (or applied value), and that overlaps with waterbody and habitat designations, is sufficiently limited.

During operation of the power station large volumes of cooling water will be discharged through the main cooling water system. Waste chemicals from various operations will contribute to the discharge as will chlorine produced oxidants and by-products resulting from chlorination of the system to prevent biofouling. As for the construction discharge the mixing zone within which there is exceedance of any given EQS or applied value must be sufficiently limited.

1.2.3.1 Chemical standards of relevance to the site

Under the Water Framework Directive, chemical status is assessed by compliance with environmental standards for priority chemicals and other substances that are listed in the EC Environmental Quality Standards Directive (2008/105/EC) as amended by Directive 2013/39/EU (implemented by the Water Framework Directive (Standards and Classification) Directions (England and Wales, 2015) which increased the list of priority chemicals to 45. Chemical status is recorded as 'good' or 'fail'. The chemical status classification for the water body is determined by the worst scoring chemical.

For the Water Framework Directive, 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) (EQSD), also known as the Priority Substances Directive and this was further updated in 2013, Directive 2013/39/EU. For Sizewell the relevant priority substances are cadmium, lead, mercury and nickel. Environmental Quality Standards (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”.

EQSs are concentrations below which a substance is not believed to be detrimental to aquatic life. These were originally developed for the EC Dangerous Substances Directive (76/464/EEC). The concept is now well established and is incorporated into the Environmental Quality Standards directive(2008/105/EC) which is a daughter directive of the Water Framework Directive (60/2000/EC). EQSs are derived using acute toxicity tests on organisms at different trophic levels. To provide a safety factor, the EQS is set substantially below the concentration observed to have a toxic effect on the test organisms. EQSs vary for each substance and can be different for fresh, estuarine or coastal waters. They may also be adjusted for individual waterbodies dependent upon the level of other local factors such as dissolved organic carbon concentration.

In the marine environment both ammonia in its ionised NH_4 and un-ionised NH_3 form may contribute to toxicity although it is the un-ionised form that is the most toxic. Ammonia may be lost from water by volatilisation or under aerobic conditions may be oxidised to nitrite and then nitrate. Various water quality parameters influence the toxicity of ammonia mainly by increasing the proportion of the most toxic, unionsed, form of ammonia. The pH of seawater has the most influence on ammonia toxicity, increasing it by 1 unit (e.g. pH 7 to 8) at 10˚C produces about a 10 fold increase in NH_3 concentration while increasing the temperature by 10˚C (10 to 20˚C) approximately doubles the NH_3 concentration. Increasing salinity from 0.5 to 32 ppt at 10˚C reduces the NH_3 concentration by about 15% (Eddy, 2005). The influence of the thermal input from Sizewell C upon the relative proportion of unionsed ammonia present within a given area of the relevant associated waterbodies and habitats will also need to be assessed with reference to the relevant standard that applies.

Nutrient inputs from agricultural areas and sewage discharges can have significant effects upon estuarine and coastal waters. The major concern for increased inputs of nutrients mainly nitrogen (nitrate) and phosphorus (phosphate) is the enhanced growth of attached and planktonic plants which if it reaches excessive levels can lead to oxygen depletion. For this reason, under the Water Framework Directive, dissolved inorganic nitrogen (DIN) thresholds are set for classification of WFD waterbodies. The assessment of nutrient status considers waterbody turbidity as more turbid waters limit light penetration and the depth within which phytoplankton can readily grow. So, in more turbid conditions a higher DIN threshold may be considered to represent Good status as it is less likely to result in undesirable increases in plant growth relative to a waterbody that is less turbid. DIN measurements for a waterbody are normalised to a salinity of 32 for coastal waters to allow different waterbodies to be compared and to take account of the fact that nutrient concentrations generally decrease from areas closer inshore that are influenced by riverine inputs relative to those further offshore.

The dissolved inorganic nitrogen (DIN) value referenced in Table 6 is based on the 99th percentile of the winter DIN values for waterbodies of intermediate turbidity. The threshold value shown in Table 6 is based on the annual average suspended particulate matter (SPM) levels which mean that under WFD for the Suffolk coastal waterbody to be considered at good status it would need be below or equal to an associated threshold 99th percentile winter DIN values for coastal waters of 980µgl^{-1} for Good and 1470µgl^{-1} for Moderate status (Water Framework Directive Standards and Classification Directions, 2015). The Suffolk coastal waterbody has been classified as of moderate status for DIN (2013-2016, Environment Agency Catchment data explorer, 2019). However, regional sea area 2, the Southern North Sea (Defra, 2010) 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).

To safeguard human health, legislative measures require the monitoring of faecal indicator organisms (FIO) concentrations in recreational and shellfish waters. The bathing water regulations (2013) classifies coastal bathing waters as of Good status based upon a 95%centile evaluation if intestinal enterococci are present at ≤200 colony forming units per 100ml sample volume and *Escherichia coli* are present at ≤500 colony forming units per 100ml sample volume. The Shellfish Water Protected Areas (England and Wales) Directions 2016 set standards for concentraion of FIO in shellfish flesh but the nearest shellfishery is over 40 kilometres South of Sizewell at Butley and so the focus was on bathing waters only.

There are no assigned marine EQS values for suspended solids, Biochemical Oxygen Demand (BOD) or petroleum hydrocarbons.

During the commissioning phase it is assumed that all Sizewell C conditioning chemicals will be discharged through the combined drainage outfall. All operational discharges will be via the cooling water system. For other chemicals likely to be present during these phases of development but for which there are no available EQS values a surrogate value has been derived. These chemicals include hydrazine, morpholine and ethanolamine. For the chemicals associated with the sequestering agents used in the demineralisation water plant (see BEEMS Technical Report TR193), there are currently no saltwater EQS or EDF validated PNEC values available. Therefore, ecotoxicity data (sourced from peer-reviewed publications and non-peer review literature such as industry reports) have been used with the recommended approach in the CIS guidance, 2003 to derive PNEC values that are used as environmental acceptance levels. The chemicals concerned are Amino tri-methylene phosphonic acid based sequestering agent (ATMP) or a sodium polymer-based compound (which comprises alkyl phosphonic acid and sodium polyacrylate). Breakdown products of alkyl phosphonic acid are acetic acid, phosphoric acid and Hydroxyethylidene Diphosphonic acid (HEDP). For some substances where no toxicity data can be sourced discharge concentrations are compared to environmental backgrounds identified during recent monitoring work (BEEMS Technical Reports TR189 and TR314). EQS or surrogate values used as environmental assessment levels are shown for all substances in Tables 45 and 46.

Table 6: Marine water quality standards referenced in assessment of planned discharges during the Sizewell C development – these represent Environmental Quality Standards (EQS) for other surface waters (TraC Waters) for priority hazardous substances and other pollutants (Directive 2013/39/EU) and for specific substances (Defra, 2014).

Determinands	**WFD EQS Annual average values (µgl^{-1})**	**WFD EQS Maximum Allowable Concentration (MAC) values (as 95 percentile) (µgl^{-1})**
Cadmium and its compounds (PS)	0.2	1.5
Lead and its compounds (PS)	1.3	14
Mercury and its compounds (PS)	-	0.07
Nickel and its compounds (PS)	8.6	34
Chromium VI (dissolved) (SP)	0.6	32
Arsenic (dissolved) (SP)	25	Not applicable
Copper (dissolved) (SP)	3.76 (2.677 x ((DOC/2) - 0.5)) µgl^{-1} dissolved, where dissolved organic carbon (DOC) > 1mgl^{-1}	Not applicable
Iron (dissolved) (SP)	1000	Not applicable
Zinc (SP)	6.8 (plus ambient background 1.1 in salt water)	Not applicable
Boron (Total)	7000 (pre Water Framework recommended standard)^{1}	-
Chlorine (SP)	-	10
Un-ionised ammonia (NH_3) (SP)^{2}	21	-
Winter dissolved inorganic nitrogen (DIN)		980^{3}
Escherichia coli		≤500 colony forming units/100ml^{4}
Intestinal enterococci		≤200 colony forming units/100ml^{4}

PS priority substance and SP – specific pollutant; 1 Mance et al. 1988; 2 Total ammonia values of 1100 (annual average) and 8000µg/l NH4-N are also recommended for habitats consideration (WQTAG086, 2005). 3 99% (70µmol) standard for period 1st November – 28th February for dissolved inorganic nitrogen for Good status for a waterbody of intermediate turbidity (between 10<100mgl^{-1} suspended particulate matter) Appendix B. 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 Environment Agency guidance and for an annual average SPM of 55.2 mgl^{-1} would give a slightly lower value of 952µgl^{-1} as a 99th percentile but the screening here would only slightly change. 4 This assessment is from bathing water regulations (2013. No. 1675) for coastal and transitional waters and represents Good standard

1.2.4 Marine Sediment standards

During the construction and operational phases of Sizewell C there are several proposed seabed disturbance activities include dredging, piling installation, anchoring of vessels, vessel movements (tug boat manoeuvring) and scour. Sediments act as a net sink for anthropogenic contaminants in marine ecosystems and contaminated sediments may have a range of toxicological effects on benthic fauna and associated species (Roberts, 2012).

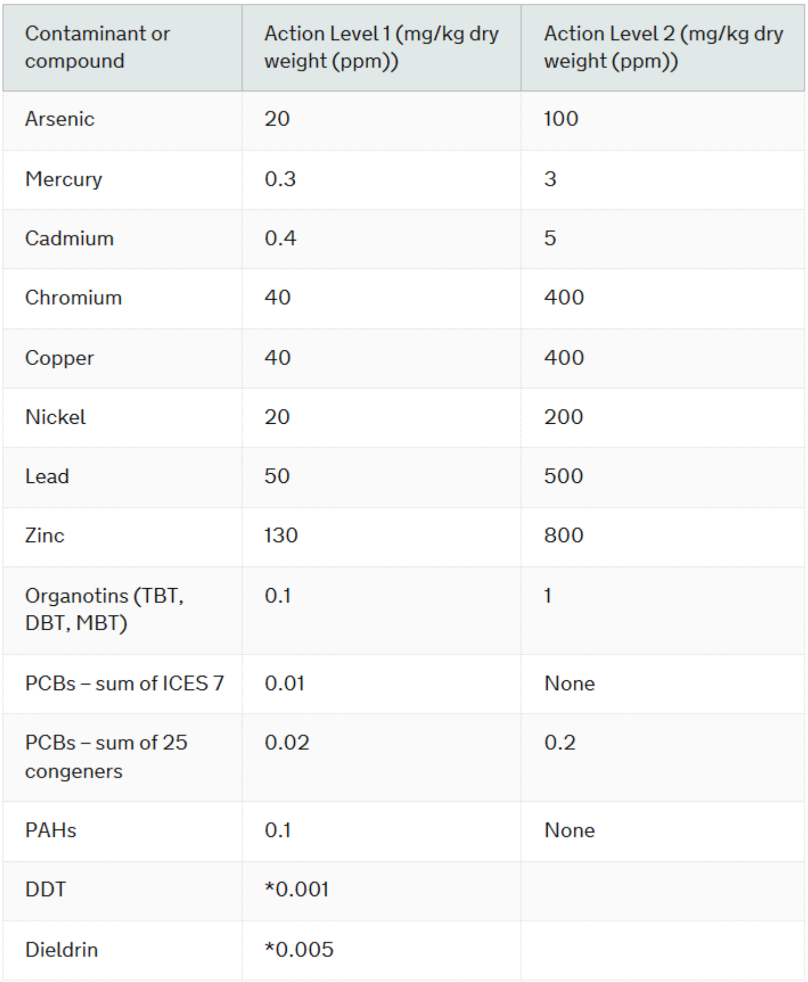
There are no statutory thresholds to assess the quality of marine sediment in the UK. However, there are upper threshold limits of sediment contamination which are acceptable for disposal to sea. These contaminant disposal limits are regulated in England by the Marine Management Organisation under the Marine and Coastal Access Act 2009. The aim of these limits is to prevent accumulation of high levels of contamination in offshore sediments and to avoid direct toxic effects on marine flora and fauna. Levels of contamination in dredged sediment are assessed against Cefas Action Levels (OSPAR, 2008). The Canadian Interim Sediment Quality Guidelines (ISQGs), although not specific to the UK are commonly also used to assess sediment quality.

The marine water chemical standards ensure that any pollutants discharged do not increase the contamination of sediments above a toxic level. This is because, the EQS for a substance is set substantially below the concentration observed to have a toxic effect on the test organisms.

1.2.4.1 Cefas Action Levels

Cefas Action Levels are used as part of a ‘weight of evidence’ approach to assessing dredged material and its suitability for disposal to sea. These values are used in conjunction with a range of other assessment methods e.g. bioassays, as well as historical data and knowledge regarding the dredging site, the material's physical characteristics, the disposal site characteristics and other relevant data, to make management decisions regarding the fate of dredged material. The Cefas Action Level limits for contaminants are shown in Table 7, these were set in 1994.

Table 7: Cefas Action Levels in sediments (MMO, 2015a).



Contaminant or compound	Action Level 1 (mg/kg dry weight (ppm))	Action Level 2 (mg/kg dry weight (ppm))
Arsenic	20	100
Mercury	0.3	3
Cadmium	0.4	5
Chromium	40	400
Copper	40	400
Nickel	20	200
Lead	50	500
Zinc	130	800
Organotins (TBT, DBT, MBT)	0.1	1
PCBs – sum of ICES 7	0.01	None
PCBs – sum of 25 congeners	0.02	0.2
PAHs	0.1	None
DDT	*0.001	
Dieldrin	*0.005	

Sediment contamination is assessed as follows:

- Below Cefas Action Level 1 limit - In general, contaminant levels in dredged material below Cefas Action Level 1 are of no concern and are unlikely to influence the licensing decision.
- Between Cefas Action Level 1 and Cefas Action Level 2 limits - Dredged material with contaminant levels between Cefas Action Levels 1 and 2 requires further consideration and testing (where appropriate) before a decision can be made.
- Above Cefas Action Level 2 limit - Dredged material with contaminant levels above Cefas Action Level 2 is generally considered unsuitable for sea disposal.

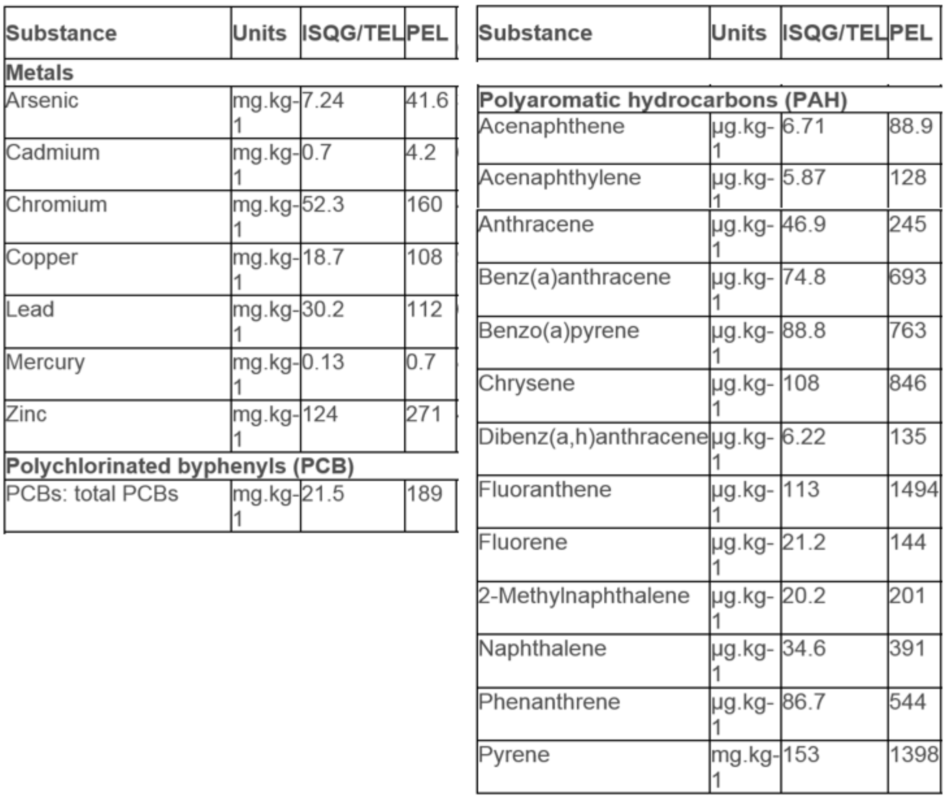
1.2.4.2 Canadian Interim Sediment Quality Guidelines

The Interim Canadian Sediment Quality Guidelines (ISQGs), although not specific to the UK are commonly used to assess sediment quality. The guidelines were developed by the Canadian Council of Ministers of the Environment as broadly protective tools to support the functioning of healthy aquatic ecosystems (CCME, 2001). They are based on field research programmes that have demonstrated associations between chemicals and biological effects and supplementary data derived from spiked sediment toxicity studies.

The guidelines consist of threshold effect levels (TELs) and probable effect levels (PELs), these are shown in
Table 8. The TELs and PELs are used to identify the following three ranges of chemical concentrations based on biological effects:

- Below TEL - Minimal effect range within which adverse effects rarely occur.
- Between TEL and PEL - Possible effect range within which adverse effects occasionally occur.
- Above PEL - Probable effect range within which adverse effects frequently occur.

Table 8: Canadian Sediment Quality Guidelines (CCME, 2001).



Substance	Units	ISQG/TEL	PEL
Metals			
Arsenic	mg.kg-1	7.24	41.6
Cadmium	mg.kg-1	0.7	4.2
Chromium	mg.kg-1	52.3	160
Copper	mg.kg-1	18.7	108
Lead	mg.kg-1	30.2	112
Mercury	mg.kg-1	0.13	0.7
Zinc	mg.kg-1	124	271
Polychlorinated byphenyls (PCB)			
PCBs: total PCBs	mg.kg-1	21.5	189

Substance	Units	ISQG/TEL	PEL
Polyaromatic hydrocarbons (PAH)			
Acenaphthene	µg.kg-1	6.71	88.9
Acenaphthylene	µg.kg-1	5.87	128
Anthracene	µg.kg-1	46.9	245
Benz(a)anthracene	µg.kg-1	74.8	693
Benzo(a)pyrene	µg.kg-1	88.8	763
Chrysene	µg.kg-1	108	846
Dibenz(a,h)anthracene	µg.kg-1	6.22	135
Fluoranthene	µg.kg-1	113	1494
Fluorene	µg.kg-1	21.2	144
2-Methylnaphthalene	µg.kg-1	20.2	201
Naphthalene	µg.kg-1	34.6	391
Phenanthrene	µg.kg-1	86.7	544
Pyrene	mg.kg-1	153	1398

1.2.4.3 Radionuclides in sediments

The UK government is a signatory to the London Convention (1972)[1] that prohibits the disposal of radioactive material at sea unless it fulfils exemption criteria developed by the International Atomic Energy Agency (IAEA). If both the following radiological criteria are satisfied:

- The effective dose expected to be incurred by any member of the public or ship's crew is of the order of 10 µSv or less in a year.
- The collective effective dose to the public or ship's crew is not more than 1 man Sv per annum

Then the material is deemed to contain *de minimis* levels of radioactivity and may be disposed at sea pursuant to it fulfilling all the other provisions under the Convention. The individual dose criteria are placed in perspective (i.e. very low), given that the average background dose to the UK population is ~2700 µSv/a (Cefas, 2006).

1.2.4.4 Marine suspended sediments standards

In the UK there are no standards for levels of suspended sediment in TraC waters. The Marine Life Information Network (MARLIN) (Tyler-Walters *et al.* 2017) identified benchmark definitions of change in suspended particulate matter that are used as supporting information for Water Framework Directive assessment of nutrient status of a waterbody (Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015). There are four WFD Waterbody 'Types' defined by annual mean concentration of suspended particulate matter (see Appendix B). The benchmark for suspended sediment is a change from one waterbody type for a period of one year.

Construction activity that disturbs marine sediment is normally regulated to minimise potential effects on marine ecology via sedimentation (i.e. potential smothering of sensitive benthic ecology) and potential remobilisation of any contaminants in the sediments. Consideration of potential effects on mobile organisms (e.g. fish) is not usually a regulatory focus as it is assumed that such organisms are able to avoid suspended sediment plumes. However, in coastal areas within the foraging range of protected birds the potential effects of increased suspended sediments on the bird prey needs to be considered. In practice such an assessment has to consider the increase in suspended sediment and the duration of such events in the context of the natural variability of the suspended sediment climate at the site.

1.2.5 Outline of what is covered in this synthesis report

This synthesis presents the evidence behind, and the effects of, the construction, commissioning and operation of the proposed Sizewell C development on marine water and sediment quality. Only the specific information for the effects of the development are included in this report. References to the underlying detailed scientific works are included if further detail is needed. As this report focuses on the absolute areas where a standard or applied value is exceeded there will be no assessment of the significance of in combination effects at this stage. The remainder of this report is divided into the following sections:

- Description of the water and sediment quality of the greater Sizewell Bay;
- Description of the marine components of the proposed Sizewell C development;
- Potential effects of the development on marine water and sediment quality

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". The process consists of three stages (screening, scoping and impact assessment). For the planned Sizewell C this report considers each of the three assessment stages for the discharges to the marine environment during construction, commissioning and operation.

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[1] Available from: http://www.imo.org/en/OurWork/Environment/LCLP/Documents/LC1972.pdf

2 Description of the Water and Sediment Quality of the Greater Sizewell Bay

2.1 Aim

This section summarises the baseline water quality of the greater Sizewell Bay, for the proposed Sizewell C marine development. For a detailed description of the baseline water quality at Sizewell reference should be made to BEEMS Technical Reports TR189 and TR314. Work undertaken that relates specifically to effects of the Sizewell C development on the marine environment is listed in the subsequent sections.

2.2 Feeder Reports

The Sizewell water quality synthesis is primarily based on information gathered by Cefas under the BEEMS marine evidence programme (the BEEMS Technical Reports, or ‘feeder reports’). For this synthesis the key BEEMS reports and their interrelationships are shown in Figure 2.The reports forming the basis of the assessments are those of the marine water quality series produced between 2014 and 2016, the coastal geomorphology and hydrodynamics synthesis and selected modelling reports. These, in turn, reference earlier BEEMS Technical Reports containing detailed methods and data analyses from the BEEMS surveys, experiments and modelling.

The main BEEMS feeder reports are:

- Sizewell coastal geomorphology and hydrodynamics synthesis. Technical Report TR311.
- Sizewell Thermal Plume Modelling: GETM Stage 3 results with the preferred Sizewell C cooling water configuration. Technical report TR302.
- Sizewell Chemical Plume Modelling: TRO, CBP’s, Hydrazine, DO and Ammonia. Technical Report TR303
- Sizewell C Discharges H1 Type assessment - supporting data report. Technical Report TR193.
- Sizewell Water Quality Literature Report. Technical Report TR131.
- Sizewell Marine Sediment Quality Report. Technical Report TR305.
- Sizewell supplementary water quality monitoring data 2014/2015. Technical Report TR314.
- Sizewell Marine Water Quality Monitoring Final Summary Report. Technical Report TR189.

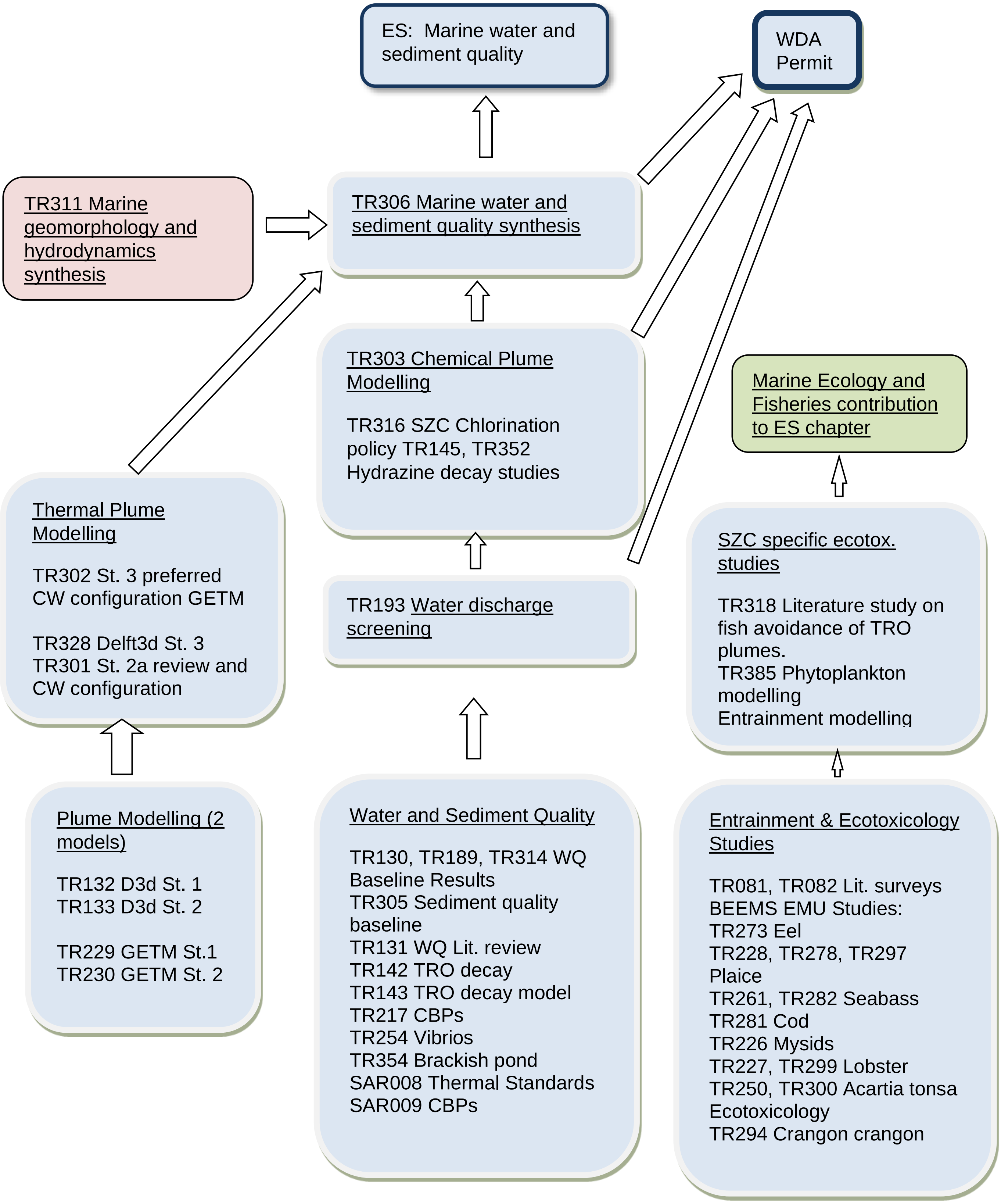


Figure 2: Feeder Reports.

2.3 Water Quality of the Greater Sizewell Bay

Supporting data used in this assessment are derived from four main sources. Historic data relating to marine water quality were sourced from the scientific literature. Most of the data from this source focussed on the quality of estuaries discharging into the Suffolk coastal waterbody. Data on coastal sea surface temperatures were collated into time-series over 48 years based on data provided on behalf of Cefas, by councils, companies and other organisations. In addition, water quality data were obtained from Environment Agency surveys. Finally new data were obtained from a Cefas monitoring programme focussed on current and planned cooling water discharge locations off Sizewell. The temperature and monitoring data are reported in detail in BEEMS Technical Report TR131 Sizewell Water quality literature review. As the data extracted from the scientific literature do not specifically focus on the Suffolk waterbody most reliance in the following sections is placed on the other data sources.

2.3.1 Historic data

2.3.1.1 Temperature data

Temperature records from sources relevant to the Sizewell power station have been collated into time-series for the previous 48 years. Individuals on behalf of Cefas, councils, companies and other organisations have obtained records of coastal sea surface temperatures, for some stations, of more than 100 years duration. Approximately half of the stations started recording coastal temperatures in the mid 1960s. Datasets include records for Lowestoft, Southwold, Sizewell Power station. Near surface temperature and salinity samples have also been collected by ferries. Based on the range of temperature data for these four locations in the Suffolk coastal waterbody from 1963 – 2013, yearly averages were derived from those years which have a complete set of monthly values. Monthly mean sea temperatures for the four sites used to derive temperature information and for which years are shown in Figure 3.

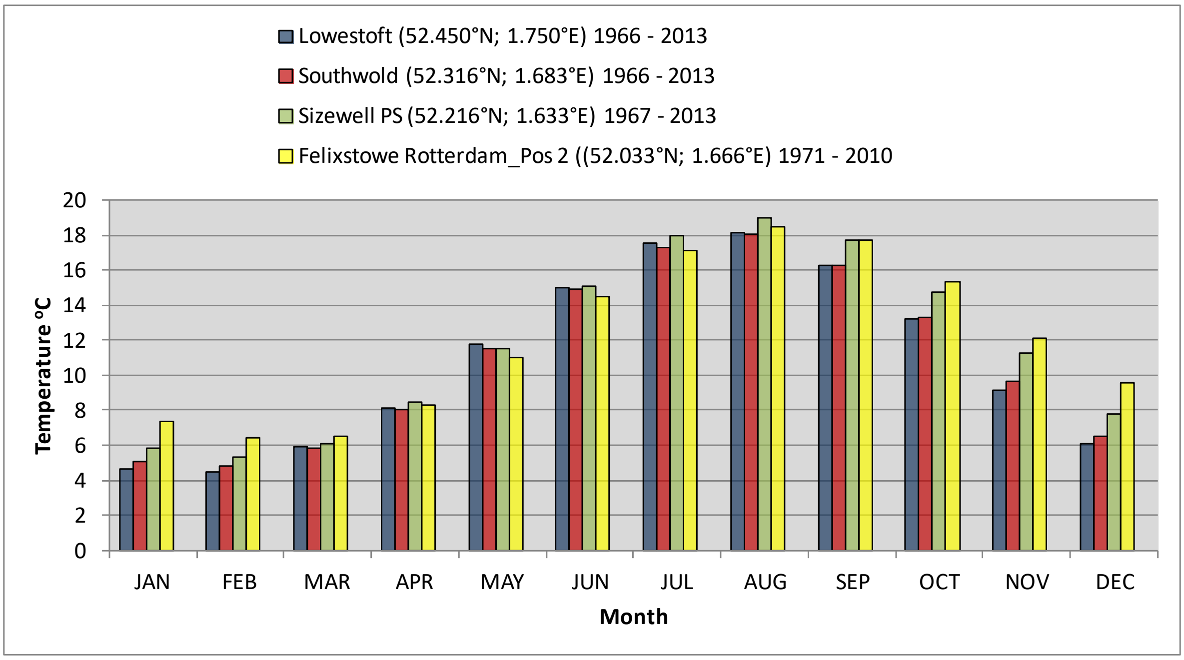


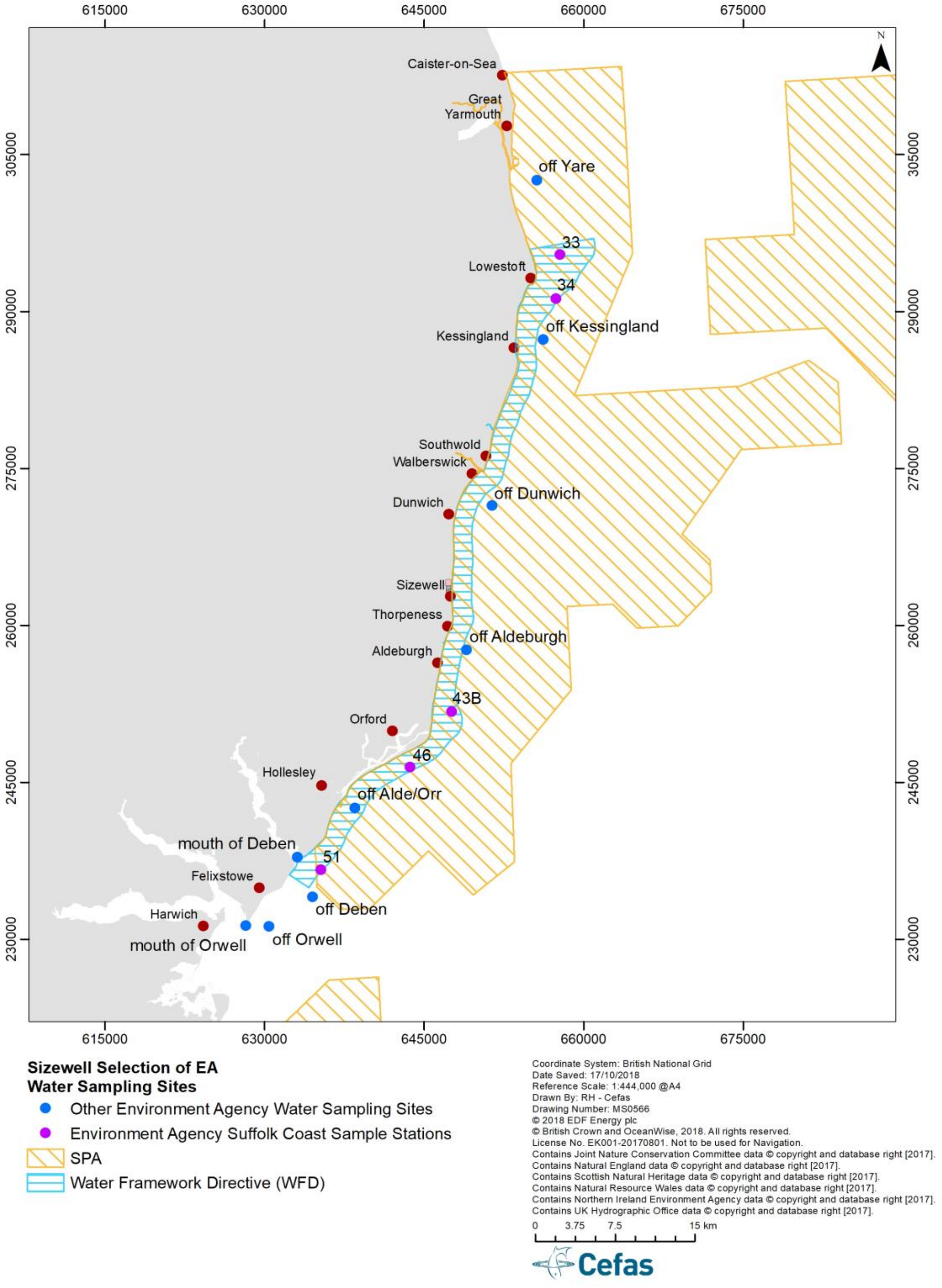
Figure 3: Monthly mean Sea Temperatures (°C) for four locations in the Suffolk coastal water 1966 -2013 (BEEMS Technical Report TR131).

The main concern regarding water temperature elevation from cooling water input to suffolk coastal water is that exceedance of specific standard values may result, or there may be an impact on the biology to the extent that (as this area is classified as heavily modified based on coastal protection) good ecological potential cannot be attained under the Water Framework Directive, or that protected species or habitats are impacted. Taking account of the recent temperature data covering the five year period between 2009 -2013 the 98 percentile is 19.4°C. Elevation of receiving water temperature due to the discharge of cooling water from Sizewell C is considered in relation to this value.

2.3.1.2 Contaminant concentrations

This section describes Environment Agency monitoring surveys for compliance and therefore the sites chosen, type of analysis and detection limits are set in this context. The data for dissolved metals cover the period 1989 to 2006 and include data for sites from off Felixstowe to just off the river Yare (Figure 4). Four of the nine locations sampled in the original survey are within the Suffolk coastal waterbody and these are referred to below.

Nutrients and inorganics data include samples collected between 1983 and the early part of 2014. The EQS are derived from Directive 2013/39/EU as regards priority substances, cadmium, lead, nickel and mercury. For the concentrations of metals in seawater in the historic dataset from various sites within the Suffolk waterbody only zinc exceeded its EQS at locations Off the Alde/Ore although high values were also measured in samples Off Dunwich. There is no clear trend in concentrations measured and values below detection are interspersed with high values.



Coordinate System: British National Grid
Date Saved: 17/10/2018
Reference Scale: 1:444,000 @A4
Drawn By: RH - Cefas
Drawing Number: MS0566
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Figure 4: Environment Agency (EA) sampling stations shown in relation to Sizewell Power Station. The numbered sample locations are the Suffolk Waterbody sampling points and the Suffolk Waterbody is delimited by the green hatched area near to shore. The brown hatched area - upper part of the Outer Thames Estuary SPA. Other EA sampling points - blue circles. The red dots are geographical locations.

2.3.2 BEEMS water quality monitoring data

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 in BEEMS Technical Report TR189. Further monitoring surveys were conducted in 2014-2015 (BEEMS TR314). This latter survey allowed more reliable data to be collected for nutrients and some metals (detection limits were not adequate for these parameters in earlier work). However, the tidal cycle surveys in the earlier work in 2010 and 2011 provides a useful perspective of daily variation in physicochemical parameters in the marine environment off Sizewell. Sampling was organised to establish the variability in analyte concentrations over several different
spatial and temporal scales (BEEMS Technical Report TR189):

- A spatial survey acquired surface and near-bed water samples from 12 stations (Figure 5) extending approximately 12 km to the north and south of the Sizewell B cooling water outfall and 3 km offshore. Maximum concentrations of compounds from the cooling water are expected to be found in surface waters due to the thermally buoyant nature of the outfall plume. Surface waters were therefore intensively sampled. To ensure that the full water column was investigated, certain stations were selected for the acquisition of near-bed samples in addition to surface water samples.
- A tidal cycle survey acquired hourly surface water samples from a vessel anchored as close as possible to the cooling water outfall (Station 5) during an ebb/flood cycle on spring tide conditions.
- A seasonal survey acquired surface water samples at the cooling water outfall (Station 5) and a reference site (Station 11) at intervals of approximately two weeks from February 2010 to February 2011.

The required sample analyses were subcontracted to several accredited UK and European laboratories. Conductivity, temperature and depth sensor (CTD) profiles showed that the waters sampled were well mixed regarding 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. There were few differences between results from inshore of Sizewell Bank (stations 1 to 9) and offshore (stations 10 to 12).

Concentrations of dissolved copper, arsenic, zinc, mercury and cadmium exceeded EQS levels on occasions. Some exceedance of the Environmental Quality Standard (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 (DEHP), though most analyses for these compounds were negative. Exceedances of EQS concentrations for these organic compounds were detected at stations 1, 5, 9 and 12. These exceedances of organic EQSs were observed in samples acquired on three sampling dates: 7th and 8th April and the 19th May 2010.

Total residual oxidant (TRO) concentrations varied between 0.01 and 0.16mgl^{-1}. The EQS for TRO is 0.01mgl^{-1} (10µgl^{-1}). The mean of all TRO measurements (n = 725) was 0.04mgl^{-1}, with a value of 0.01mgl^{-1} (half the limit of detection) used to represent negative results. Slight localised elevation of TRO was observed near the Sizewell B cooling water outfall and was below the level of detection within 2.4 km to the north and 500 m to the south. Elevated TRO was observed at the southern extremity of the survey area (at stations 9 and 12) but there was no spatial pattern to indicate that this elevation was connected to the power station outfall.

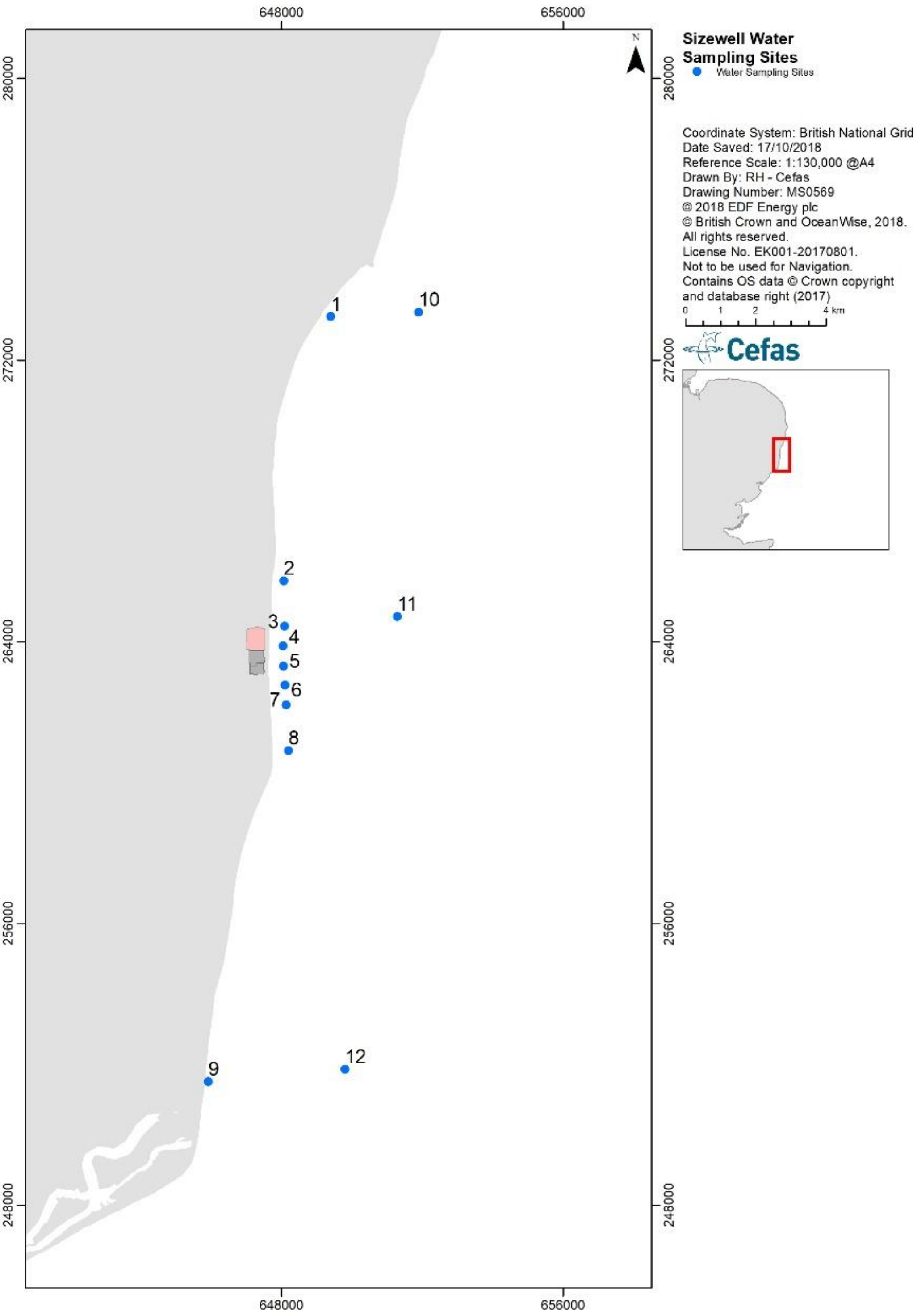

Figure 5: Location of the BEEMS sampling sites in the 2010 Sizewell water quality monitoring programme.

Analysis of some samples indicated the presence of Hydrazine (N_2H_4), an ammonia-derived compound that is an oxygen scavenger and is used in power plants to inhibit corrosion in steam generation circuits. Hydrazine is used to condition the secondary circuit of PWR power stations and is also used in the primary circuit during start up. However, doubts about the validity of the ultraviolet-visible spectrophotometry results, based on the limits of quantification of the technique and potential interference, led to the use of an alternative analytical method. For the final three months of the programme a gas chromatography mass spectrometry (GC-MS) technique was used on water samples to measure hydrazine concentrations in addition to the spectrophotometric technique. The GC-MS technique was far more sensitive and indicated that hydrazine concentrations were generally below the limit of detection (0.01µgl^{-1}). Prior hydrazine results are therefore not considered valid.

Three positive results above the limit of detection were also obtained from morpholine analyses conducted on water samples from stations 5 and 11. However, morpholine is not used by Sizewell B power station and as morpholine does not occur naturally and only relatively few positive values were obtained with no obvious pattern or trend it is unclear the origin of these elevated values.

No other concentrations of environmental concern were measured in the analyses carried out on water samples acquired at stations 5 and 11. All radionuclide concentrations measured in seawater samples were very low and were consistent with routine local radionuclide monitoring by the Environment Agency.

The results of the marine water quality monitoring programme (BEEMS Technical Report TR189) show that the concentrations of many elements and compounds are relatively uniform in the programme area. A small percentage of the samples acquired indicate that EQSs may occasionally be exceeded, but there is no indication that these are caused by the Sizewell B power station.

The measured ammonia concentrations from the 2009/10 water quality monitoring programme reported in BEEMS Technical Report TR189 were subsequently regarded as suspect and found not to agree with WFD measurements undertaken by the Environment Agency in the Suffolk coastal waterbody (but with no measurements taken in Sizewell Bay) which indicated mean ammonia values of approximately 20 - 27µgl^{-1} NH_4-N (BEEMS Technical Report TR131) compared to a mean value of 420µgl^{-1} NH_4-N reported in TR189. A subsequent monitoring programme was undertaken from February 2014 to January 2015 to provide additional data primarily for nutrients (including ammonia) but also to supplement information on metals concentrations in seawater, water temperature, salinity, dissolved oxygen and levels of chlorine produced oxidants present as a result of the existing Sizewell B discharge (BEEMS Technical Report TR314). Sampling was conducted spatially over 4 sites in the Sizewell area and temporally over two annual seasonal cycles.

Except for zinc, the mean measured concentrations of all the metals in the water samples were below their respective environmental quality standards.

Under the Water Framework Directive, the 99th percentile winter dissolved inorganic nitrogen (DIN) (425µgl^{-1}, or 30.36µmol l^{-1}) value was within an acceptable range for waterbodies of intermediate turbidity. The mean phosphate concentration was relatively high (33.48µgl^{-1}, 0.35µmol l^{-1}) but will be considered as a site background also in the context of the local suspended particulate levels. Ammonia concentrations were relatively low and mean and 95 percentile values together with relevant pH, salinity and temperature data will be used to derive the background concentration of un-ionised ammonia as part of the discharge assessment.

Most of the chlorine produced oxidant concentrations measured (over 80%) were ≤0.04mgl^{-1}. Unsurprisingly samples taken from the outfall at Sizewell B show the highest values.

For the monitoring studies reported in TR314 dissolved oxygen concentrations were between 6.96 and 11 mg l^{-1} which was well above the requirement for High status (5.7mgl^{-1}). Lowest measured values were in summer with 6.96 -7.04 mg l^{-1} recorded in July 2015.

2.4 Sediment Quality of the Greater Sizewell Bay

Sediments act as a net sink for anthropogenic contaminants in marine ecosystems and contaminated sediments may have a range of toxicological effects on benthic fauna and associated species (Roberts, 2012). There are no statutory thresholds in order to assess the quality of marine sediment in the UK, however the levels of contamination in dredged sediment are assessed against Cefas Action Levels in order to help reduce any impacts (OSPAR, 2010). These contaminant disposal limits are regulated in England by the Marine Management Organisation under the Marine and Coastal Access Act 2009[2]. The Interim Canadian Sediment Quality Guidelines (ISQGs) provide supporting information on sediment quality, however they are not specific to UK and are not regulated by the Marine Management Organisation under the Marine and Coastal Access Act 2009.

As part of the Sizewell C 2015 geotechnical survey (Fugro, 2015) that collected vibrocores from a number of locations samples were taken from a subset of 14 vibrocores at or close by areas likely to be dredged (

Figure 6) that were analysed for chemical and heavy metal contaminants; 5 of those cores were also sampled for radionuclide composition. Sediment samples were analysed by various laboratories (sampling and analytical methods described) for the following contaminants:

- Heavy metals and insecticides – Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), Zinc (Zn), DDT and Dieldrin.
- Organotin and Particle size – Monobutyl-tin (MBT), Dibutyl-tin (DBT), Tributyl-tin (TBT) and Particle Size Analysis (PSA).
- Organic and chlorinated compounds – Polyaromatic Hydrocarbons (PAHs), Total Hydrocarbon Content (THC) and Polychlorinated biphenyls (PCBs).
- Radionuclides.

The sediment samples collected at Sizewell indicate that organotin and some heavy metals were below Cefas Action Level 1 (Table 5.12) 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 (Table 9). 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). 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.

PCBs and organotin were below detection levels in most samples and where detected were considerably below the relative Action Level 1. The results from the sediment quality data analysis, show that the material is likely to be acceptable for disposal to sea based on the Cefas Action Levels for each determinand.

Based on the Canadian ISQGs, there are some areas that are in the probable effect range within which adverse effects occasionally occur on biota from several determinands. The results show that there are areas where the sediment is in the probable effect range within which adverse effects may occur on biota from arsenic (VC 18 at 2.00 – 2.20 m and VC 30 at 5.00 – 5.20 m) and dimethyl naphthalene's (in eleven samples) (see Table 9). T The vibrocore 30 location with arsenic above the probable effect range coincides with the proposed BLF access channel (Figure 6). As the levels of arsenic found across the site are below Cefas AL2, there is a low risk of bioavailable contaminants and the material is likely to be deemed acceptable for disposal to sea.

Figure 6). The naphthalene concentration was elevated above Cefas Action level 1 and also exceeded PEL in several samples but the levels determined are comparable with location background concentrations typically found in this area (0.932 mgkg^{-1} for naphthalene, Kelly *et al.* 2002) and as the ISQG is a conservative value, there is not a concern in relation to PAH contamination. 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; LWM 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

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[2] Available from: http://www.legislation.gov.uk/ukpga/2009/23/contents

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 LWM 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 LWM 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.

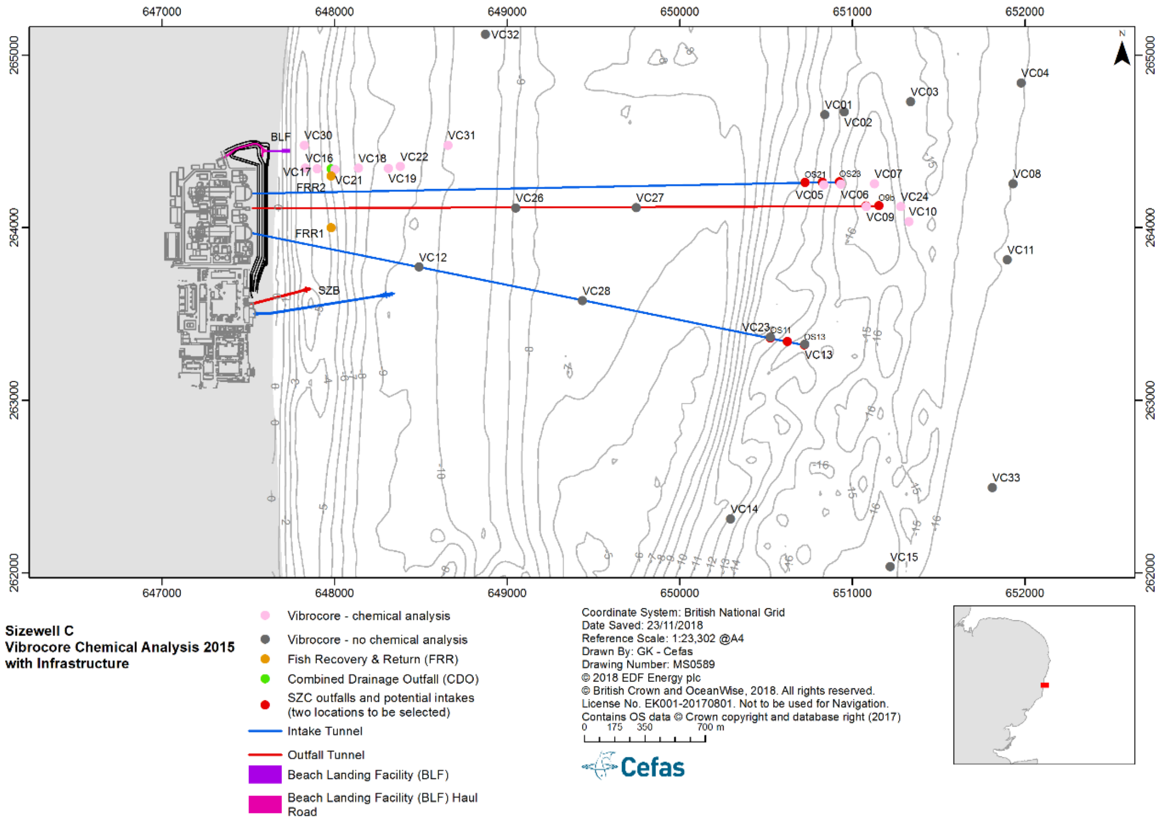


Figure 6: Position of Sizewell C 2015 vibrocore sampling stations from the geotechnical survey and selected cores from which samples were taken for chemical analysis in relation to Sizewell C infrastructure.

Table 9: Vibrocore results in the probable effect range within which adverse effects may occur on biota, based on Canadian ISQGs.

Sample	Depth (m)	As*	dimethyl naphthalenes*
		$mgkg^{-1}$	$mgkg^{-1}$
Cefas AL1		20	0.1
Cefas AL2		100	
Canadian TEL		7.24	0.0202
Canadian PEL		41.6	0.201
VC18	2.00 - 2.20	84.7 🟦	
VC30	5.00 - 5.20	91.5 🟦	
VC05	0.00 - 0.20		0.227 🟦
VC05	3.00 - 3.20		0.224 🟦
VC07	0.00 - 0.20		0.39 🟦
VC09	0.00 - 0.20		0.274 🟦
VC10	0.00 - 0.20		0.369 🟦
VC10	2.00 - 2.20		0.342 🟦
VC17	2.00 - 2.20		0.263 🟦
VC21	2.00 - 2.20		0.252 🟦
VC24	0.00 - 0.20		0.631 🟦
VC30	3.00 - 3.20		0.22 🟦
VC30	4.00 - 4.20		0.237 🟦

The radionuclide results show that radionuclide concentrations in marine sediment at Sizewell are low (with many values below the limit of detection) and consistent with routine local radionuclide monitoring (Environment Agency *et al*. 2015). *The action levels and Canadian TEL and PEL are colour coded to show which sediment locations and contaminants are at a given action level or TEL/PEL.

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 (FRR2), 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.

Particle size analysis (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) Particle Size Analysis (PSA) results show that most of the samples (79 %) are comprised mainly of sand (approximately 65 – 99 % sand).

Therefore, due to the sandy nature of the material and levels of contamination below Cefas AL2 found in the marine sediment at Sizewell, there is a low risk of bioavailable contaminants. The Sizewell results are consistent with the results of the UK National Marine Monitoring Programme (Cefas, 2004), which did not identify any areas off the Suffolk coast that had high levels of contamination.

2.4.1 Suspended sediment concentration in Sizewell Bay

Sediments in sea water are the result of both natural processes (e.g., coastal erosion, catchment runoff and resuspension of sea bed sediments) and human activities (e.g., fishing, shipping, aggregate extraction, dredge disposal, marine construction). The amount of sediment in sea water, or ‘turbidity’, is one of several factors that define coastal ecosystems and the organisms that can survive there. Several monitoring studies have measured the suspended sediment regime off Sizewell (BEEMS Technical Reports TR189, and Dolphin, Silva and Rees, 2011 for a project evaluating natural sediment variability in Regional Environmental Assessment areas in the North Sea and English Channel. From satellite data for the period 1/7/2002 to

31/5/2010 monthly mean, maximum and standard deviation of suspended particulate matter (SPM) were derived. SPM data showed an average mean value at Sizewell during April to August of 31mgl^{-1}(and average monthly maximum 80mgl^{-1}) and during September to March 73mgl^{-1}(and average monthly maximum 180mgl^{-1}). An annual mean SPM for these data was 55.3mgl^{-1}. 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. With reference to the suspended sediment levels associated with WFD nitrogen standards (Appendix B) and based on the satellite data and previous monitoring surveys Sizewell is classed as of intermediate turbidity. Additional surveys of suspended particulate matter conducted over a tidal cycle at Sizewell in July and August showed a mean and range for July of 25.2 (8.65 – 68.35) mg l^{-1}, and for August of 16.67 (7.21 – 38.38) mg l^{-1}. Previous satellite data produced a mean and range SPM for July of 18.3 (8.6 – 49.5) mg l^{-1} and for August of 29.7(10.2 – 94.0) mg l^{-1}. These data suggest a broad comparability between satellite data and actual measurements.

3 Description of the marine components of the proposed Sizewell C development

This section details the development's marine components - the beach landing facility (BLF), cooling water system, and associated activities for their construction and operation. Our understanding of these marine components as at March 2020, with relevance to water quality, is set out below with more detail of relevance to Ecological receptors and geomorphic features provided in BEEMS Technical Report TR311.

The development includes a hard and soft coastal defence feature (SCDF) (Figure 7). Design and maintenance of the SCDF is discussed in ES Appendix 20A. In summary, the SCDF would be maintained for as long as mitigation was active. Maintenance of the SCDF would require vehicular access and works close to the shoreline. To avoid any impact on water quality adoption of series of measures under construction code of practice a would be adopted to mitigate against any impacts upon marine water quality.

The following components of the development that may have an effect on the marine environment and are potentially relevant to water quality are:

(i) A beach landing facility (BLF) for the station construcion and operation

A Beach Landing Facility (BLF) would be used to import rock armour, Abnormal Indivisible Loads (AILs) and receive some marine freight during the construction phase and be retained through operation for delivery of occasional AILs over the operational life of the site. During the power station's operational life, cross-shore works would be constrained in space and time to the occasional needs for AIL deliveries (estimated as once every 5-10 years). The BLF consists of a piled deck that will connect to the hard-coastal defence feature and the AIL haul road, plus additional fenders and ramp.

(ii) Cooling water system (including intakes, outfalls and fish recovery and return outfall)

The cooling water system would consist of two intake tunnels both >3km long, excavated under the seabed with a tunnel boring machine from landward with excavated arisings going to landward. These boring machines may be disposed of in-situ, just beyond the vertical shaft that connects to the intake and outfalls heads.

Two vertical shafts would be driven down to meet each tunnel offshore of the Sizewell Banks. A number of shafts connect the intake heads and outfall heads to the tunnels. It is proposed to dispose of the associated arisings locally.

The intake and outfall heads would be mounted at the end of the vertical shafts. The design of the intake heads is not finalised and is subject to further engineering studies. The outfall head is likely to have the same design as that proposed for Hinkley Point C.

Two Fish Recovery and Return (FRR) systems would also be part of the cooling water system. The exact position of the FRR outfalls is still subject to engineering design, however, assessment suggests that the optimal easting is between BNG Easting 647977 and 648127. The northing positions of each FRR are aligned with the two EPR forebays, allowing a minimum tunnel length of ca. 400m offshore from the HCDF. This location is away from the longshore bar systems and the bathymetric gradients are low and with a very low rate of elevation change. The tunnels would be directionally drilled from onshore with drill cuttings returned to land. Concrete headworks would anchor the FRR outfall heads to the subterranean tunnel.

(iii) **A combined drainage outfall (CDO) for the construction period**.

A discharge point will be required to discharge the treated sewage effluent and other wastes associated with construction and commissioning before the main Sizewell C cooling water system is available. Discharges from the CDO would be treated with oil separators to minimise potential hydrocarbon contamination from mobile or fixed plant operations and a siltbuster or similar technology to reduce sediment loading. 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.

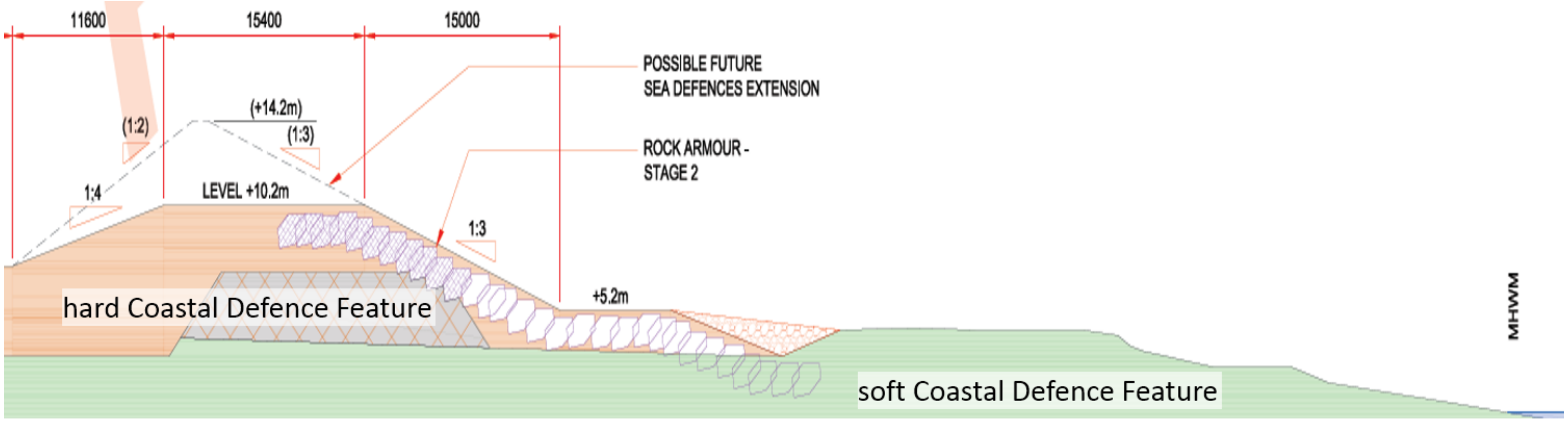


Figure 7 Cross-section of the proposed Coastal Defences at Sizewell C. Note that this drawing is indicative and does not presently include the correct foundation depths.

4 Potential effects of construction and commissioning phases of Sizewell C development upon marine water and sediment quality

This section details the potential effects of the development's marine components and their associated construction and commissioning activities on the marine water and sediment quality adjacent to the Sizewell C development site. The marine components with potential to cause effects relevant to water or sediment quality are:

i. the Beach Landing Facility (BLF);

ii. cooling water intakes;

iii. cooling water outfalls;

iv. fish recovery and return system outfall; and

v. combined drainage outfall (treated sewage and construction wastewater).

4.1 Potential sources of water and sediment contamination during construction that are screened out of further assessment

Several construction activities represent potential sources of contamination to marine water and sediment quality and are screened out of further consideration as follows:

4.1.1 Potential effects of chemical release from sediment resuspension

Except for the construction of the coastal protection features, all the construction activities listed in Section 3 present a risk of remobilising any contaminants present in the local seabed sediments although the largest disturbance would be primarily from dredging and drilling activity.

The marine sediment quality off Sizewell was characterised in terms of contamination in BEEMS Technical Report TR305. The report concluded that due to the sandy nature of the material and levels of contamination below Cefas AL2 found in the marine sediment at Sizewell, there is a low risk of release of contaminants to the water column.

With respect to the contribution of sediment disturbance to nutrient concentration in the water column studies from the scientific literature indicate that resuspension events are unlikely to have a significant effect on water column PO_4 concentrations, other than locally, where in the short term, there may be a temporary "spike" in concentrations until phosphates mobilised from sediment porewaters reassociate with suspended sediment particles and newly formed Fe-Mn oxyhydroxides or clay minerals, before settling out (Dunn *et al.* 2017 and Defforey *et al*. 2018). Marine sediment resuspension studies from the scientific literature have also shown that a relatively low percentage of sediment NH_4 may be released to the water column (0.58 – 5.50% of the depth integrated NH_4) and within a few hours the NH_4 concentration returns to levels prior to resuspension (Dunn *et.al.* 2017).

The proposed seabed disturbance activities associated with the construction and operational phases of Sizewell C are, therefore, considered unlikely to cause any chemical release effects to the water and sediment quality of the local area due to sediment composition and low level of contaminants (BEEMS TR305). The issue of sediment resuspension of contaminants is therefore not considered further.

4.1.2 Potential for effects from accidental chemical release from vessel movements

The potential for chemical and oil spills during vessel movements, whilst recognised, would be managed by compliance with IMO regulations. Therefore, any chemical release effects to the water and sediment quality of the local area would be minimised by compliance with regulations.

4.1.3 Potential for introduction of non-native species from ballast water

The potential for non-natives to be introduced during ballast water activities, whilst recognised, would be managed by compliance with the IMO Ballast Water Management Convention (adopted in 2004). All ships in international traffic are required to manage their ballast water and sediments to a certain standard, according to a ship-specific ballast water management plan. All ships will also have to carry a ballast water record book and an international ballast water management certificate. Therefore, no foreign material release effects to the water and sediment quality of the local area are expected.

4.1.4 Potential for harmful effects of chemicals leaching from marine structures and coatings

Any chemicals used in marine construction will be selected from the list of notified chemicals assessed for use by the offshore oil and gas industry under the Offshore Chemicals (Amendment) Regulations 2011. Any coatings or treatments must be suitable for use in the marine environment in accordance with best environmental practice (Guidance for Pollution Prevention). Therefore, negligible release effects from this source to the water and sediment quality of the local area are expected.

4.1.5 Temporary and variable construction discharges

Other temporary and more variable discharges to marine water may form part of the surface drainage strategy during the construction phase together with the range of expected discharges detailed above. The main expected contaminants in these discharges are suspended solids, Biochemical Oxygen Demand (BOD) and hydrocarbons. Assessment using the Environment Agency/Defra screening of contaminant contributions from surface drainage sources (Defra and Environment Agency Guidance, 2016) is not appropriate due to their highly variable nature over the construction period. Hydrocarbons can be removed from effluent prior to discharge by the incorporation of suitable oil separators within temporary drainage systems and any potential for chemical and oil spills during construction activities, whilst recognised, would be covered under the government waste management guidelines. Therefore, no chemical release effects to the water and sediment quality of the local area are expected from these variable sources and they are therefore screened out of further assessment.

4.2 Beach Landing Facility

4.2.1 Beach landing facility construction (dredging)

North Sea Barges (or similar) would be used to deliver freight (AILs, rock armour and potentially other materials) to the BLF for transfer onto the main development site or construction area as appropriate. A plough or scraper method would be used to gain clearance over the outer longshore bar and to flatten the inner bar so that barges can come safely aground, on a planar surface, on the falling tide after they dock onto the BLF deck.

The total dredge volume modelled for the BLF is 4,600m^3. The proposed plough dredge method does not extract material; however, banking of redistributed sediments may occur in the local vicinity causing burial of surficial sediments and associated biota.

On both spring and neap tides the sediment only settles on the bed over a relatively small area close inshore. Depth average location maximum SSC of more than 100mgl^{-1} above daily maximum background extend approximately 5 km north and south of the dredge area for the capital dredge over an area of up to 108ha at the sea surface and 83ha as a depth averaged plume. (satellite data show that the lowest SPM values are present at Sizewell during June with a mean average value of 12.1mgl^{-1} and range 6.9 to 27.5 highest SPM occurs in January with a mean average of 89.3, and range 10.4 - 217mgl^{-1}). A small area of up to 7ha would experience an instantaneous SSC plume of >1,000 mg/l above background levels. Ambient conditions at the site are highly variable and the surface waters are considered as of 'intermediate turbidity' according to WFD criteria. Following the completion of the dredge the plume quickly disperses. On spring tides material in suspension is at concentrations of less than 20mgl^{-1} above background within three days (BEEMS Technical Report TR480). During dredging and for several days following completion SSC would increase to a level that would be defined as 'turbid' (see Appendix B). The spatial extent of SSC elevation at >50mg/l, which would be equivalent to a WFD turbid classification (i.e. 100 – 300mg/l) when considered in addition to mean SSC background concentration during most of the year, would be 248ha. An area of 248ha is <2% of the Suffolk Coastal waterbody area. A single dredging event including the time required for SSC to be close to background would represent <0.1% of the year.

4.3 Cooling Water intake (Construction)

4.3.1 Cooling Water Intake - Dredging

The intake structures would be emplaced during the construction period and exist for the entire operational life of the station and a substantial part of the decommissioning period. The intake tunnels would be bored from landward. At the planned location of the intake/outfall heads, the sea bed sediments would be removed, connecting shafts drilled down through the bedrock and finally the intake heads lowered into place. The design of the intake heads has not yet been undertaken.

Any wastewater generated by drilling of the horizontal cooling water tunnels would be returned to land for treatment before discharge via the CDO (see section 4.6.2)

It is assumed that the head foundations would be installed to the bedrock. The sediment depth is likely to vary at each head location and the assumed dredge volume is based on a worst-case sediment depth of 6m. An excavated volume of 17,406.5m^3 per intake head has been calculated for a total of four heads.

During the dredging and associated local disposal of surficial sediments from the location of the CWS intake structures, an elongate area extending approximately 13km to the north, 22km to the south and a couple of km east-west is affected by increases in SSC of more than 100mgl^{-1}. SSCs within the plume, depth averaged SSCs within the plume peak at more than 2,000mgl^{-1} above background. These elevated concentrations are relatively short lived, with more typical SSC values of 100mgl^{-1} along the plume axis. The maximum instantaneous plume area with increases in depth average SSC of more than 100 mgl^{-1} is around 373 Ha. Following completion of the dredge, the plume quickly dissipates. The elevated concentrations are shown to decay to background levels within *circa* two days on neap tides and two days on spring tides after the completion of the disposal operations. Elevated SSC are not expected to occur for more than about eight days for the dredge scenarios modelled (BEEMS Technical Report TR480). Dredging would temporarily increase the classification of the surface waters to 'Turbid', i.e. the area (553ha) where SSC elevation is >50mg/l would be equivalent to a WFD 'turbid' classification (i.e. 100 – 300mg/l) when considered in addition to mean SSC background. An area of 553ha is <4% of the Suffolk Coastal waterbody area. Dredging to establish all four heads including the time required for SSC to return to background would represent ca.,2% of the year.

4.3.2 Cooling Water Intake – Drilling and shaft insertion

Drilling the connecting shafts to a depth of 15m is estimated to take 3 weeks for each shaft. For the intake shafts with and external diameter of 8m, a total drill volume of 750m^3 is anticipated for each of the four shafts. The drill cuttings which will be mostly coarse material and are likely to be disposed of locally. The external diameter of the outfall shafts is likely to be 9m, giving a volume of 955m^3. Drill volumes are likely to be precautionary as they assume drilling from the seabed level. It is likely however, that dredging will remove the surface sediment layers (up to 6m).

The rate of release of drill arisings is derived from assuming 15 days of drilling, at 12 hours a day giving a discharge of 0.017m^3 s^{-1}. 90% of this is likely to be coarse material > 1cm diameter. 5% may be sand and a further 5% fine material <63µm. The bulk of the material will be (Coralline) Crag (sandy limestone) which has a relatively low density (BEEMS Technical Report TR311).

During the drilling of the bedrock at the intake structures, a very diffuse plume with concentrations of around 5mgl^{-1} relative to background develops. Concentrations at this level are around the annual monthly minimum values for satellite data. Based on measured SPM data over a tidal cycle in July which had a mean 8.5, and range 18.3 -49.5mgl^{-1} the plumes created during drilling of the bedrock are therefore unlikely to be discernible above background values (BEEMS Technical Report TR480).

4.3.3 Cooling Water Intake – Installation of Head

The intake heads would be lowered into place and are therefore not being cast in-situ and there are no predicted foreign material release effects to the water and sediment quality of the local area.

4.4 Cooling Water Outfall (Construction)

4.4.1 Cooling Water Outfall - Dredging

As with the intakes, the outfall has to be seismically qualified, which means that the overlying sediment has to be removed, connecting shafts drilled and the outfall head lowered into positon. There are two outfall heads, which are larger than the four intakes but carry the same volume of water.

Any wastewater generated by drilling of the horizontal cooling water tunnels will be returned to land for treatment before discharge via the combined drainage outfall (see section 4.6.2)

It is assumed that the head foundations would be installed to the bedrock. The sediment depth is likely to vary at each head location and the assumed dredge volume is based on a worst-case sediment depth of 6m. An excavated volume of 11,742m^3 per outfall head has been calculated.

Dredging would be similar to that for the intakes and would temporarily increase the classification of the surface waters to ‘Turbid’, i.e. the area (553ha) where SSC elevation is >50mg/l would be equivalent to a WFD turbid classification (i.e. 100 – 300mg/l) when considered in addition to mean SSC background. An area of 553ha is <4% of the Suffolk Coastal waterbody area. Dredging to establish both outfall heads including the time required for SSC to be close to background would represent ca.,1% of the year.

4.4.2 Cooling Water Outfall – Drilling and shaft insertion

Drilling the connecting shafts to a depth of 15m is estimated to take 3 weeks for each shaft. For the intake shafts with an external diameter of 8m, a total drill volume of 750m^3 is anticipated for each of the four shafts. The drill cuttings which will be mostly coarse material and are likely to be disposed of locally. The external diameter of the outfall shafts is likely to be 9m, giving a volume of 955m^3. Drill volumes are likely to be precautionary as they assume drilling from the seabed level. It is likely however, that dredging will remove the surface sediment layers (up to 6m). Drilling for the vertical connection shafts would result in SSC plumes that would be indiscernable from background conditions (BEEMS Technical Report TR480)

4.4.3 Cooling Water Outfall – Installation of Head

The outfall heads will be lowered into place and are therefore not being cast in-situ and there are no predicted foreign material release effects to the water and sediment quality of the local area.

4.5 Fish Recovery and Return System Construction

4.5.1 Fish Recovery and Return System – Dredging

The FRR outfall heads are assumed to comprise of a concrete block approximately 3m long, 4.5m high, and 3m wide (subject to final engineering design). To estimate a worst-case dredge volume the headworks and estimated scour protection is applied. Scour protection may be placed to limit downward scour and to ensure that scour generated from the structure keeps the area clear of sediment. The total surface footprint is ca. (9m x 23m) or 207m^2 for each FRR system. The dredge volume is approximately 3,690m^3 per FRR system.

It is likely that the FRR systems would be installed separately approximately one year apart in sequence with the reactor they are associated with. Therefore, modelling considered FRR dredging of the two headworks to be temporally distinct events. Plumes with instantaneous SSC of >100mg/l above daily maximum background levels are expected to form over instantaneous areas of up to 89ha at the surface. A small area of 1ha is expected to experience an instantaneous SSC of >1,000mg/l above background at the sea surface. The area effected by sediment disturbed during the dredging and local disposal of sediment from the FRR outfalls extends north-south along the coast, with limited offshore extent. Following the completion of the dredge the plume quickly disperses. No areas are subjected to increased surface SSC of more than 50 mg/l for more than six hours (BEEMS Technical Report TR480).

4.5.2 Fish Recovery and Return System – Drilling

The FRR tunnel would be approximately 0.8m diameter and directionally drilled from onshore with drill cuttings returned to land (BEEMS Technical Report TR311), therefore there are no predicted sediment resuspension effects to the water and sediment quality of the local area.

4.5.3 Fish Recovery and Return System –installation of Head

The FRR heads will be lowered into place and are therefore not being cast in-situ and there are no predicted foreign material release effects to the water and sediment quality of the local area.

4.6 Main Site Combined Drainage Outfall (CDO) Construction

4.6.1 Combined drainage outfall - Dredging

The method of construction for the CDO has not yet been finalised but is likely to be like that of the FRR and include a directional drilled tunnel with a terminating outfall block. The design of the outfall head has not yet been undertaken but for this report has been assumed to comprise a concrete block like the FRR block. The position of the construction discharge outfall will be suitable for alignment with the sewage treatment system and constrained by the location the BLF, FRR and cooling water tunnel construction. The tunnel would be directionally drilled from onshore with drill cuttings returned to land.

The design of the CDO head has not yet been undertaken and is assumed to be similar dimensions to the FRR. It is assumed that dredge spoil will be disposed of on-site via a pipe that transports the dredge material 500m down drift. Sediment dispersal modelling has been completed based on these assumptions.

The area effected by sediment disturbed during the dredging and local disposal of sediment extends north-south along the coast, with limited offshore extent. Location maximum depth average SSC of more than

100mg $l^{-1}$are constrained to within 6.5 km to the north and 5.5 km to the south of the release location. The remainder of assessment as for FRR.

4.6.2 Waste water and treated sewage discharge via the CDO

Construction phase drainage that may be discharged to the marine environment includes:

- Surface water drainage
- Effluent from the treatment of sewage and from potable supply (black and grey water) by the on-site treatment works;
- Water pumped from both groundwater and excavations during construction dewatering activities.
- Wash water from cleaning concrete production equipment.
- Waste water from horizontal cooling water system tunnelling operations (during construction, see below).

The handling of the of waste water generated from construction of the CDO and potentially the Fish Recovery and Return tunnels has yet to be finalised but is likely to contribute much smaller quantities of groundwater and for a shorter period than those described and assessed in the following sections.

The CDO will be constructed by TBM and will be the primary discharge point for construction phase discharges of tertiary treated sewage, main site dewatering, TBM effluents and commissioning phase hydrazine releases. Discharges will be treated with a silt-buster or similar technology to minimise suspended solids being discharged into the receiving waters.

Wastewater volumes which include that used in various tunnelling processes as well as groundwater seepage are taken from those used for HPC. The construction discharge schedule developed for Hinkley Point C assumes as a worst case that tunnelling wastewater is primarily made up of groundwater only. Thus, the tunnelling wastewater and sewage discharges for HPC have been adapted to include the groundwater discharges expected for Sizewell C and the resulting volumes and discharge schedule are used in TR193. There are no details available for chemical selection and quantities required for the tunnelling schedule and those used at HPC may not be appropriate to the geology at Sizewell.

4.6.3 Indicative construction schedule

As different site discharges may be present at the same time the timing, duration and source concentrations of the likely discharges are important to determine. Prior to CDO completion construction effluents will be tankered off site for appropriate disposal.

A cut-off wall will be constructed around the main construction site and over a 28-day period, groundwater will be lowered within this at an estimated discharge rate of $124ls^{-1}$ or $446m^3hr^{-1}$. For the remainder of the construction period groundwater dewatering is estimated to occur at a rate of $15ls^{-1}$ or $54m^3hr^{-1}$. These discharges are anticipated to be via the CDO.

Package units for treatment of sewage and wastewater from welfare facilities would be established during the construction period with an estimated average discharge rate of $13.3ls^{-1}$ and potential maximum of $30ls^{-1}$ based on current plans at Hinkley Point.

Small amounts of concrete wash water are also likely to be discharged this is expected to contribute relatively small daily volumes up to $10m^3$ a day ($0.1ls^{-1}$).

For assessment, maximum loads are to be addressed within modelling scenarios. The issues of concern being, maximum loads of; heavy metals, Dissolved Inorganic Nitrogen (DIN), faecal coliforms from treated sewage effluent, metals and DIN from groundwater and any tunnel boring additives that are not recovered for reuse.

Five different discharge scenarios or Cases (A – E) are identified during the construction phase at Sizewell C which is scheduled over a 3.5-year period and these include inputs from different activities which potentially contribute different chemical contaminants. There is also a maximum case variation to Case D – D1 that includes a maximum volume contribution of treated sewage effluent which is unlikely to persist over prolonged periods but is included to help inform permitting. The volume discharges for these discharge cases are shown in Table 10.

The maximum discharges of flows that contain metals will occur during Case A. The maximum DIN input will be during Case D (between weeks 45 and 53 when the groundwater element reaches 42ls^{-1}). Case D is relatively transitory. Case D1, which includes an extreme case of sewage discharge, is also likely to be highly transitory. Once the SCL works are complete (Case E) the total groundwater discharge falls to 15ls^{-1}. The waste from the TBM soil conditioning chemicals if present is likely to make the largest contribution during Case E as two tunnel boring machines would be in operation and two volumes of makeup water containing conditioning chemicals would be employed. This assumption is based on the work conducted at HPC and it may be that conditioning chemical volume figures change when more is known regarding the tunnelling process required for Sizewell C. The total discharge volume during Case E is approximately 34ls^{-1}.

Table 10: Construction discharge scenarios during different phases (Case A-E) of construction at Sizewell C.

Date and activity change	Main site Groundwater (ls^{-1})	Sewage (ls^{-1})	Tunnelling wastes (and associated) discharges (ls^{-1})	Case	Total Discharge (ls^{-1})	Comments
WK 1 discharge available 28-day duration						
	124	0	0	A	124	Worst Case Metals
WK 17 tunnelling start						
	15		7	B	22	
WK 26 permanent Sewage Treatment Plant			SCL ramp up			
	15	13.3	22	C	50.3	
WK 49			GW + soil conditioning 1 TBM			
	15	13.3	26.7	D	55	
WK 49		Occasional Max sewage	Made up of GW + (soil conditioning 1 TBM approx. 3ls^{-1})			
	15	30	26.7	D1	71.7	Worst Case Sewage
WK 81			2 TBMs			
	15	13.3	(approx. 6ls^{-1})	E	34.3	Worst Case TBM

For assessment, maximum loads are to be addressed within modelling scenarios. The issues of concern being, maximum loads of; heavy metals, Un-ionised ammonia, Dissolved Inorganic Nitrogen (DIN), Biochemical oxygen demand, faecal coliforms from treated sewage effluent, metals and DIN from groundwater and any tunnel boring additives that are not recovered for reuse.

The worst-case scenarios for each construction phase are:

- **Case A** is associated with the highest groundwater element over the first 28 days of construction when a cut off wall is constructed around the site and is the worst case for metals and will be screened at 124ls^{-1}

- **Case D** is the most likely high discharge for DIN and ammoniacal nitrogen after the initial 28 days as it contains main site and tunnelling groundwater, and sewage at a discharge rate of $13.3ls^{-1}$ at a maximum ammoniacal nitrogen contribution of $20{,}000\mu gl^{-1}$. Additional contributions to N from hydrazine use during commissioning will also be included when known.
- **Case D1** provides the highest contribution of DIN and ammoniacal nitrogen as it is similar to Case D but represents an occasional maximum for sewage with a discharge rate of $30ls^{-1}$ and maximum ammoniacal nitrogen of $20{,}000\mu gl^{-1}$.
- **Case E** is the worst case for the TBM machines with the potential for 2 lots of ground conditioning chemicals to be discharged although recovery systems mean this is likely to be a negligible input. Less groundwater is contributed from tunnelling and the main site groundwater contribution is also low as is the sewage discharge rate.

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 Environmental Quality Standards (EQSs). Where no EQS is available approaches are described for derivation of an alternative reference value.

The focus of this report is the potential impact of activities upon water and sediment 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. Supporting information and additional detail for some of the assessments is provided in BEEMS Technical Report TR193. The same information but considering areas of overlap with the Water Framework waterbodies and Habitats are considered in BEEMS TR483 or for individual biology receptors will be considered in the Ecology section of the Environmental Statement (Volume 2, Chapter 22).

5 Assessment of construction discharge

5.1 Background

As part of a surface water risk assessment (Environment Agency and Department for Environment Food and Rural Affairs, 2016) the concentration of substances present in the discharge must be assessed against a list of specific pollutants and their Environmental Quality Standards (EQS). Some substances, termed priority hazardous substances have associated concerns for toxicity, accumulation and persistence in the environment therefore the quantities of these are strictly controlled and are subject to an assessment of annual load discharged

Further tests are conducted for all substances discharged to determine if the concentrations in the discharge exceeds their respective EQS. For any substances that breach the EQS in the initial screening tests (Test 1) a further screening test is applied that takes account of initial dilution upon discharge (Test 5).

The EA Test 5 screening applies to the discharge from the CDO because the discharge is to the subtidal environment and beyond 50m from mean low water spring (MLWS) tidal level.

More detail on the approach to these assessments is provided in BEEMS TR193.

5.2 Total loads for Cadmium and Mercury.

As part of the surface water pollution risk assessment for environmental permit there are specific requirements for the minimisation of the annual loads of the priority hazardous substances cadmium and mercury. To determine significant loads for these contaminants the average discharge concentration is multiplied by the average flow and the quantity in kg per year is derived. Figure 8 shows that shows the discharge rate for groundwater left axis and blue line. Groundwater discharge is very high (above left axis maximum shown) in the first 28 days (124ls^{-1}) during the main dewatering on site and then decreases rapidly to around 15ls^{-1}. From around week 16 to 76 groundwater varies due to overlapping contributions from tunnelling of intake 1, the outfall and intake 2. Over this whole period the cumulative load of cadmium and of mercury derived from the groundwater is shown by the brown and red lines and the scale on the right-hand axis. Over this 3.5 year period the cumulative load for cadmium is 0.45kg and for mercury is 0.05kg. Both these load figures meet the requirement to not exceed a significant annual load of 1kg for mercury or 5kg for cadmium. Trace contamination of raw materials used in demineralisation of water used during cold commissioning may contribute additional loadings of mercury and cadmium but based on maximum annual loadings during normal operation when the systems are in full use the additional annual loadings, cadmium 0.37kg and mercury 0.099kg (Table 48) would not result in exceedance of the significant loads.

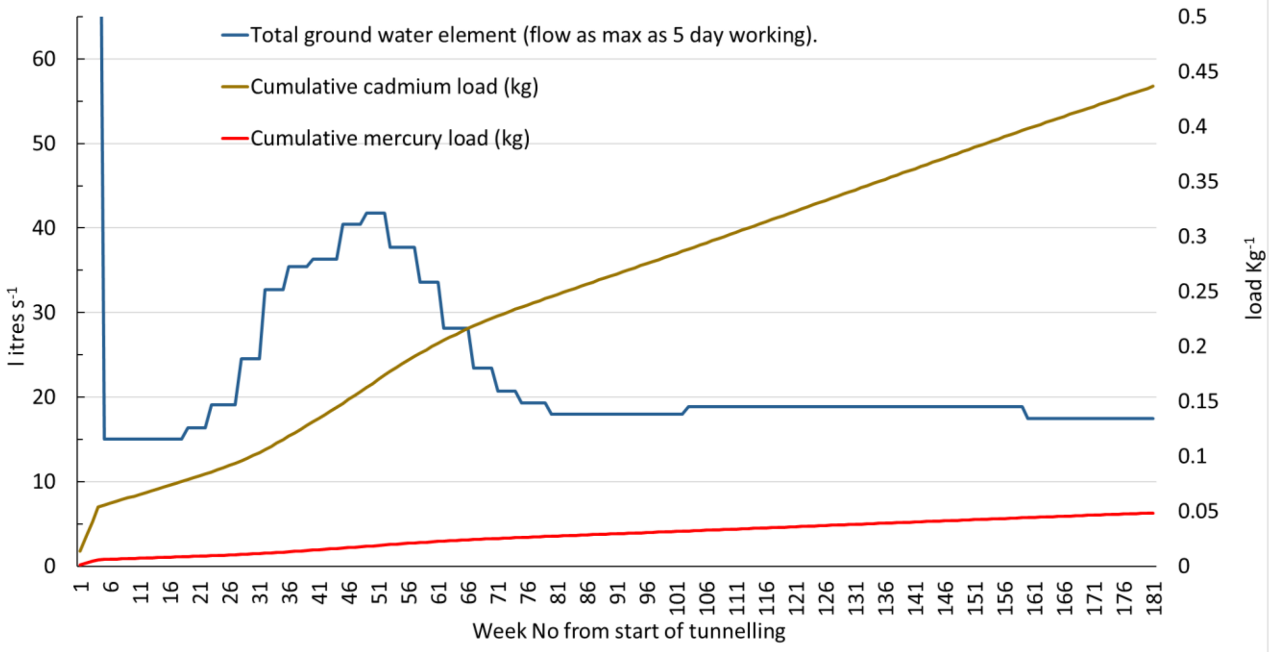


Figure 8: Just over three-year timeline of groundwater discharge (ls^{-1} left axis) and resulting cumulative load for Mercury and Cadmium (kg right axis).

5.3 Screening of chemical discharges

For the screening assessment tests 1 and 5 (as referenced in Clearing the Waters for All, Defra and Environment Agency Guidance, 2016) were applied to the predicted daily and annual discharge concentrations for chemicals likely to be discharged during the construction period. For test 1 the calculated concentration for a chemical is compared to its benchmark value that is either an EQS or PNEC, based on available toxicity data or refers to a background value from monitoring data for the site.

Discharge concentrations were calculated based on the quantity of various chemicals used in different processes and upon dilution in the relevant water flows. When calculating summary statistics for all substances, any values below the method detection limit were adjusted to a value equal to the detection limit. For metals, modelling tests use both total and dissolved concentrations to assess potential deterioration of surface water quality (Environment Agency, 2014). The total concentration of substances is used in the initial screen and in subsequent modelling to take account of uncertainty regarding the partitioning of substances into the dissolved phase as the groundwater mixes with the seawater. More detail on the handling of data and its analysis are provided in BEEMS TR193.

The updated guidance for surface water pollution (Environment Agency, 2016) recommends the application of an initial test (Test 1) for discharges to Transitional and Coastal (TraC) waters in which the discharge concentration is compared to the relevant quality standard or equivalent for that substance. Where the discharge concentration exceeds the standard concentration, further assessment is required. When the discharge concentration is divided by the EQS in Test 1 any values of 0.5 and above are taken forward to the next stage of screening. As this construction discharge will be subtidal and is over 50 metres offshore, a further test (“Test 5”) is recommended. Test 5 divides the concentration of a substance and volume discharged (the discharge specific Effective Volume Flux, EVF) by its EQS minus background concentration (the location specific Allowable Effective Volume Flux, AEVF). If the EVF is not greater than the AEVF, then the discharge is insignificant and is screened out. The AEVF references the discharge depth and this value can be up to a maximum of 3.5 metres. For Sizewell the discharge depth for construction relative to chart datum is greater than 3.5 metres therefore 3.5 this is the AEVF used for comparison

5.4 Metals and other contaminants present in groundwater

The volume of water that would need to be disposed of during the initial dewatering phase will be around $300,000m^3$ based on the hydraulic properties of the materials within the cut-off wall around the main construction site. It is estimated that to lower groundwater within the cut-off wall to the design level will take 28 days at a rate of $124ls^{-1}$. Following the initial lowering of water levels there will be some nominal ongoing discharge throughout the construction phase to deal with nuisance water (rainfall, seepage through the cut-off wall) but the volumes will be very small at estimated values of $15ls^{-1}$. Exploratory boreholes across the site showed different levels of contamination with dissolved metals and dissolved inorganic nitrogen (DIN) (Table 11). No other contaminants were detected (Atkins, 2016).

Table 11: Groundwater substance concentration range measured in Sizewell C construction site and relevant EQS values and marine background concentrations.

Substance	**Mean dissolved concentration μgl^{-1}**	**95% dissolved concentration μgl^{-1}**	**Saltwater EQS AA μgl^{-1}**	**Saltwater EQS MAC μgl^{-1}**	**Marine Background concentration μgl^{-1}**
Arsenic	3.55	11.5	25	-	1.07
Cadmium	0.10	0.18	0.2	1.5	0.05
Chromium	6.39	18.45	0.6	32	0.57
Copper	1.87	4.25	3.76	-	2.15
Lead	1.07	1.07^1	1.3	14	-
Zinc	7.34	17.5	6.8^2		15.12
Mercury	0.013	0.023	-	0.07	0.02
Iron	395	1500	1000	-	50
DIN	3.55	5636	980^3	-	426

1: For lead only 3 of 151 values above detection limits results in a mean value higher than the 95th percentile which is at the detection limit therefore the higher mean value is used here, 2: The EQS for zinc may be adjusted to take account of local background, 3: 99% (70µmol) converted to N standard for period 1st November – 28th February for dissolved inorganic nitrogen for Good status, Appendix B. Based on unpublished guidance more specific DIN value may be derived based on site average SPM 55mg/l however the value is used for initial screening but a more thorough investigation is undertaken using modelling.

In initial screening of the contaminants present in the groundwater it can be seen from Table 12 that the 95th percentile dissolved concentrations exceed the respective EQS for chromium, copper, and DIN. The zinc 95 percentile concentration in the discharge exceeds the mean EQS for zinc. It is not possible however to evaluate the zinc discharge using the initial dilution test 5 as the background concentration data also exceeds the EQS.

A second screening test (Test 5) was applied considering discharge rate to chromium, copper and DIN. For metals which are predominantly present in the groundwater their concentration is greatest during the first 28 days when the dewatering rate is $124ls^{-1}$. Calculation of AEVF for chromium, copper and DIN shows a failure of test 5 for chromium only. Chromium and zinc were therefore taken forward for a modelling assessment.

5.4.1 Modelling assessment of metals

Both zinc and chromium were modelled for Case A ($124ls^{-1}$) with a source concentration of $17.5\mu gl^{-1}$and $18.45\mu gl^{-1}$, respectively. A US EPA supported mixing zone model, CORMIX was used to predict the rate of chemical plume dilution and plume geometry from the CDO. Some comparisons were also run using the validated General Estuarine Transport Model (GETM) of Sizewell. The GETM set up parameters are described in BEEMS Technical Reports TR301 and TR302 for the thermal plume, and TR303 for the chemical discharges. GETM is a 3D hydrodynamic model with an inbuilt passive tracer to represent zinc and chromium. As a worst case, it was assumed that there was no loss of dissolved metals due to sediment absorption or biological uptake. Using these assumptions, concentrations can be scaled, as the modelled concentration was simply a function of dilution.

CORMIX Modelling shows that for zinc the outfall plume would no longer be detectable above background within 3m of the outfall. For chromium the outfall plume would fall below the EQS within 25m. The output data suggest an initial dilution, for both zinc and chromium, was 47-fold at 25m from the discharge (i.e. the same size as a single grid cell in GETM). GETM slightly under-predicts the initial dilution.

For GETM with the discharge volume of 124ls^{-1} entering the model surface layer the total volume in the upper grid cell is approximately 120m^3. GETM shows a 40-fold dilution in the first 25m, meaning the plume extends slightly further. The mean surface area in exceedance of the EQS for chromium, predicted by GETM, is 0.34ha, or 5 grid cells. For zinc, the total surface area is 0.11ha, or 2 grid cells.

Both CORMIX and GETM are conservative estimates as they do not include additional mixing and dilution due to waves.

5.5 Ammoniacal nitrogen (NH_4-N) in combined construction discharge sources

Ammonia enters freshwater and marine water bodies from sewage effluent inputs, from industrial and agricultural activities and from the breakdown of organic matter. In the marine environment the toxicity of ionised ammonia (NH_4) 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 NH_4 can also be toxicologically significant. Total ammonia values of 1100 (annual average) and 8000µg/l NH_4-N (WQTAG086, 2005) are therefore set as guide values for habitats andthese are considered. In general, the un-ionised form of ammonia is more toxic than the ionised form. At higher pH values, un-ionised ammonia represents a greater proportion of the total ammonia concentration. Temperature increase also raises the relative proportion of un-ionised ammonia, but this effect is much less marked than for pH change, e.g. a temperature increase of 10°C (from 10 to 20°C) may double the proportion of un-ionised ammonia but change from pH 7 to pH 8 produces an approximately tenfold increase (Eddy, 2005). A greater percentage of ammonia will also be in the un-ionised form when the salinity is lower.
The concentration of un-ionised ammonia can therefore be derived from knowledge of the total ammoniacal nitrogen concentration (i.e. NH_4 as N), the salinity, the pH and temperature using the EA calculator (Table 13). Of these the pH is the most important with an approximate doubling in un-ionised ammonia concentration between pH 7.5 and 8.
The EQS for un-ionised ammonia is 21µgl^{-1} expressed as an annual average, however being consistent with the previous screening, this value is compared with the 95th percentile source contributions. The 95th percentile values used for the source terms were a groundwater ammonium concentration of 5557.2µgl^{-1} as N and a treated sewage effluent maximum concentration of ammoniacal nitrogen 20000µgl^{-1} as N. 20000µgl^{-1} as N represents the design standard of the sewage treatment plant. Source concentrations of ammonia were entered in the EA calculator with starting parameter values for groundwater for pH, temperature and salinity to derive the initial proportion of un-ionised ammonia. As the freshwater construction discharge from site mixes with seawater it becomes more saline and the pH increases. The ammonia concentration in the discharge decreases with dilution. The proportion of un-ionised ammonia also decreases with increasing salinity but the elevated pH of seawater increases the proportion of un-ionised ammonia. The changing proportion of un-ionised ammonia was calculated by producing a plot of dilution against un-ionised ammonia concentration taking account of changes in pH and salinity (BEEMS TR193).

The two components of the mixing relationship were:

a. freshwater, with salinity derived from the average pH (7.3) and 95th percentile of ammoniacal nitrogen (Atkins, 2016), and an average temperature of 11.43ºC (BEEMS TR131).

b. seawater, with a mean temperature of 11.43ºC, 50th percentile salinity 33.1 (BEEMS TR189) and 50th percentile seawater pH 8.05 (BEEMS TR189). The average ammoniacal nitrogen in the sea water background was 11.38µgl^{-1} as N (BEEMS TR314).

Cases Amax, D1max, Dmax and sewage only are considered (Table 12).

Table 12: Un-ionised ammonia concentrations for groundwater (GW), treated sewage (STW) and combined discharge derived using the EA calculator as a source term before mixing.

Discharge	Ammoniacal nitrogen (N) (µgl^{-1})	Salinity	Temp °C	pH	Un-ionised ammonia (µgl^{-1})
Case A	5,557	1	11.43	7.3	22.8
Case D	9,049	1	11.43	7.3	37.2
Case D1	11,600	1	11.43	7.3	47.6
Sewage discharge only	20,000	1	11.43	7.3	82.1

For some Cases small sources which would dilute the concentration, but which may not be present all the time have not been considered (e.g. in case D there could be 4 litres per second of additional water not containing DIN).

1) Case A total discharge is 124ls^{-1} with a 95th percentile concentration of 5,557µgl^{-1} ammoniacal Nitrogen as N.
2) Case D total discharge is 55ls^{-1} with a 95th percentile concentration of 9,049µgl^{-1} ammoniacal Nitrogen as N.
3) Case D1 total discharge is 71.7ls^{-1} with a 95th percentile concentration of 11,600µgl^{-1} ammoniacal Nitrogen as N.
4) Sewage only discharge is13.3ls^{-1} at a planned maximum of 20,000µgl^{-1} ammoniacal Nitrogen as N.

Mixing of the different sources contributing ammoniacal nitrogen and the ratio of un-ionised to ionised ammonia upon mixing with seawater is evaluated using dilution rates specific to the Sizewell C construction discharge using CORMIX-US EPA supported mixing model (CORMIX Version 10.0GT HYDRO1 Version 10.0.1.0 April 2017) and these data are presented and discussed in section 6 with more detail provided in BEEMS TR193.

5.5.1 Modelling assessment of Ammoniacal nitrogen (NH4-N) in combined construction discharge sources (groundwater and sewage)

Ammoniacal nitrogen exists in both ionised and un-ionised form in the combined groundwater and sewage discharges from the construction site with the ratio of each determined by pH, temperature and salinity. Un-ionised ammonia is generally considered more toxic and has an annual average EQS of 21µgl^{-1}. A mixing figure was used to determine the ratio of un-ionised to ionised ammonia as the groundwater and sewage mix with seawater (BEEMS TR193). The derived values were considered in combination with the estimated dilution rates derived from the CORMIX modelling. Case A, Case D1 and Sewage only discharges have been modelled with CORMIX. As Case D is a lower flow rate and source input, its impact will be lower, and was not modelled.

It is evident from the derived data that there is exceedance of the EQS (21µgl^{-1}) when less than 68% mixing has occurred for Case A, 84% mixing for Cases D, 88% for D1 and 94% for the sewage only case. In relation to Case A, a dilution factor of 2.13, (68% mixing) occurs after 3.67m for a discharge of 124ls^{-1}. For case D1, a dilution factor of 7.33 (88% mixing) occurs after approximately 3.89 m. The sewage only case which is unlikely to occur, would be compliant with a dilution factor of 15.67 (94% mixing). This dilution is likely to have occurred within 6.3 m of the discharge (BEEMS TR193). The total ammonium concentration at the point of mixing described above is at background 11.38µg/l NH_4-N and well below levels of concern at mixing distance 1100µg/l (WQTAG086, 2005).

5.6 Dissolved inorganic nitrogen (DIN) in combined construction discharge sources

The maximum concentration of DIN in the sewage discharge could be up to 23000μgl^{-1} as N (including all potential sources). The mean flow rate is 13.3ls^{-1} but flow may peak intermittently up to 30ls^{-1}. It should be stressed that the 95th percentile concentration of the sewage treatment plant is still 5000μgl^{-1}. This value has been used previously and is still a conservative estimate of the total loading discharged. Maximum discharge flow occurs during the first month at 124ls^{-1} but consists only of groundwater contributions to DIN (Table 13). Thereafter it is possible that maximum discharge flow could occur during the Case D period. Using mean conditions for concentration and total maximum combined flow, regime D1$_{mean}$, becomes 71.7ls^{-1} at 2680μgl^{-1} (as N). In a very unlikely case the maximum sewage flow (30ls^{-1}) and maximum concentrations for sewage (23000μgl^{-1}) and 95th percentile for ground water (5636μgl^{-1}), would be 71.7ls^{-1} at 12900μgl^{-1} (as N) referred to as D1. The latter stages of the construction/commissioning period are E and E$_{max}$ with flow rates of approximately 28.3ls^{-1} (potential volume of 34.3 if tunnelling chemicals present) and concentrations of 2890μgl^{-1} and 5340μgl^{-1} respectively.

Table 13: DIN concentrations for groundwater (GW), treated sewage (STW) and combined discharge.

Case	Groundwater flow ls^{-1}	DIN concentration μgl^{-1}	Sewage Flow ls^{-1}	DIN concentration μgl^{-1}	DIN Discharge concentration μgl^{-1}
A	124	5636 (95%)	0	0	5636
D1 mean	41.7	1021 (mean)	30	5000	2686
D1	41.7	5636 (95%)	30	23000	12901
E mean	15	1021 (mean)	13.3	5000	2891
E	15	5636 (95%)	13.3	5000	5337

The discharges during construction that may contain DIN are likely to be of variable duration and concentration. Table 14 illustrates some potential cases. However, the highest most continuous daily loadings will be contributed during Case D1$_{mean}$, which includes a maximum sewage discharge rate and highest groundwater discharge rate (except for the initial dewatering period in the first month of construction). The total flow rate during D1$_{mean}$ is 71.7ls^{-1}and a concentration (represented by the 95th percentile for sewage) of 2680μgl^{-1} would lead to a discharge of 16.6kgd^{-1}.

During commissioning, ammonia is used (contributing approximately 0.66kgd^{-1} average daily discharge nitrogen) from the steam generator of the EPR and turbine hall and as this precedes construction/operation of the cooling water system the discharge will also occur through the CDO. Nitrogen input from commissioning is added to the groundwater and sewage loading derived for Case D1$_{mean}$ to provide a representative worst-case daily loading of 17.3kgd^{-1} DIN. This loading is therefore used for assessment of the potential impact on phytoplankton growth for the construction/commissioning period.

5.7 Phosphorus in combined construction discharge sources (groundwater and sewage)

Phosphorus is present in groundwater and treated sewage effluent and as these discharges will continue during commissioning of the EPRs any input of phosphorous from commissioning will be added to the total loading. A concentration 10,000μgg l^{-1} as P was derived for treated sewage from package units based on Natural England, 2016. For groundwater a 50th percentile value of 40μgg l^{-1} as TP was derived for Thames groundwater by Stuart and Lapworth, 2016. For the commissioning input reference was made to HPC-EDECME-AU-000-RET-000063, 2017 and a maximum discharge of phosphate per day based on a period of hydraulic testing and preservation of closed cooling circuits, chilled water and electrically produced hot water systems). A value of 594kg PO_4 over 85 days was used to derive a daily value of 6.99kg PO_4 or 2.28kg as P. Adding the commissioning load to that of treated sewage and groundwater (~26kg) gives a total load of 28.2kg. This phosphorus load was combined with the DIN inputs described in section 5.6 above and use to run a phytoplankton growth model (BEEMS TR385) and as briefly described in section 5.8.

5.8 Application of a phytoplankton box model to simulate growth under the influence of nutrient inputs during construction and commissioning

The effect of chlorination at Sizewell B on phytoplankton that pass through the power station was simulated with an emphasis on the spring bloom and summertime production using a phytoplankton box model. The combined loadings of nitrogen and phosphorus as previously described from the construction and commissioning inputs together with relevant inputs from SZB resulting from the use of conditioning chemicals and the discharge of treated sewage were assessed. 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 construction, so that no change in phytoplankton growth beyond natural variability would be observed.

A model run over an annual cycle predicts a 0.13% difference in annual gross production (BEEMS TR385) of carbon and this level of change would not be discriminated above natural background variation.

5.9 Assessment of BOD discharges during construction

The sewage treatment works is expected to achieve a maximum concentration of Biochemical Oxygen Demand (BOD) of $40mgl^{-1}$ (i.e. over the 5-day BOD test). Based on the expected number of staff on site during the construction phase and waste water production of 100 litres/per head/per day (Based on Hinkley Point C) a more typical sewage discharge of $13.3ls^{-1}$ (Case D) is expected through most of the construction phase but a maximum of $30ls^{-1}$ is also considered as Case D1. Groundwater contribution is not yet confirmed so a value of $5mgl^{-1}$ BOD (representing Good status classification of surface waters of specific types) and this together with relevant groundwater flow rates is taken account of for Case A, D and D1 to allow assessment.

The background BOD near to the Sizewell B cooling water discharge based on monitoring from 2010 (BEEMS Technical Report TR189) has a mean value of $2mg\ l^{-1}$. Dissolved oxygen levels at the site are ‘high’ with a mean DO concentration of $7.5mgl^{-1}$ (BEEMS Technical Report TR303) adjusted to an equivalent salinity of 35 this represents $6.27mgl^{-1}$ (Water Framework Directive Standards and Classification Directions, 2015). 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 $100mmol\ m^{-2}d^{-1}$ (Hull, 2016) or $3.2gm^{-2}d^{-1}$. Using $13.3ls^{-1}$ and BOD of $40mgl^{-1}$ and taking account of a groundwater contribution of $5mgl^{-1}$ a daily BOD of 121kg was calculated for Case D1, 64kg for Case D and 53kg for Case A. Every $1.5mgl^{-1}$ BOD is estimated to result in $0.5mgl^{-1}$ oxygen use (OSPAR Comprehensive studies report, 1997). Therefore, oxygen required to meet these BOD loadings would be D1 40.6kg/day, D 21.3kg/day and Case A 17.7kg/day. The maximum loading of oxygen would be transferred across 1.2ha in a day. For the more usual situation during construction (case D) this would be around 0.7ha. The maximum oxygen demand scenario is negligible relative to the high exchange rate across Sizewell Bay and the potential rate of reaeration at the sea surface. Therefore, these discharges would be expected to have a negligible impact on the well mixed highly oxygenated waters off Sizewell. Dissolved oxygen levels are likely to remain at high status. The discharges of BOD during construction are of negligible significance for dissolved oxygen modification.

5.10 Assessment of coliforms, enterococci – bathing water standards and shellfish

This assessment is based on bathing water regulations (2013. No. 1675) for coastal and transitional waters for which Good status requires that at the bathing water monitoring points 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 construction period meets the required standard.

Based on data in support of the Hinkley Point C development (pers. Comm., EDF), 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 UV 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. The distance from the discharge point at which this dilution occurs has been estimated using the Cormix estimates of dilution rates relevant for the 13.3ls^{-1} sewage discharge (Section 6 and Appendix C). The maximum flow rate of 30ls^{-1} could potentially occur although only briefly, therefore dilution has also been conservatively estimated using the 30ls^{-1} simulation.

Following either sewage treatment at a secondary or tertiary (UV) level the distance from the CDO discharge point, at which enough dilution occurs to be below relevant microbiological standard levels, has been estimated using CORMIX for Case D (30ls^{-1}) sewage discharge and Case D1 (72ls^{-1}) (Appendix C). The discharge plume is buoyant and will be on the surface. CORMIX estimates show that the concentration of Intestinal Enterococci is likely to exceed the bathing water standard (200 cfu/100ml) only within 66m of the discharge for the 30ls^{-1} case, without UV treatment. For the larger discharge volume (72ls^{-1}) the bathing water standards are exceeded for 460m. With UV treatment, even at the higher discharge volume, exceedance is limited to within less than 1 metre of the discharge. Typically, the sewage discharge may not be discharged on its own, but as part of other discharges, these other discharges will add direct dilution which compensates for the inhibition of mixing. The discharge has been modelled using the total volume although the sewage component is only a percentage of this therefore the assessment is conservative. The discharge point is not in designated bathing waters. Treatment from the plant is sufficient to ensure that *E.coli* concentrations in discharged waters comply with bathing water standards within a maximum of 3.1km from the discharge point (without UV treatment) and <1m (with UV treatment).

5.11 Tunneling wastewater and chemicals

The waste from the TBM soil conditioning chemicals if present is likely to make the largest contribution during Case E as two tunnel boring machines would be in operation and two volumes of makeup water containing conditioning chemicals would be employed. This assumption is based on the work conducted at HPC and it may be that conditioning chemical volume figures change when more is known regarding the tunnelling process required for Sizewell C. The total discharge volume during Case E is approximately 34ls^{-1}of which ~6ls^{-1} is contributed by soil conditioning water and chemicals.
The offshore cooling water infrastructure consists of two subterranean intake tunnels and one outfall tunnel. Tunnels would be excavated by tunnel boring machines (TBMs) from land. Spoil from the cutting face of the TBMs would be removed by a screw conveyor, then transported by conveyor belt to the landward muck bay for licenced disposal.

Groundwater would be generated from digging the galleries allowing access to the tunnels. During the transport of spoil material, groundwater and TBM chemicals can leach from the conveyor belts and fall to the tunnel floor. Wastewater on the tunnel floor would be discharged via the CDO. Discharges would be treated with a silt-buster or similar technology to minimise sediment inputs.

Various chemicals may be required during the tunnelling process:

- fuelling and lubrication of the TBM;
- sealing the tunnel walls against water/soil ingress, and;

- ground conditioning.

Fuel and lubricants would be subject to management protocols and oil/chemical spills will be contained by appropriate treatment and disposal. Sealants and greases are impervious to water and will remain associated with the tunnel walls or be removed with the spoil.
The underlying geology at Sizewell differs from Hinkley Point and a bentonite slurry tunnelling method is anticipated at Sizewell. Bentonite is a clay mineral regularly used in construction and offshore drilling operations. Bentonite is included on the OSPAR list of PLONOR substances (pose little or no risk to the environment). Although bentonite recovery systems are used with TBMs (as bentonite is a valuable resource in the tunnelling process) the potential release of fine material into the receiving waters is assessed.

In some TBM soil conditioning applications several different surfactant chemicals may be required. The use and discharge of two surfactant chemicals the anti- clogging agent BASF Rheosoil 143 and the soil conditioning additive CLB F5 M that are planned for use with the HPC tunnelling operation and that present higher risk quotients in terms of chemical properties are modelled. This approach has been taken to provide a representative upper bounding assessment of potential effects of discharges from this process.

As with the groundwater metals, the release and mixing of TBM chemicals in the construction discharge was modelled by considering them as passive tracers (no decay rate). As such, a single model run was carried out with single tracer at a release rate of 34.3 ls^{-1} with an initial concentration of 100 μgl^{-1}. The results were then scaled to the appropriate concentrations for each chemical, as the modelled concentration was simply a function of dilution. The discharge was modelled as a freshwater input with no thermal uplift. More detail on the model parameters is provided in BEEMS TR193.

A tunnelling discharge of bentonite at a concentration of 8.8mgl^{-1} was modelled using GETM (further details BEEMS TR193). The concentration of bentonite in suspension is orders of magnitude lower than baseline suspended sediments concentrations predicted during construction (BEEMS TR480), with 95th percentile concentrations of 10μgl^{-1} restricted to sea surface areas of mean 1.35ha and a 95th percentile area of 10.8ha. There was no exceedance at the bed above 6μgl^{-1}. Limited data on survival of organisms exposed to bentonite suspensions indicate that effects only occur when concentrations exceed 1gl^{-1} of suspended material (WHO, 2005). The low toxicity of bentonite, the small areas affected, and the low discharge concentrations are likely to have negligible effects on water quality.

For the soil conditioning chemical discharges, the total Rheosoil plume areas at the EQS (40μgl^{-1} as a mean and 95th percentile) were calculated. There was a small area of 1.01ha exceedance of the mean EQS at the surface and no exceedance of the EQS at the bed. CLB F5 M discharges did not exceed the EQS at the seabed and the areas at the surface exceeding the EQS were relatively small with 3.14ha and 25.01ha above the EQS for mean and 95th percentile assessments.

The most toxic of the active ingredients for BASF Rheosoil 143 Sodium lauryl ether sulfate was modelled for the tunnelling discharge and is an example of an alcohol ethoxysulphate. Although tunnelling would occur over several years only very small areas at the surface are predicted to exceed the EQS for Rheosoil and this group of surfactants are shown to be readily degradable with no indication for the formation of persistent or markedly toxic metabolites (HERA, 2004). The most toxic active component of CLB F5 M, mono- alkyl sodium sulphate is an example of an alkyl sulphate and experimental and field data also indicate this group to be readily degradable (HERA, 2002).

5.12 Construction discharge summary

Discharges during construction will be variable, of relatively low volume and will not continue at this level beyond the construction period. It is anticipated that to lower groundwater within the cut-off wall to the design level will take 28 days and will result in a discharge rate of 124ls^{-1}. During this period based on 95th percentile values of dissolved chromium and maximum estimates of the zinc concentration both metals are likely to exceed acceptable levels in the construction discharge. Assessment of mixing and dilution of the metals discharge using the CORMIX model and GETM (section 5.4.1) confirms that exceedance of the EQS for chromium is limited to within 25m of the discharge and that zinc would no longer be detectable above background at around the same point (More detail on the screening calculations is provided in BEEMS TR193).

Given the potential for dilution at the discharge point the maximum likely ammonia concentration and the equivalent contribution to nitrogen and to un-ionised ammonia input during construction are unlikely to represent a significant risk of deterioration in marine water quality. However, the effect of mixing with seawater on the proportion of un-ionised ammonia present in the discharge was assessed (section 5.5.1) by determining the proportion of un-ionised ammonia for a given percentage dilution and with reference to CORMIX dilution plots determining the distance required to reach a point at which the un-ionised ammonia concentration is below the EQS. For sewage only case representing the maximum ammonia contribution during construction the un-ionised ammonia would be below the EQS within 6.3 metres. Total ammonia concentrations would also be below annual average and maximum allowable concentrations based on habitats guidance at 6.3 metres for the sewage only case. The influence of the nutrients DIN and phosphorus present in construction discharges upon phytoplankton growth was assessed using a box model (BEEMS TR385). Run over an annual cycle the model showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.13% for maximum construction (and commissioning) inputs of DIN and phosphorus. Biochemical oxygen demand from combined groundwater and sewage inputs during construction (section 5.8.1) was shown to have a limited influence within a few hectares of the discharge.

The results of the microbiological assessment of the sewage effluent discharge are also presented and discussed in section 5.9. Taking account of effluent treatment at maximum sewage discharge rates during construction the discharge via the CDO would be meet the Good standard for bathing waters within 66m of the discharge if treated to secondary level and to within a few metres if UV treated. The nearest designated bathing waters are approximately 10km North of the discharge and so this would have negligible effect.

5.13 Commissioning discharges via the CDO

Commissioning of the UK EPR reactor is proposed to take place in two stages, namely (i) cold flush testing (CFT) and (ii) hot functional testing (HFT). The commissioning process for each unit would last for about 24 months. Both CFT and HFT processes will produce liquid effluents.

5.13.1 Cold Flush Testing

Prior to operation of the EPR units there would be a period of commissioning tests. Tests use demineralised water for preparing plant systems. This would include the substances shown in Modelling has been conducted to assess the potential interaction of any hydrazine discharge (BEEMS TR494) with designated areas and specific features (BEEMS TR494). The predicted phosphate load and nitrogen contribution from un-ionised ammonia discharged during commissioning is accounted for within the construction/commissioning assessment of phosphorus and DIN potential influence on phytoplankton growth (section 5.8). Other potential chemical discharges during commissioning include un-ionised ammonia, ethanolamine and hydrazine. Prior to the release of hydrazine from the holding tanks, hydrazine would be treated to reduce the discharge concentration. Various treatment options are under investigation and it is anticipated that a discharge concentration of 15µgl^{-1} would be achieved as a representative upper bounding concentration. As a discharge concentration of 15µgl^{-1} exceeds the EQS and fails the Test 5 dilution test this discharge concentration is modelled using GETM. Table 15 shows the H1 screening test 1 and 5 for the ethanolamine and un-ionised ammonia discharges. As un-ionised ammonia concentrations fail test 5 further modelling was also conducted for this discharge.

Table 14 and these figures which are based on HPC will be used in a modelling assessment. Testing of the primary and secondary circuits requires them to be filled and flushed several times each. The maximum daily discharge volume is 1500m^{3}d^{-1}, equivalent to the contents of the two 750m^3 tanks that serve this waste stream. NNB GenCo proposes to empty each tank once a day, although not at the same time. No operational cooling system will be available for the disposal and dilution of commissioning phase effluents during the cold flush testing (CFT) stage for the first unit to be constructed during the phased development of the Sizewell C site. Therefore, the only available discharge route for this wastewater stream will be through the CDO. If there is overlap in the period when each EPR is being commissioned this would increase discharge duration and load, but discharge concentration may be similar.

Cold flush testing mainly involves cleansing and flushing the various plant systems with demineralised water to remove surface deposits and residual debris from installation NNB GenCo’s intention would be for CFT effluent to be discharged to the Sizewell Bay via the CDO serving the Sizewell C construction site. The discharges resulting from CFT will be subject to a separate, later water discharge activity permit application. Modelling has been conducted to assess the potential interaction of any hydrazine discharge (BEEMS TR494) with designated areas and specific features (BEEMS TR494). The predicted phosphate load and nitrogen contribution from un-ionised ammonia discharged during commissioning is accounted for within the construction/commissioning assessment of phosphorus and DIN potential influence on phytoplankton growth (section 5.8). Other potential chemical discharges during commissioning include un-ionised ammonia, ethanolamine and hydrazine. Prior to the release of hydrazine from the holding tanks, hydrazine would be treated to reduce the discharge concentration. Various treatment options are under investigation and it is anticipated that a discharge concentration of 15µgl^{-1} would be achieved as a representative upper bounding concentration. As a discharge concentration of 15µgl^{-1} exceeds the EQS and fails the Test 5 dilution test this discharge concentration is modelled using GETM. Table 15 shows the H1 screening test 1 and 5 for the ethanolamine and un-ionised ammonia discharges. As un-ionised ammonia concentrations fail test 5 further modelling was also conducted for this discharge.

Table 14: H1 Test 1 and 5 for discharges of ethanolamine and un-ionised ammonia during commissioning.

Substance	**Estimated discharge concentration µgl^{-1}**	**Saltwater AA EQS µgl^{-1}**	**Background concentration µgl^{-1}**	Effective volume flux Total flow 83.3 l/s	TraC Water test 5 EVF < 3.0 (Pass/Fail)
Ethanolamine	4000	160	-	2.08	Pass
Unionised ammonia	12000	21	0.2	47.6	Fail

5.13.2 Hydrazine cold commissioning discharge assessment

To investigate the potential interaction of the hydrazine discharge concentration with relevant environmental sensitivities the results for assessment against the acute and chronic PNEC are compared against three criteria:

The likelihood that hydrazine could enter the Minsmere Sluice and/or affect passage of migrating Eels; Levels of hydrazine at the seabed over the Coralline Crag; The area of intersection of the acute hydrazine plume with Little Tern foraging areas.

The Minsmere sluice controls the seawater that can flow into various drainage channels including those used to periodically supply a saline input to the Minsmere salt marshes.

The Coralline Crag is a geological formation of special ecological interest in the area of Aldeburgh and Orford (Suffolk

In addition to the two PNEC values considered in this report (acute and chronic), the area exceeding 200ngl^{-1} as a 95th percentile, as more recently set by the Canadian Federal Water Quality Guidelines for hydrazine was also evaluated (Environment Canada 2011).

The 95th percentile results show that the plume at the surface is shorter and thinner than the mean plume. The plume at the seabed shows a similar elongated narrow plume (BEEMS TR494). The area exceeding the derived acute and chronic PNECs is less at the bed than the surface. At the surface ca., 12.9 and 30.5ha exceed the acute (4ngl^{-1}) and chronic (0.4ngl^{-1}) PNEC respectively. At the surface the exceedance for the 200ngl^{-1} Canadian standard is 0.34ha, which represents three model grid cells (25 x 25 m) around and including the hydrazine discharge from the CDO.

The hydrazine plume is transported northward towards Minsmere during the falling tide, meaning that the sluice water supply that is periodically used to add additional saltwater to the Minsmere salt marshes is unlikely to be exposed to hydrazine. The likelihood of any hydrazine exposure in the sluice water would also be made considerably less likely due to rapid degradation of hydrazine with a half-life of ca.,30 minutes. The passage of Eels into or out of the saltmarshes via the sluice is unlikely to be affected by the presence of hydrazine as hydrazine plumes would only intersect the sluice during an ebbing tide when water levels would be falling, and the sluice would be closed. The predicted peak concentrations of hydrazine in proximity to the sluice in any case at 0.12ng/l are ca., 800,000 times below levels shown to cause sublethal behavioural avoidance effects in the freshwater bluegill fish (*Lepomis macrochirus*) (Fisher et al., 1980) so Eels moving to or from the saltmarshes in the vicinity of the sluice would also not be exposed to significant concentrations of hydrazine.

In terms of the coralline crag the peak hydrazine concentration at the seabed over the crag does not exceed the acute PNEC and only exceeds the chronic PNEC for 15 minutes a day. In the Greater Sizewell Bay.

The hydrazine plume never intersects foraging areas for two of the three SPA breeding colonies of birds. Whilst the plume intersection with 15µgl^{-1} release concentration regularly exceeds 1% of the foraging range for the Minsmere little Tern colony, the duration of the plume is short, with concentrations exceeding the acute PNEC for no longer than 4 hours.

More details for these assessments are provided in BEEMS TR193.

5.13.3 Un-ionised ammonia cold commissioning discharge assessment

The discharge of un-ionised ammonia during the commissioning phase of the EPR construction was modelled using the validated GETM model of Sizewell. Ammonia is added to feedwater during commissioning to elevate pH and to reduce corrosion of ferrous metals. The maximum loading of ammonia planned during commissioning is expressed as a concentration of 12000µg l^{-1} un-ionised ammonia. The pH in various circuits during commissioning is ca.,10 and at this level this is equivalent to a total NH4-N concentration of 17,806µgl^{-1}. This ammonia concentration and the physicochemical conditions of the EPR commissioning demineralised water provide the starting point for calculation of a dilution curve as the effluent mixes with seawater. During mixing the reduction in pH from 10 to around 8 and the increasing salinity act together with dilution to change the concentration and ratio of unionised ammonia. A mixing level of 94.4% is enough together with the changing pH, and salinity that occurs as the wastewater mixes with seawater to reduce the unionised ammonia below its EQS and is equivalent to a 16.8-fold dilution.

Modelling using CORMIX indicates that this level of dilution is achieved within ca.,10m of the point of discharge. The modelling results from GETM show there is no plume in exceedance of the EQS for the un-ionised ammonia. In the direct vicinity of the outfall (<5m) the un-ionised ammonia of the discharge will exceed the EQS. But this behaviour is smaller than the model grid cell size (25m). Comparisons against previous nearfield modelling using CORMIX suggest a 16.8-fold dilution is achieved within approximately 10 m. As for the construction discharge assessment the total ammonium concentration at the point of mixing described above is at background 11.38µg/l NH4-N and well below levels of concern (WQTAG086, 2005) at mixing distance.

5.13.4 Hot functional testing

Hot functional testing begins following completion of CFT and when all the required systems are available. It takes place before fuelling the reactor and only once the cooling water infrastructure is in place and operational. The objective of HFT is to test the reactor and associated systems under pressure, temperature, flow and chemical conditioning as close to normal operating conditions as practicable without putting nuclear fuel at risk. The effluent produced during HFT would be diluted in the 132m^{3}s^{-1} cooling water flow within the cooling water system before being discharged via the outfall tunnel to the adjacent marine environment.

Due to the current stage of the project and the long lead time until commissioning takes place, detailed information on the nature of the discharges during HFT is limited, but it is assumed that HFT can be considered as running the systems under normal operating conditions. Therefore, the assessment for operational discharges would also apply to that during HFT.

5.13.5 Chlorination testing

Coastal power stations require a means of chlorine dosing for biofouling control. Based upon the known risk of biofouling at Sizewell, SZC Co would need to chlorinate the Sizewell C cooling water (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 Total Residual Oxidant (TRO) dose of 0.2mgl^{-1} in critical sections of the CW plant and at the inlet to the condensers.

Testing of this system would be undertaken during commissioning, but it is assumed that this would only occur once the full cooling water system was in place and operational.

The chlorination strategy for Sizewell C is presented in BEEMS Technical Report TR316. This will be continuous dosing and will respect the operational needs of the plant, the Environmental Quality Standards and the Habitats Regulations thresholds. It is currently expected that the Sizewell C intake heads, tunnels and forebays will not be chlorinated.

The expected discharges from the chlorination process include:

- Residual oxidants measured as total residual oxidants and expressed in terms of chlorine equivalent concentration. Also, various chlorination byproducts the range and proportions of these are variable and relate to the presence of organic material and bromine or bromide concentrations in the sea water being treated.
- Trihalomethanes the most dominant of which in terms of concentration is bromoform at Sizewell.

It is assumed that during commissioning chlorine would be dosed to achieve a target TRO concentration of 0.2mgl^{-1}. Therefore, as this would be the same as for the operational phase the detailed modelling assessment for operational chlorine dosing described in section 5.3 would also apply to the chlorination tests.

5.14 Inter-relationship effects construction and cold commissioning discharges via the CDO

This section provides a description of the identified inter-relationships that have the potential to affect marine water quality and sediment from construction of the proposed development. These are the effects arising from construction work acting in-combination to form additive, synergistic or antagonistic effects. Figure 9 shows potential extent and overlap of influences on water quality during the construction/cold commissioning period. Various construction activities and including cold commissioning would produce discharges via the CDO. Thus far assessments have been conservative accounting for all potential sources for a given substance and making worst case assumptions regarding the overlap of different source discharges. This section considers the potential interaction of dredging associated with the establishment of infrastructure and separately considers chemical discharges from the CDO and potential interaction within the thermal and chemical discharge plume from Sizewell B.

5.14.1 In-combination effects from simultaneous dredging activities

During the construction phase, there is the potential that simultaneous dredging activities could occur. Maintenance dredging for the BLF is anticipated to occur at approximately monthly intervals during the campaign period. As a worst-case, it is assumed there is a temporal and spatial coincidence of the plumes from maintenance dredging for the BLF (plough dredger) and dredging (cutter suction dredger) and disposal material from (a) cooling water infrastructure and (b) the southern FRR outfall.

The suspended sediment plumes from the BLF maintenance dredge and the cooling water infrastructure do not interact, forming two discrete plumes. Therefore, the concurrent activities result in a greater spatial area of impacts rather than interactive effects. Increases in the total size of the instantaneous SSC plume are minimal.

The suspended sediment plume from the BLF maintenance dredge and the FRR dredge plume do interact. At the sea surface the maximum instantaneous area exceeding 100mg/l increases to 111ha. This increase is greater than the sum of the two individual activities; however, the plume is highly transient and the total duration of increases in SSC would be reduced due to the temporal overlap. The total area likely to be affected by SSC elevated to 50mg/l at the surface above background (if BLF maintenance, CWS intake and FRR outfalls are simultaneously dredged) and that would be likely to raise the tubidity classification from intermediate to turbid would represent an area equivalent to 5% of the Suffolk Coastal waterbody (this assessment considers absolute areas only as actual overlap of the CWS sediment plumes with this waterbody would be more limited). This area of exceedance would occur for <5% of the year assuming e.g. monthly maintenance dredging and dredging of six CWS intakes and outfalls. The original assessment of individual activities for each development component causing changes in SSC on marine water quality and sediment therefore remains the same.

5.14.2 In-combination effects construction discharges from the CDO and thermal and chemical discharge from Sizewell B

Construction discharges containing metals and un-ionised ammonia and potentially surfactants from tunnelling have very small areas of EQS exceedance close to the CDO and therefore the interaction with the thermal and chemical plume from Sizewell B at concentrations above EQS or equivalent level is very limited.

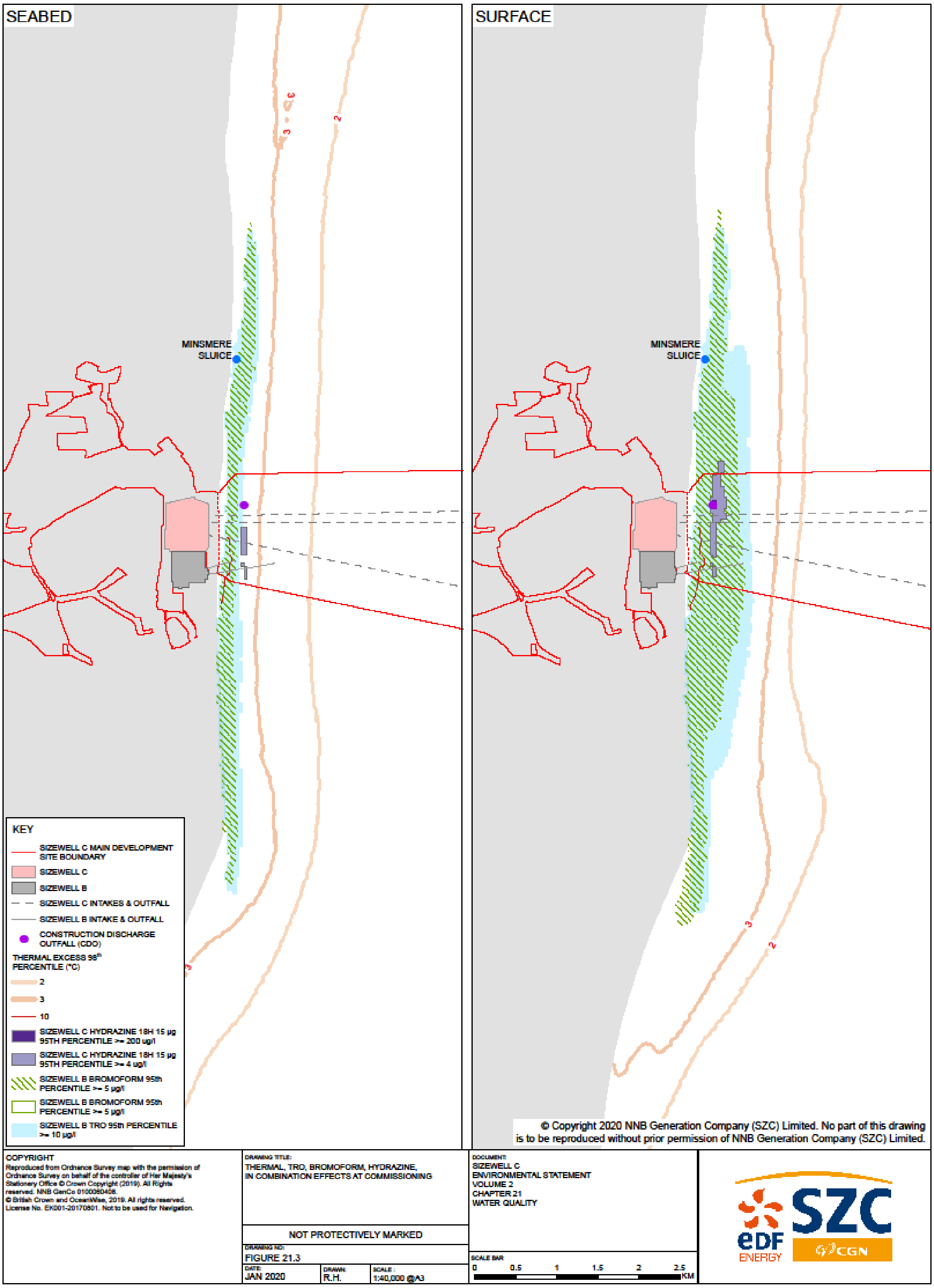
Chlorine and ammonia at similar molar concentrations and at low concentration can react in full strength seawater to form, predominantly, dibromamine which has higher toxicity than TRO alone (Inman and Johnson, 1977). However, the TRO concentration derived from Sizewell B that would intersect the CDO discharges would be ca. 20µg/l and the concentration of ammonia NH_4-N rapidly decreases to ca., 11µg/l at around 25 metres of the discharge meaning that the concentration of any combination products would be at very low concentrations and within a limited area around the CDO.

Thermal elevation in proximity to the CDO discharge is predicted to be up to 5°C degrees above background.

Increase in temperature is known to increase chlorine toxicity, particularly when exposure temperatures approach the limits of a species' tolerance range (Taylor, 2006). Temperature dependent toxicity is suggested to be a result of increased uptake rates and physiology at higher temperatures. A 5°C increase in temperature more than halved the LC50 concentration of free chlorine and chloramine in 30-minute exposures in the rotifer Brachionus plicatilis, larvae of the American lobster Homarus americanus, and American oyster larvae Crassostrea virginica (Capuzzo, 1979). However, in the same studies the eurythermal copepod A. tonsa was unaffected by temperature increases. Chlorinated effluents typically dilute relatively quickly in receiving environments, as such the potential for synergistic interactions in the field would be reduced (Taylor, 2006).

In the case of the CDO discharges and overlap with the Sizewell B thermal plume the TRO concentrations would be at sublethal levels and in this case a temperature elevation of 5°C would not be expected to have a measurable effect on the toxicity of combined or free chlorine residuals and so the assessment is the same for the individual discharges from the CDO and in combination with any thermal influence.

A negligible effect assessment is therefore made for the interaction of the CDO discharge (metals, the un-ionised ammonia, tunnelling surfactants) and Sizewell B cooling water discharge (including TRO, CBP thermal elevation) with individual chemical discharge assessments unchanged.



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THERMAL, TRO, BROMOFORM, HYDRAZINE, IN COMBINATION EFFECTS AT COMMISSIONING

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VOLUME 2
CHAPTER 21
WATER QUALITY

Figure 9: Overlap of thermal plumes from Sizewell B and chemical plumes from the CDO during construction/cold commissioning of Sizewell C.

6 Potential effects of the operational phase of the development on marine water and sediment quality

This section details the potential effects of the development's marine components and the associated operational activities on the receptors defined in the Sizewell C EIA scoping document (SZC Co, 2014a); namely the water and sediment quality of the greater Sizewell Bay. These marine components consist of:

i. the Beach Landing Facility (BLF);

ii. cooling water outfalls and

iii. fish recovery and return system outfall.

Expected effects of activities and discharges to local marine waters from Sizewell C during the operation may be broadly characterised as:

- Sediment disturbance
- Thermal elevation of the cooling water
- Surface drainage from across the developed site;
- Grey and black water drainage from on-site purification plants;
- Effluent from demineralisation plant;
- Chemicals discharged during the operation of the 2 units; and
- Discharges associated with chlorination
- Influence of thermal elevation on other parameters

6.1 Beach Landing Facility Operation

A Beach Landing Facility (BLF) will be used to import rock armour, AILs and receive marine freight during the construction phase, and occasional AILs over the operational life of the site. During the power station's operational life, cross-shore works would be constrained in space and time to the occasional needs for AIL deliveries (estimated as once every 5-10 years).

6.1.1 Dredging the BLF

North Sea Barges (or similar) will be used to deliver freight (AILs, rock armour and potentially other materials) to the BLF for transfer onto the main development site or construction area as appropriate. A plough or scraper method will be used to gain clearance over the outer longshore bar and to flatten the inner bar so that barges can come safely aground, on a planar surface, on the falling tide after they dock onto the BLF deck.

During establishment of the BLF the total dredge volume to be modelled is 4,600m^3. The proposed plough dredge method does not extract material; however, banking of redistributed sediments may occur in the local vicinity causing burial of surficial sediments and associated biota.

The capital dredging requirements of the BLF access channel and the subsequent disposal of dredge spoil present a risk of remobilising any contaminants present in the local seabed sediments. Maintenance dredge modelling simulates removal of 10% of the total capital dredge volume. Following the initial capital dredging event, a plume with an instantaneous suspended sediment concentration (SSC) of >100mg/l above daily maximum background levels is expected to form inshore over an area of up to 108ha at the sea surface and 83ha as a depth averaged plume. A small area of up to 7ha would experience an instantaneous SSC plume of >1,000 mg/l above background levels. Maintenance dredging, occurring at approximately monthly intervals, would result in up to 28ha of sea surface expected to experience >100mgl^{-1}, and 1ha expected to experience >1,000mgl^{-1} above background SSC on each occasion. The spatial extent of SSC elevation 248ha at >50mg/l would be equivalent to a WFD turbid classification (i.e. 100 – 300mg/l) when considered in addition to mean SSC background concentration during most of the year. An area of 248ha is <2% of the Suffolk Coastal waterbody area

The marine sediment quality off Sizewell was characterised in terms of contamination in BEEMS Technical Report TR305. The report concluded that due to the sandy nature of the material and levels of contamination below Cefas Action Level 2 found in the marine sediment at Sizewell, there is a low risk of release of contaminants to the water column. The proposed seabed disturbance activities associated with the operational phases of Sizewell C are, therefore, considered unlikely to cause any chemical release effects to the water and sediment quality of the local area due to the sediment quality.

The potential for chemical and oil spills during vessel movements, whilst recognised, would be managed by compliance with IMO regulations. Therefore, no chemical release effects to the water and sediment quality of the local area are expected.

The potential for chemical and oil spills during operational activities, whilst recognised, would be covered under the Government Pollution Prevention Guidelines. Therefore, no chemical release effects to the water and sediment quality of the local area are expected.

As for the capital dredge of the BLF, plots of SSC (BEEMS TR480) show a plume with highest concentrations occurring in a relatively narrow band along the coast. The concentrations for the maintenance dredge are lower than those associated with the capital dredge as a result of the much lower volume of sediment release. Depth average location maximum SSC of more than 100 mg/l above background extend approximately 5 km north and south of the dredge area for the capital dredge. Following the completion of the dredge the plume quickly disperses. On spring tides material in suspension is at concentrations of less than 20mg l^{-1} above background within three days. On neap tides, the plume concentrations in suspension also quickly return to values which are close to background, however some resuspension of material is expected once the larger range spring tides occur. (BEEMS Technical Report TR480).

6.2 Cooling water discharge

6.2.1 Thermal plume assessment

The proposed Sizewell C power station would comprise a twin-unit European Pressurised Reactor (EPR), with a design cooling water outfall rate of 132m^{3}s^{-1} (2 x 65.9m^{3}s^{-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^{3}s^{-1}) would supply the main cooling water systems (CRF) via the station drum screens. The thermal uplift of the 12m^{3}s^{-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^{3}s^{-1} would be discharged at 11.6°C ΔT (BEEMS Technical Report TR302. This is within 1.4% of the total heat flux of the estimated cooling water discharge of 131.8m^{3}s^{-1} at a net 11.15°C thermal uplift and the modelling reported in TR302 is, therefore, considered enough accuracy for thermal assessment purposes. The cooling water will be extracted from the Southern North Sea via two separate intake tunnels each with 2 intake heads and will be returned through one single outfall tunnel with 2 outfall heads. As Sizewell B will be operational until at least 2035 the in-combination effect of Sizewell B and Sizewell C needs to be considered. The thermal plume has been modelled taking account of mixing and dilution in a tidal regime.

6.2.2 Chemical plume screening assessment

Potential discharges to the marine environment have been assessed for the operational phase of the planned Sizewell C. For large cooling water discharges that are discharged to estuaries or coastal waters a specific screening assessment recommended by Defra and Environment Agency, (Clearing the Waters for All, 2016) is applied. More detail on these assessments is provided in BEEMS Technical Report TR193).

To assess the significance of specific chemical discharges the methodology uses as its reference existing Environmental Quality Standards (EQSs). Where no EQS is available for a given substance then any available toxicity test data are used to generate a Predicted No Effect Concentration (PNEC) as a reference for short term acute exposure and longer-term chronic exposure. Where insufficient or no toxicity data can be sourced then the marine background concentration for a substance from monitoring conducted adjacent to the Sizewell site is used.

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) 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 waters (“surface waters”).

Substances are assessed in two stages: screening and modelling.

For discharges where a simple assessment cannot be applied or where a potentially unacceptable area of exceedance of an EQS or equivalent is indicated then more detailed modelling is undertaken.

6.2.3 Chemical loading for discharges via the cooling water system

Operation of 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. The cooling water drawn from the Southern North Sea off Sizewell will be chlorinated to prevent fouling and passed through condensers to effect cooling and returned to the Southern North Sea.

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

- Seawater cooling system;
- Primary system;

- Secondary system;
- Site oily water drainage system;
- Production of demineralised water; and
- Sanitary effluent treatment.

In addition to the cooling water discharge, trade effluents will be produced as a result of normal operation of Sizewell C and once appropriately treated will be discharged in combination with the cooling water (e.g. process effluents from some of the systems above and sanitary effluents).

The data for chemical discharges associated with cooling water effluents during the operational phase have been mainly provided as maximum loading rates over annual and 24-hour periods for most chemicals within the discharge (Appendix D). The derivation of the load calculations for some substances requires more detailed explanation and so this is provided e.g. for nitrogen and hydrazine which are included in the chemical discharges to the marine environment during operation and are discussed in the following sections.

6.2.3.1 Surface drainage and groundwater

The site will be managed to avoid contamination of surface drainage therefore the variable natural surface drainage from the site would not be assessed using the screening methodology. Groundwater discharges from the operational site would be made at a maximum rate of 15ls^{-1} (BEEMS Technical Report TR193). These discharges would be subject to discharge consent. 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 routed via the cooling water discharge, they are unlikely to be of concern.

6.2.3.2 Demineralisation plant discharges

Various process operations in the nuclear plant require the use of demineralised water. Effluent from this process 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. 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 screening assessment uses the discharge loading values for a combined desalination and demineralisation plant. This is considered to provide bounding conditions of a worst-case discharge scenario for the assessment. The expected effluents from a combined desalination and demineralised plant are presented in TR193. For the Sizewell C demineralisation plant one of two sequestering agents will be used i.e. either an Amino tri-methylene phosphonic acid (ATMP) based sequestering agent or a sodium polymer-based compound (which comprises 10% alkyl phosphonic acid and 90% sodium polyacrylate).

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 annual loads of the priority hazardous substances cadmium and mercury. Based on operational experience and feedback (OEF) from EDF's French fleet of nuclear power stations. Annual and daily loadings for cadmium (0.37kg/y and 0.005kg/day) and mercury (0.099kg/y and 0.0011kg/day) are based on characteristics of reverse osmosis reject water. Both the annual load and scaled up daily loading figures meet the requirement to not exceed a significant annual load of 1kg (daily scaled to year cadmium 1.8kg/day and mercury 0.4kg/day) for mercury or 5kg for cadmium.

Accounting for these loadings in the operational assessment for large cooling water discharges, cadmium including local background, produces a maximum (24h) discharge concentration of 0.13µgl^{-1} and relative to its 95th percentile EQS a quotient of 0.13/1.5=0.09. Based on an assessment against the cadmium annual average EQS and the relevant annual average loadings predicted a quotient of 0.25 results. For mercury the assessment against the 95th percentile and annual average EQS results in quotient values of 0.29 and 0.28.

These values are all low and are largely contributed by site background values which are ca.,100 times higher than the maximum predicted daily discharge concentration and more than this for the annual values.

6.2.3.3 Hydrazine load derivation

The main operational waste streams that would potentially contribute to the discharge of hydrazine are shown in Table 16. Waste streams fed from the primary circuit include hydrazine loads that 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).

Waste stream hydrazine loads derived from the secondary circuit daily so these are used for the screening assessment as they are regularly subject to discharge. The daily value represents a daily worst case value that may occur on a given day dependent upon operational processes. The annual value is a total for the year and represents the generally lower daily values that more regularly occur during operation and that are summed to produce the annual figure.

Table 15: Operational phase chemical discharges of hydrazine from sum of waste streams for 2 EPR units (based on EDECME120678 PREL A, 2011).

	Waste stream discharge primary circuit	Waste stream discharge secondary circuit
Hydrazine (daily value) (kg)	1	3
Hydrazine (annual value) (kg)	3	24.3

6.2.3.4 Nitrogen load derivation

For the operational phase, for the screening assessment consideration is made of the contribution of all nitrogen sources in terms of the potential to affect the nutrient status of waterbodies receiving a discharge. In addition, all contributions to ammoniacal nitrogen are considered too as these can contribute to the un-ionised ammonia concentration for which due to its high toxicity, there is an established EQS.

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 and is explained in the following section.

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 EA 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 are used in the EA 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. The physicochemical data for the site are derived from BEEMS report TR189. Comparable summary statistics for physicochemical parameters were derived for surveys from 2010/11 and 2014/15 but as the differences in the datasets were not large and modelling was developed around the earlier dataset and the scenarios provide a precautionary assessment it was not considered necessary to re run this modelling using slightly updated values from the 2014/15 survey although the more reliable data for ammonia background from the latter survey was used.

Sizewell C nitrogen discharges are derived from several sources and waste streams. The un-ionised ammonia figures in Table 17 were calculated using the Environment Agency calculator (Clegg and Whitfield, 1995) which requires input data for temperature, salinity, pH and total ammonia and takes account of typical (annual average) and worst-case (24 hour) temperature uplift (Table 18). All these source data were specific to the Sizewell site. The data recorded during the 2010 monitoring survey at Sizewell (BEEMS Technical Report TR189) and for the historic temperature record for the site (BEEMS TR131) were the reference source for the relevant physicochemical data used to derive un-ionised ammonia values for screening and the background ammonia concentration in the local seawater was derived from BEEM TR314.

For annual assessment a 98th percentile temperature value (19.4˚C), a 50th percentile pH (8.02) and 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 (BEEMS Technical Report TR302) 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.

For the 24 hour assessment a combination of maximum likely daily loading of total ammonia and plausible extreme combination of physical conditions that will result in the maximum proportion of un-ionised ammonia is considered. 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 (BEEMS Technical Report TR303 Edition 4). Hence a value of 23.2˚C together with the 98th percentile background temperature (19.4˚C) 95 percentile background pH (8.2) and 5 percentile background 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. as a potential barrier to fish migration).

Table 16: Operational phase chemical discharges of nitrogen from sum of waste streams for 2 EPR units (based on EDECME120678 PREL A, 2011 and adapted using input data from TR131 ED 2 and TR303 Edition 4).

Substance	Maximum annual loading (kg yr^{-1})	Maximum 24-hour loading (kg d^{-1})
Nitrogen (as N) (excluding hydrazine, morpholine and ethanolamine)	10130	332[1]
Nitrogen (in terms of ammonia ions NH_4 excluding hydrazine, morpholine and ethanolamine)	13009	77[1]
Nitrogen (in terms of Un-ionised ammonia NH_3	958[2]	27

1 For the annual figures total nitrogen is mostly contributed by the ammonia sources but for the maximum loadings nitrogen sources in addition to ammonia contribute to waste streams. 2 figures are back calculated from the un-ionised ammonia concentration derived from the un-ionised ammonia calculator using the NH_4 concentration that results from the combined sanitary and conditioning inputs and site background physicochemical data (see Table 18)

6.2.3.5 Sanitary waste discharges and calculation of un-ionised ammonia for combined inputs

Information on sanitary waste discharges during the operational phase are based on plans for HPC. For estimation of loadings from the treatment works into the cooling water for the screening assessment the following have been assumed:

- Maximum number of operational staff present during 24 hours (under outage conditions) – 1900 personnel (normal operation 700 staff + 200 contractors and outage 600-1000 extra);
- Waste water production per person – 100 litres/day; and
- Discharge concentrations – BOD 20mgl^{-1}, Total Ammonia 20mgl^{-1} and Total Suspended solids 30 mgl^{-1}. Based on these criteria the calculated discharge loadings are presented in Table 18. Further details relating to the calculation of these loadings are presented in EDF (2011).

The values for total ammonia and suspended solids have been combined with other respective sources for each for the screening assessment, to obtain a total discharge loading figure for the 2 EPRs during operation.

Table 17: Calculated discharge concentration of un-ionised ammonia (as N) for treated sanitary effluent and combined inputs.

Parameter	Derivation of value	24 hour value	Annual value
BOD	Sanitary loading	3.8kg d^{-1}	1,387kg yr^{-1}
Suspended solids	Sanitary loading	5.3kg d^{-1}	1,916kg yr^{-1}
Total Ammonia	Sanitary loading	3.8kg d^{-1}	1,387kg yr^{-1}
Total Ammonia (Circuit conditioning)	Circuit conditioning loading	77kg d^{-1}	13,009kg yr^{-1}
Maximum ammonia concentration in discharge NH4-N	Based on a 62.5[1] and 116[2] cumec flow	10.49µgl^{-1}	3.06µgl^{-1}
Temperature data used in calculator	Based on maximum site background 19.5°C + either thermal uplift of 23.2 or 11.6 °C[1]	42.6°C	31.1°C
pH data used in calculator	Based on 95 percentile and 50th percentile	8.23	8.05
Salinity data used in calculator	Based on 5 percentile and 50th percentile	31.7	33.27
Site background ammonia NH4-N	Based on 95 percentile and mean	26.3µgl^{-1}	11.38µgl^{-1}
Total ammonia in discharge including background NH4-N	95 percentile and mean background added to respective mean and 95 percentile discharge	36.78µgl^{-1}	14.44µgl^{-1}
Un-ionised ammonia concentration NH_3-N	Calculated with EA un-ionised calculator using combined discharge concentration plus background ammonia	7.324µgl^{-1}	0.96µgl^{-1}

[1] see BEEMS Technical Report TR302 – worst-case scenario when 2 out of 4 pumps were under maintenance the flow of cooling water would be halved; [2] This provides a conservative assessment i.e. based on plant not at full capacity as at 132m^3s^{-1}there would be greater dilution

6.2.3.6 *Sanitary waste discharges and microbiological parameters*

Similar staff numbers on site during operation at Sizewell are anticipated as for the current assessment for Hinkley Point C and on this basis, estimates are made of maximum discharge concentrations of inputs into the sewage treatment plant. Secondary treatment implies a 100 factor (2 log) reduction in Coliforms and enterococci. If UV treatment is applied a 5.4 log reduction would occur. The dilution factor required to reduce the coliforms to levels that would comply with bathing water standards has been derived.

6.2.3.7 *Chlorination and chlorination byproducts*

Sizewell C would require an annual TRO discharge permit in order to allow year-round protection of critical plant- essential cooling water systems for the nuclear island and turbine hall (SEC, SEN respectively) and the condensers. It is assumed that chlorination would be applied at dose level to produce a TRO concentration of 0.2mgl^{-1} at the drum screens. The TRO discharge concentration from the CW systems at the outfall would be 0.15mgl^{-1} and this is the value included in the screening assessment Table 41 and Table 42.Chlorination of seawater at Sizewell is likely to lead to the production of chlorination byproducts which exert their own toxicity. The primary byproduct identified as likely to be produced at Sizewell is bromoform for which laboratory-based simulation studies indicate may be present at a concentration of 29µgl^{-1} (see section 7.2.4) so this is considered in the screening assessment.

6.2.3.8 Thermal elevation of cooling water discharge

The proposed Sizewell C power station would comprise a twin-unit European Pressurised Reactor (EPR), with a design cooling water outfall rate of 132m^3 s^{-1} and a mean excess temperature of 11.6˚C. The cooling water will be extracted from the North Sea via two separate intake tunnels each with 2 intake heads and will be returned through one single outfall tunnel with 2 outfall heads. As Sizewell B will be operational until at least 2035 the in-combination effect of Sizewell B and Sizewell C needs to be considered. The thermal plume has been modelled taking account of mixing and dilution in a tidal regime and is described in section 7.

6.2.3.9 Dissolved oxygen saturation as influenced by the thermal plume

At a constant salinity, temperature has a direct effect on the concentration of dissolved oxygen. The dominant effect on oxygen concentration in the plume comes from the change in temperature and the likely saturation of the warm plume. The plume as it comes out of the power station will be warmer (approximately 11.6ºC) than the intake and will have less capacity to carry oxygen. If the original intake water was fully saturated, then the hotter water will be supersaturated greater than 100% saturation (as the O_2 has nowhere to go) and will escape to the atmosphere soon after discharge. In some water bodies, due to biological oxygen demand, the observed oxygen values are reduced below those of saturation; if such a body of water were to be heated then it would not reduce the oxygen available, if it stayed below 100% saturation.

In the specific case of Sizewell Bay there is no evidence of high biological oxygen demand. Several surveys designed to measure water quality at Sizewell were undertaken over a year; the results of which are presented in BEEMS Technical Report TR189. The results show that there are no apparent oxygen deficits in this water, the minimum oxygen saturation from 83 observations is 91% and the average is 101% saturation.

Calculations of the concentration of dissolved oxygen at saturation have been derived from the GETM model output using 50 percentile salinity values (33.27) from the annual data obtained during 2010, and the derived temperature fields from each run using the method of Benson and Krause (1984). As the field observations showed no biological demand, none has been applied to the results.

6.2.3.10 Un-ionised ammonia ratio as influenced by thermal plume

Criteria for defining the level of un-ionised ammonia that is acceptable have been defined by the UK Technical Advisory Group (UKTAG) (Johnson *et al.* 2007). Un-ionised ammonia concentrations have been calculated using the Environment Agency provided calculator (Clegg *et al.*1995) using the GETM output for temperatures and observed values for salinity, pH and background ammonia levels. The regulatory approach for ammonia considers an annual average with an EQS value of 21µgl^{-1}. The model runs replicate an annual cycle. Results have therefore been derived using an average temperature and average ammonia values and these are shown in Table 19. As various extremes of physicochemical parameters can affect the proportion of un-ionised ammonia some additional consideration of the potential worst case, results are also presented with 95 percentile temperatures and mean ammonia, pH and salinity, and also 95 percentile values of pH and ammonia and the 5 percentile value of salinity with mean temperature and it is these that are shown.

Table 18: Values used for calculation of un-ionised ammonia in thermal plume

	Salinity	**pH**
5th centile (yearly)	31.72	Not applicable
50th centile (yearly)	33.27	8.05
95th centile (yearly)	Not applicable	8.23

7 Assessment of the operational phase of the development on marine water and sediment quality

7.1 Thermal modelling assessment

BEEMS Technical Report TR301 summarises the setup, calibration and validation of the 2 hydrodynamic models of Sizewell that were setup in accordance with Environment Agency guidance on modelling of nuclear new build developments. That report describes why a GETM model was selected for thermal and chemical modelling of the station and the studies that were undertaken to select the locations of the cooling water intakes and outfalls. The thermal plume from both Sizewell B and Sizewell C was modelled using the validated Sizewell GETM in BEEMS Technical Report TR302. The modelling simulations of the thermal plume consider the preferred cooling water (CW) configuration (configuration 12) with offshore intakes at I3 and I4 and an offshore outfall at O9 determined from the TR301 study. The geotechnical data necessary to finalise the location of the outfall structure are not yet available. The location O9 was selected as the furthest west that a Sizewell C offshore discharge could be built. Modelling demonstrated that outfall locations further east would produce lower thermal effects and that O9 could be considered as bracketing the worst case option for environmental assessment purposes (BEEMS Technical Report TR302).

Sizewell B will be operational until at least 2035 and therefore the modelling undertaken in the study was of the in-combination effect of Sizewell B and Sizewell C. The modelled Sizewell C cooling water system represented a realistic CW configuration with a total of 4 intake heads and 2 outfall heads.

To take account of different power station combinations and operation levels three power station scenarios were considered:

a. ZeroReferenceV2: no power stations present

b. ReferenceV2: present day situation with only Sizewell B.

c. Conf12: Sizewell C with 4 intake heads and 2 outfalls, all offshore from the Sizewell-Dunwich bank, additionally to Sizewell B.

The GETM runs used in this report are listed in Table 20 and the location of the cooling water heads in Table 21.

The three basic configurations were run for one year with meteorological forcing from the ERA atmospheric model with assimilation of observations, and boundary forcing from a larger scale model domain, which includes wave energy (BEEMS Technical Report TR229). The effect of the power stations is evaluated by calculating the difference in temperature between the intended run and the Zero Reference run, which has no power station discharge. The difference is calculated for each hourly snapshot and the annual mean and the 98th percentile are calculated from this difference. The 98th percentile was chosen because it is a metric required under Habitat Regulations Assessment (HRA) and Water Framework Directive (WFD) assessment processes. In 2006 WQTAG 160,” Guidance on assessing the impact of thermal discharges on European Marine Sites” cited in Turnpenny and Liney, 2006, recommended interim thermal standards for assessing SAC/SPA sites in estuarine and coastal sites under the Habitats Regulations based upon standards contained within the Freshwater Fish Directive. For a SPA these guidelines state that the annual mean water temperature uplift should not exceed 2°C at the edge of the mixing zone.

There are currently no uniform regulatory standards in place to control thermal loads in transitional and coastal waters (BEEMS Science Advisory Report SAR008). 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 Water Framework Directive (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 2°C 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 21.5°C as a 98th percentile (Wither *et al.* 2012). These criteria are not applicable to the southern North Sea SAC designated for harbour porpoise. Absolute temperature thresholds for marine mammal sensitivity assessments consider SPA thresholds (28°C as a 98th percentile). Thermal thresholds are provided in Figure 10.

For assessment against thermal standards unbiased estimates of absolute plume temperatures are also required. BEEMS Technical Report TR301 has demonstrated that the GETM absolute temperature estimates cannot reliably be used for this purpose as the model produces overestimates of absolute temperature (although these are also provided for reference). A more reliable prediction of 98th percentile absolute temperature can be derived at any location 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. Further description and justification of this approach is provided in BEEMS Scientific Position Paper SPP098.

The actual seawater background temperature for Sizewell, outside the influence of the existing Sizewell B plume, was calculated from observations from the Cefas Coastal Temperature Network (BEEMS Technical Report TR131 Ed 2) and the 98th percentile of the surface temperature for the period 2009-2013 was 19.4°C. To calculate the plume area where temperatures are:

a) at or above 28°C as a 98th percentile then becomes calculating the area where the mean excess temperature is >8.6°C (i.e. 28°C -19.4°C).
b) at or above 23°C as a 98th percentile then becomes calculating the area where the mean excess temperature is >3.6°C (i.e. 23°C -19.4°C).

BEEMS Technical Report TR302 provides detailed thermal plume maps for each of the tests described above.

The Sizewell C and Sizewell B plumes are separate at high plume temperatures but at lower temperatures, the Sizewell C plume acts to increase the size and temperature of the Sizewell B plume at the surface and the seabed (BEEMS Technical Report TR301). This means that the thermal effects of Sizewell C also contribute to a magnified Sizewell B plume (the Sizewell C plume is smaller and largely outside the 1nm offshore limit). Figure 11 and Figure 12 illustrate the effect of the Sizewell C cooling water discharge on Sizewell B.

7.2 Thermal modelling assessment

BEEMS Technical Report TR301 summarises the setup, calibration and validation of the 2 hydrodynamic models of Sizewell that were setup in accordance with Environment Agency guidance on modelling of nuclear new build developments. That report describes why a GETM model was selected for thermal and chemical modelling

Table 19: GETM runs used (BEEMS Technical Report TR302).

Run ID	Description	Intake location	Discharge location	Discharge flow and Delta T (m^3s^{-1} @ °C)	Time period
ZeroReferenceV2-annual	Pristine condition	n.a.	n.a.	n.a.	1/1/2009 00:00 -1/1/2010 00:00
ReferenceV2-annual	Sizewell B	IB	OB	51.5 @ 11.0	1/1/2009 00:00 -1/1/2010 00:00
Conf12-annual	Sizewell B and Sizewell C	IB I3a,I3b I4a,I4b	OB O9a, O9b	51.5 @ 11.0 125 @ 11.6	1/1/2009 00:00 -1/1/2010 00:00
Conf12_maint-May	Maintenance at Sizewell C	IB I3a,I3b	OB O9a	51.5 @ 11.0 62.5 @ 23.2	1/5/2009 00:00 -1/6/2009 00:00

Table 20: Location of power station cooling water intake and outfall heads associated with the reference runs.

	Latitude WGS84 (degrees N)	Longitude WGS84 (degrees E)	Easting BNG (m)	Northing BNG (m)	Depth ODN (m)
Sizewell B					
IB	52.21472	1.63332	648297	263612	9.0
OB	52.21525	1.62658	647834	263647	5.1
Sizewell C					
I3a	52.21948	1. 66931	650726	264262	12.9
I3b	52.21945	1. 67077	650826	264264	13.6
I4a	52.21148	1. 66572	650526	263360	11.5
I4b	52.21126	1. 66714	650624	263341	13.5
O9a	52.21807	1.67435	651080	264125	16.9
O9b	52.21803	1.67544	651155	264125	16.8
WGS84: World Geodetic system 1984, BNG: British National Grid, ODN: Ordnance Datum Newlyn					

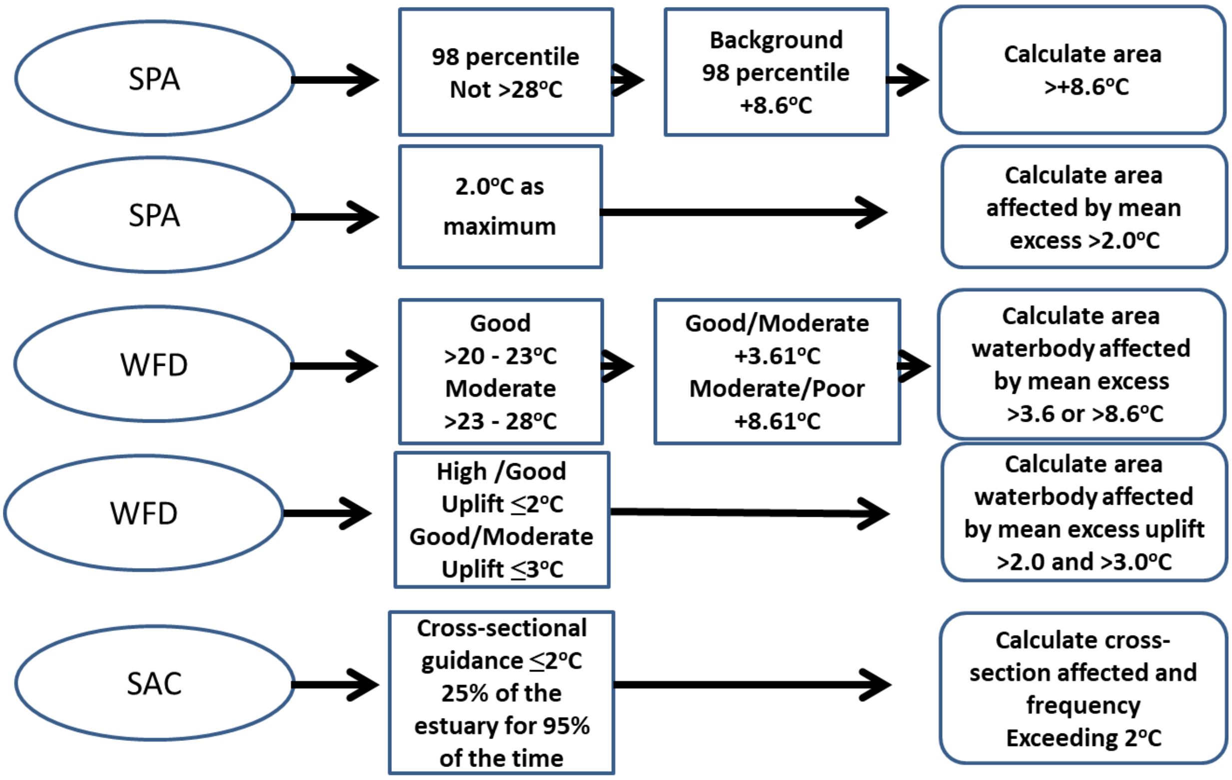

Figure 10: Summary of assessments made against relevant temperature standards using the GETM Sizewell model. Above values reference a 98% baseline temperature value of 19.39˚C for the Suffolk coastal waterbody derived from the product of monthly means for four sites: Lowestoft, Southwold, Sizewell, and Felixstowe Rotterdam (coastal) between 2009 – 2013, equivalent for Sizewell is 19.6˚C.

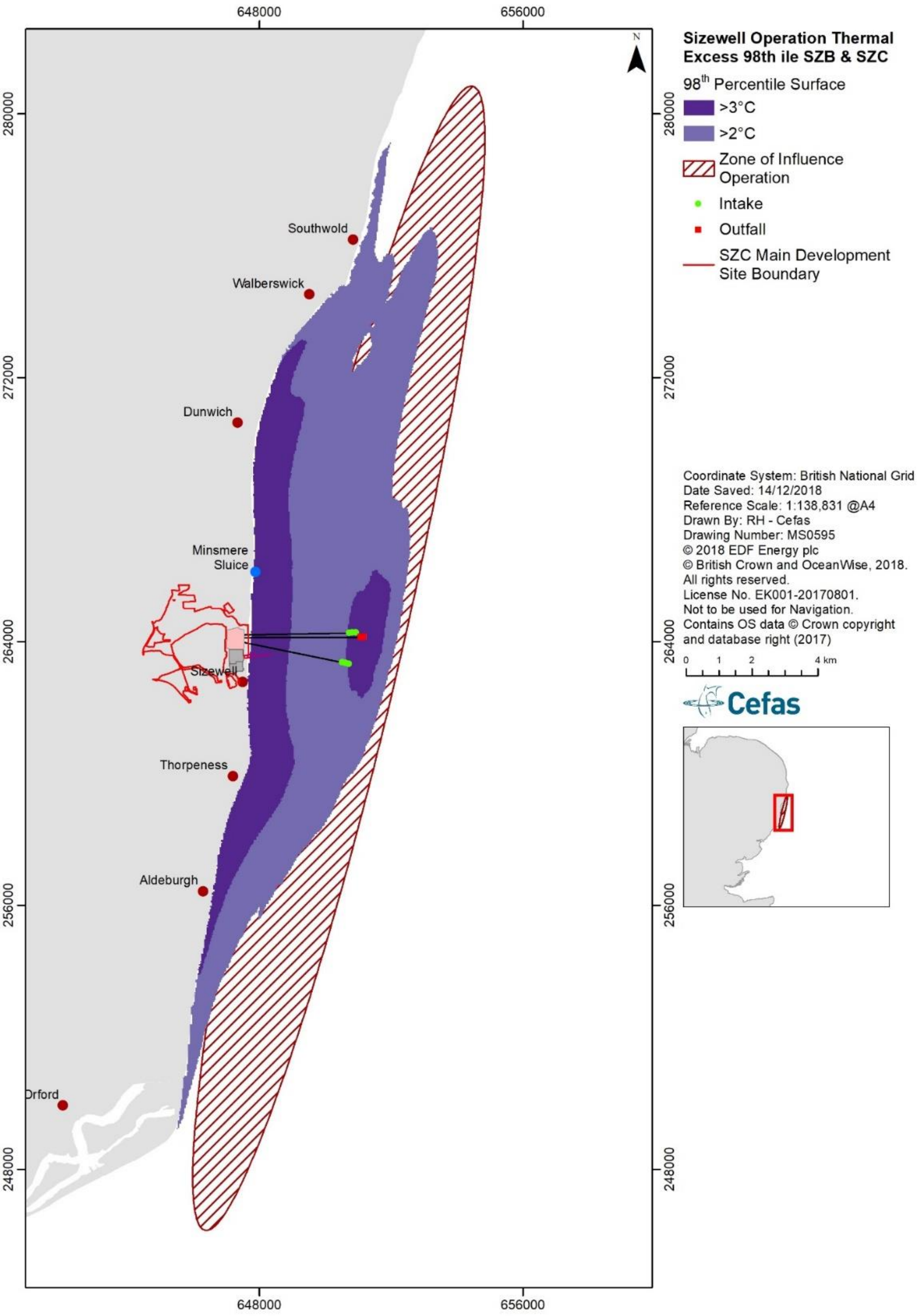

Figure 11: 98th percentile of excess surface water temperature showing >2 and >3°C for run with Sizewell B and Sizewell C operating (Conf12).

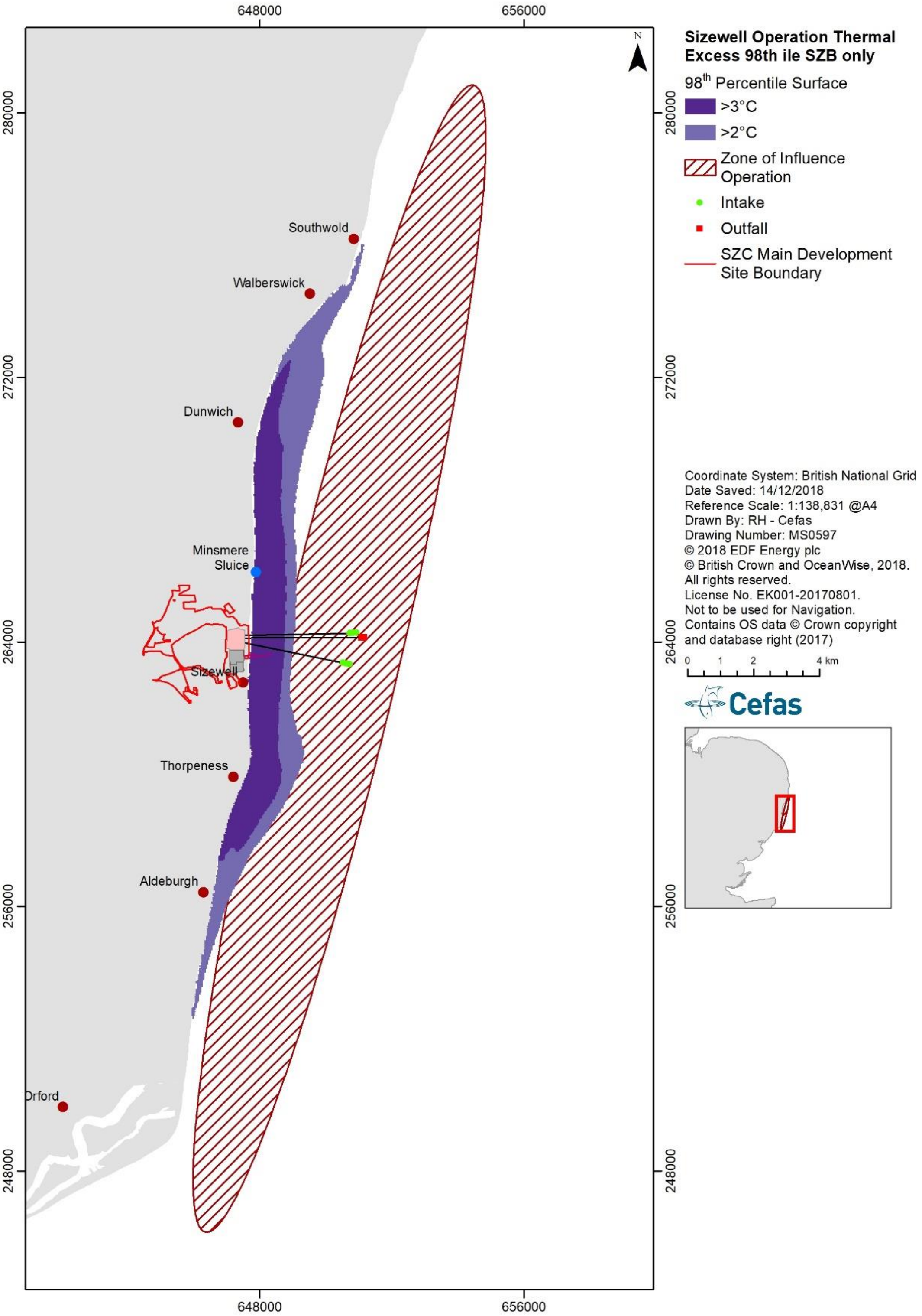

Figure 12: 98th percentile of surface excess water temperature showing >2 and >3°C contours for run with only Sizewell B operating (ReferenceV2).

Unlike chemical standards which normally have a clear evidence link to ecological effects, thermal standards are not always evidence based due to a lack of reliable data (BEEMS SAR008). To be protective of the most sensitive species, thermal standards have, therefore, been set on an indicative basis and, as such, they act as trigger values for further investigation of potential ecological effects.

The extent and magnitude of the thermal plume from the existing Sizewell B and proposed Sizewell C is assessed against thermal standards relevant to the zone of influence for the site.

7.2.1 Application of Habitats thermal assessment to ZoI

As described in section 1.0 two threshold values are recommended as trigger assessments for SPAs:

3. Temperature uplift ≤ 2˚C as a Maximum Allowed Concentration (MAC) at the edge of the mixing zone
4. 98th percentile of the absolute temperature ≤ 28˚C

The uplift threshold is specified as a 100 percentile. 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 (The plume maps at a 2ºC uplift as a 100%ile threshold are shown in Appendix E)

The absolute temperature standard for SPAs of ≤ 28˚C as a 98%ile does have a better evidence link and is considered relevant to assess (BEEMS SAR008)

Absolute area of exceedance of thermal standards for habitats and scale relative to ZoI

The absolute areas of exceedance for each standard for the SPA thermal standards are shown in Table 21. 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 + Sizewell C. The corresponding maps are shown in Appendix E. According to WQTAG160 the exceedance of the threshold requires further evaluation of the potential environmental impact with respect to ecological receptors within that area.

The second criterion for SPAs concerns the 98th percentile of the absolute temperature. The predicted absolute areas where the plume temperatures exceed 28˚C are shown in Table 22 column 5 and are all below 1ha. This contrasts greatly with the criteria for maximum uplift that is exceeded across Sizewell Bay even for the Sizewell B case. At the request of the Environment Agency the area of exceedance has also been calculated using GETM absolute temperatures outputs which produce inaccurate temperature predictions that are overestimates (Table 24 column 6). The plume maps of absolute temperatures are in BEEMS Technical Report TR303 Edition 3. Using either method, the absolute area exposed to risks of thermal lethality to marine species from temperatures > 28˚C is small.

Model runs output instantaneous thermal fields at hourly resolution for a period of one year. Accordingly, a 98th percentile represents the cumulative spatial area that individual cells (25x25m) within the model domain exceed a threshold temperature for 7.3 days at any point during the year. The 98th percentile statistics are not necessarily consecutive and could be days or months apart.

Table 21: Total area where the Habitat temperature standards are exceeded.

Model run	Position		Max excess temp. >2°C (100th percentile)	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	9,375.03	0	0.78
	Seabed	ha	5,219.05	0	0
Conf12 annual Sizewell B+Sizewell C	Surface	ha	22,463.87	0.11	4.15
	Seabed	ha	16,451.21	0	1.57
Sizewell C only	Surface	ha	16,775	0	0
	Seabed	ha	12,244	0	0

Note: BEEMS Technical Report TR301 has demonstrated GETM absolute temperature predictions are overestimates (last column above).

7.2.2 Waterframework Directive thermal assessment

The WFD standards for water quality apply for both absolute water temperatures and temperature uplift:

1. Annual 98th percentile of the absolute water temperature

T < 20˚C = High
20˚C < T ≤ 23˚C = Good
23˚C < T ≤ 28˚C = Moderate
T > 28˚C = Poor

2. Annual 98th percentile uplift in water temperature

Uplift ≤ 2˚C = High
2˚C < Uplift ≤ 3˚C = Good
Uplift > 3˚C = Moderate

Table 22 and Table 23 show the results of applying these standards to the predictions from the Sizewell B+Sizewell C thermal plume modelling.

Applying a mean excess temperature of 3.6˚C to the baseline temperature value of 19.39˚C for the Suffolk coastal waterbody provides an assessment for exceedance of the >23˚C ‘Good/Moderate’ threshold. A maximum of 89.6ha at the surface exceeds this threshold for Sizewell C and Sizewell B in combination. There is less exceedance at the seabed with the lowest area of 8.75ha at the bed predicted for Sizewell B alone. Based on GETM absolute values the maximum exceedance at the surface is 4.15ha for Sizewell C and Sizewell B and at the bed the lowest area of exceedance is 0ha.

As absolute temperature exceedance only is considered here (i.e. no areas of intersect with specific designations) the evaluation of the 28˚C threshold for WFD is the same as that considered for the SPA assessment.

Exceedance of the 2˚C threshold for WFD results in a predicted area of maximum 7899ha at the surface for Sizewell B and Sizewell C (Table 24). A minimum area of 2433ha of exceedance is predicted at the surface for Sizewell B alone. For exceedance of the 3˚C threshold for WFD the predicted absolute areas of exceedance are lower with a maximum of 2200ha at the surface for Sizewell B and Sizewell C in combination and the lowest area affected at the bed for Sizewell B alone (667.67ha).

Table 22: Total areas where the Water Framework Directive absolute temperature standards are exceeded.

Model run	Position		98th %ile >23°C. Calculated from mean excess temp.>3.6°C (Area at GOOD or below threshold)	98th %tile >28°C. Calculated from mean excess temp.>8.6°C (Area at MODERATE or below threshold)
Reference V2 annual Sizewell B	Surface	ha	44.86	0
	Seabed	ha	8.75	0
Conf12 annual Sizewell B+Sizewell C	Surface	ha	89.60	0.11
	Seabed	ha	25.57	0
Sizewell C only	Surface	ha	0	0
	Seabed	ha	0	0

Table 23: Absolute areas where the Water Framework Directive uplift temperature standards are exceeded.

Model run	Position		Excess temp. >2°C as a 98%ile Area at GOOD	Excess temp. >3°C as a 98%ile Area at MODERATE or below
ReferenceV2 annual Sizewell B	Surface	ha	2,433.30	1262.57
	Seabed	ha	2126.71	667.67
Conf12 annual Sizewell B+Sizewell C	Surface	ha	7899.17	2200.05
	Seabed	ha	6240.64	1,552.56
Sizewell C only	Surface	ha	1551	305.7
	Seabed	ha	170.6	0

The exceedance of the relevant thresholds requires further evaluation of the potential environmental impact with regards to ecological receptors within that area.

7.2.3 Potential thermal barriers to fish migration

It is known from laboratory thermal preference experiments that fish species can choose to avoid areas of high temperature and there is, therefore, a possibility that thermal plumes could act as barriers to migration; principally in transitional waters.

Existing thermal standards for transitional waters specify that an estuary’s cross section should not have an area larger than 25 % with a temperature uplift above 2˚C, for more than 5% of the time. There are no such standards for coastal waters, nevertheless an assessment is provided in BEEMS Technical Report TR483 on whether a coastal plume could act as barrier to migration for those species that migrate between coastal and transitional waters.

There are various thermal standards under WFD and Habitats Directive criteria. The thermal plume is predicted to exceed these criteria and therefore there is the potential to affect the quality. However, the exceedance area is a small percentage of the relevant designated areas. The resistance of marine water and sediment quality receptors to temperature changes is therefore predicted to be 'medium'. Resilience is considered high as waters are well mixed so facilitating rapid equilibration with seasonal background. Therefore, sensitivity is judged to be low and overall impact minor but requiring further consideration of potential impacts for ecological receptors.

BEEMS Technical Report TR431 has summarised the available evidence to identify for each designated SAC/SPA species, that has the potential to be impacted by the Sizewell C development:

a. those species that have marine prey as an important component of their diet;

b. the foraging range of each species (where applicable); and

c. what their marine prey species are likely to be in the Sizewell area.

The marine prey species identified are as follows: sprat; herring; anchovy; swimming crab; waste from fishing vessels; whiting; bass; eels; bivalves; polychaetes; crustacea; gobies; dover sole and dab (BEEMS Technical Report TR431).

BEEMS Technical Report TR483 will consider the impacts of the Sizewell C development on the identified marine prey species for each designated SAC/SPA species.

7.2.4 Climate change influence on thermal discharges

The effects of future climate change and warming sea temperatures in relation to thermal discharges is considered further (with more details provided in Appendix F). This section considers the influence of climate change on future thermal parameters in relation to the operation of Sizewell C and Sizewell B. At the time of writing the recently updated UKCP18 marine climate predictions (November 2018) do not include sea temperature data. Future climate scenarios for Sizewell are based on UKCP09 data, which provides predictions of future climate for 2070-2100 relative to a baseline of 1961-1999 for the broad Sizewell area. These assessments focus on absolute temperatures as thermal uplifts are predicted to be largely independent of ambient water temperature and would remain the same.

The primary effect of future warming sea temperatures is the elevation of the background temperatures such that entrained species experience more frequent periods of the year in which the ambient + 11.6ºC uplift of Sizewell C exceeds lethal thresholds.

To ascertain absolute temperatures in the future, the influence of climate change was added to the predicted thermal uplifts due to the proposed development. The approach considered Sizewell B and the proposed development operating together up until 2055 as a worst-case. Sizewell C operating alone in 2055 and 2085 were also considered as well as an extreme (2110) hypothetical operating scenario. The thermal uplift due to the UKCP09 monthly increase in mean temperature, centred on 2006, was applied to this contemporary annual baseline projecting forward to 2055, 2085 and 2110. This climate uplift (98th percentile occurring in August) and the 98th percentile ambient temperature (also occurring in August) was then applied to the mean excess temperature rise due to the power stations. This is considered precautionary as the mean uplifts due to thermal discharges tend to be lower in the summer months. The results indicate that future climate change is not predicted to significantly increase the absolute areas in exceedance of 28ºC, which remain under 1ha for all scenarios tested. Following the decommissioning of Sizewell B, 28ºC as an absolute temperature is not predicted to be exceeded as a 98th percentile even under the extreme climate case of the proposed development operating in 2110. Therefore, thermal effects in the receiving waters are predicted to remain minimal.

During the operation of both stations, absolute temperatures of 23ºC increase from 89.6ha at the surface and 25.6ha at the seabed for the present day to a worst case of 506.2ha at the surface and 264.4ha at the seabed in 2055. In the likely event Sizewell B is no longer operational in 2055, the exceedance of the absolute 23ºC threshold is predicted to be just 5.38ha at the surface and 0ha at the seabed with Sizewell C operating alone.

By the extreme date of 2110, large areas exceed 23ºC as a 98th percentile; 7,080ha at the surface and 6,540ha at the seabed. However, the results are due to the influence of climate warming, which is predicted to be +3.045ºC as a 98th percentile across the model domain, hence a station uplift of just 0.56ºC is enough to exceed contemporary thermal standards. In 2085, towards the end of the likely operational life-cycle of the proposed development, seabed areas in exceedance of 23ºC are predicted to occur over just 0.22ha, whereas surface exceedance occurs over an area of 69.1ha. The total area of the thermal plume above 23ºC in 2085 is therefore smaller and further offshore than the contemporary predictions for the two power stations operating together.

Whilst climate change would act in-combination with the proposed development to increase areas of exceedance, receptors exposed would be acclimated to a modified thermal baseline. Furthermore, changes in species composition may have occurred independently of the proposed development. For species exposed to the thermal plume, effects would be like those predicted for the current baseline.

Confidence in predicting the exact effects of climate change and thermal discharges on species ability to adapt is reduced further into the future. However, once Sizewell B ceases operating the thermal footprint from the proposed development is predicted to be smaller than the present-day thermal footprint. Predictions of effects based on current baselines is considered valid considering future climate change.

7.3 Chemical discharge modelling assessment

7.3.1 Screening results

The results of the screening tests for 24-hour and annual discharge assessment are shown in Appendix D. Initial screening (more detail is provided in BEEMS Technical Report TR193) Appendix D Table 46 shows chemical loadings. Table 47 shows the assessment for large cooling water discharges that are discharged to TraC waters for 24h operational discharges and Table 48 shows respective results for the annual operational discharges. Table 48 discharge concentrations are compared to the Water Framework Directive annual average environmental quality standards (WFD AA-EQS = Annual Average EQS), and in Table 47 the WFD EQS MAC = Maximum Acceptable Concentration EQS where these are available or AA values if not. In some cases, alternative or surrogate values have had to referenced i.e Pre-WFD EQS values have been adopted for assessment of boron; Coastal and Transitional Water WFD EQS for chromium is for chromium VI; and in some cases, toxicity data values are compared. Where no toxicity data are available background concentrations measured at the site are compared. For nitrogen reference is made to the winter dissolved inorganic nitrogen 99th percentile for TraC waters of intermediate turbidity (suspended solids levels of 10 to <100mgl^{-1}, Appendix B).

Reference to Table 47 shows that for the 24 hour discharge assessment, hydrazine, chlorine produced residual oxidants (TRO) 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 and are further discussed at the end of this section.

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 95th 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 95th percentile load calculations which use site background 95th 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 over three times above the background and so as phosphate can contribute to nutrient status it will be given further consideration in section 7.2.9.

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, un-ionised ammonia, DIN 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 it is the background concentration that has the most influence on the scale of the cooling water discharge concentration relative to the EQS. As the 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 expected in short term discharges 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 (see Appendix D) 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 10.

The 24-hour discharge concentration of dissolved inorganic nitrogen was 49% of the site 99% winter standard for water bodies of intermediate turbidity. The discharge concentration is below the standard value but as the loading of DIN may influence algal growth this is further assessed in section 7.2.8.

The 24-hour discharge concentration of acrylic acid is 52% of the PNEC (0.34µgl^{-1}, see Table 5). The bioconcentration factor for acrylic acid is estimated at 1.0 and so is very low and it is readily degradable (Staples et al., 2000). Acrylic acid is therefore likely to have negligible effects at the predicted discharge concentration.

For annual loadings in the operational cooling water discharge hydrazine, chlorine and bromoform again exceed relevant PNEC or EQS values in the screening assessment and so more detailed modelling will also consider this discharge scenario. Discharges during the operational phase would also equal or exceed the annual average PNEC for lithium hydroxide, phosphates, aluminium, lead, zinc and acrylic acid (Appendix D, Table 48).

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 7.2.9.

Zinc fails the annual loading discharge 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 (Staples et al., 2000) it is likely 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 further consideration in section 7.2.6. Un-ionised ammonia concentration was low at 0.05% of its EQS but un-ionised ammonia is also given further consideration in section 17.2.7 in relation to the influence of temperature elevation on the percentage of un-ionised ammonia.

For those substances that failed the screening assessment and for which significant discharge concentrations relative to their EQS are predicted further modelling is required. The chlorinated cooling water would fail initial screening at the point of discharge at a target value of 0.15mgl^{-1} total residual oxidants as compared to a maximum EQS of 0.01mgl^{-1}. The screening results also show that the residual hydrazine concentration would have the potential upon discharge and initial dilution to exceed relevant EQS or equivalent applied values. The most dominant chlorination byproduct bromoform was also subject to modelling using GETM.

The modelling has been undertaken using the validated GETM model of Sizewell used for thermal plume studies and previously described in BEEMS Technical Report TR302 and TR301 and which was chosen to support the chemical runs because it is better able to reproduce the natural variability due to meteorological and tidal conditions. The water quality parameters described below were fully coupled GETM runs with the hydrodynamical parameters.

The following chemical discharges or processes were investigated:

- Chlorination of the power station cooling water system to avoid bio-fouling. The total residual oxidants (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 (BEEMS Technical Report TR143).

- Chlorination by-products (CBP's) 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 of highest concentrations present, 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 (BEEMS Technical Report TR217). Bromoform is lost through volatilization to the atmosphere, with the loss rate a function of the thermal stratification and values obtained from the literature (see Mackay and Leinonen (1975)) and coupled into the GETM Sizewell model.

- The addition of hydrazine to control the oxygen concentration in the power station secondary circuit. Hydrazine is an oxygen scavenger that is used in power plants to inhibit corrosion in steam generation circuits. Hydrazine is used to condition the secondary circuit of PWR power stations and is also used in the primary circuit during start up. During normal operation most of the hydrazine injected daily into the secondary circuit is broken down by the high temperatures present, but trace amounts will be present in the power station effluent which is discharged via the cooling water system. Based on a conservative assessment of the residual hydrazine concentrations, the screening assessment indicates that following discharge and initial dilution the Predicted No Effect Concentration will be exceeded. Hydrazine is modelled by using an empirical decay formulation derived in the laboratory and coupled into the GETM Sizewell model (BEEMS Technical Report TR145).

  As the thermal input from the cooling water discharge can influence chemical and physical effects within the influence of the discharge the effects of the thermal input from Sizewell C were investigated for dissolved oxygen saturation:

- Reduction in dissolved oxygen (DO) in seawater due to the warming effect of the discharge plume. The Water Framework Directive (WFD) threshold is defined with respect to the 5 percentile, with High status being >5.7mgl^{-1} and Good status being >4mgl^{-1}.
- The potential increase in the ratio of un-ionised to ionised ammonia due to the elevated temperature of the discharged cooling water. The ammonia inputs and proportion of un-ionised ammonia are considered in more detail in terms of the influence of the thermal elevation on the proportion of un-ionised ammonia (Table 32). This assessment provides a worst-case evaluation of un-ionised ammonia inputs.

Phosphorus also passed the screening assessment but had one of the higher values in screening test 1 based on 24-hour loadings (352.5kg as PO_4). Converting this loading to PO_4-P gives a value of 115kg. The site background PO_4-P concentration is 33.5 µg l^{-1}. An area of 353x353m (12.5ha) at depth of ~16m (at the point of cooling water discharge) would contain an equivalent planned 24-hour load of a PO_4-P (66kg). A predicted PO_4-P daily exchange in summer between Sizewell Bay and outer tidal excursion and the wider area is 2440kg (BEEMS TR385) therefore the planned daily PO_4-P loading from Sizewell C would represent ~3% of this exchange value.

The microbiological assessment for operation of Sizewell C is based on that for Hinkley Point C. During operation the maximum number of staff on site is estimated at 1900 based on HPC and on numbers present during an outage. Mixing of the treated sewage effluent with the cooling water will achieve a dilution of ~2000. Assuming the same level of treatment is applied during operation as for the construction period then with UV treatment (assumed 5.4 log reduction) the discharge would comply with bathing water standards at the point of discharge.

7.3.2 Chlorine produced oxidant (TRO) assessment

Sizewell B has a permit to discharge cooling water with a maximum TRO concentration of 0.3mgl^{-1} all year round and this source term has been used for the modelling studies in this report.

For Sizewell C the TRO concentration at the outfall will depend on the chlorination strategy applied within the power station. BEEMS Technical Report TR316 presents an analysis of the possible chlorination options for Sizewell C and a recommendation for a preferred strategy that is based upon minimising environmental effects whilst maintaining the safe operation of the plant. TR316 recommends that a worst-case TRO concentration of 0.15mgl^{-1} at the outfalls should be used for plume modelling purposes based upon the preferred chlorination option in that report. This is the source term adopted for the modelling studies in this report. The GETM Sizewell model runs used in this report are listed in Table 24.

Table 24: GETM TRO modelling runs.

Run ID	Description	Intake location	Discharge location	TRO discharge at the outfall ($\mu g\ l^{-1}$)	Discharge flow and Delta T (m^3s^{-1} @ °C)	Time period
TRO_2outf-May	Conf12 with TRO discharge from Sizewell C and Sizewell B	IB I3a,I3b I4a,I4b	OB O9a, O9b	300 150,150	51.5 @ 11.0 132 @ 11.6	1/5/2009- 1/6/2009
TRO_2outf-MayTROB	Conf12 with TRO discharge from Sizewell B only	IB I3a,I3b I4a,I4b	OB O9a, O9b	300 0, 0	51.5 @ 11.0 132 @ 11.6	1/5/2009- 1/6/2009
ReferenceV2-annual	Sizewell B	IB	OB	n.a.	51.5 @ 11.0	1/1/2009 – 1/1/2010
Conf12-annual	Sizewell B and Sizewell C	IB I3a,I3b I4a,I4b	OB O9a, O9b	n.a.	51.5 @ 11.0 132 @ 11.6	1/1/2009 – 1/1/2010

The Maximum Allowable Concentration (MAC) for total residual oxidants in seawater is $10\mu gl^{-1}$ (UKTAG, 2013, Defra 2014). This forms the Environmental Quality Standard (EQS) for acute concentrations, which is taken as the 95th percentile of the concentration values. In the results both the average concentrations and the 95th percentile are presented. No EQS has been set for mean or chronic concentrations.

Two scenarios were considered:

- chlorination of Sizewell B plus Sizewell C operating in combination, and
- chlorination of Sizewell B only.

A discharge of $132m^3s^{-1}$ has been modelled for TRO for Sizewell C. For each model run a month-long simulation was analysed and the mean and 95th percentile of the TRO concentrations was extracted. The TRO plume areas at the EQS ($10\mu gl^{-1}$ as a 95%ile) have been calculated and are shown in Table 25. For Sizewell C only, there is a small area of 2.13ha exceeding the EQS at the seabed and 337.65ha at the sea surface. Figure 13 shows that the Sizewell C plume does not mix with the Sizewell B plume.

Table 26 presents the area of the plume that exceeds a concentration threshold., To show the depth profile for the plume not only the EQS value was included but also other values between 1 and $20\mu gl^{-1}$. Analysis of the TRO modelling runs shows that the EQS will only be exceeded in the mixing zone at the surface for Sizewell C and both at the surface and seabed for Sizewell B. An important observation from this modelling is the separation of the TRO plumes from Sizewell B and Sizewell C discharges with no interaction between them down to the level of $1\mu gl^{-1}$ of TRO (Figure 13). This is important because it implies that, within reason, the chlorination regimes of the two developments can be managed independently.

Table 25: Absolute areas exceeding the TRO EQS (These values are based on 132 m^3s^{-1} discharge from Sizewell C).

Model		TRO =10µgl^{-1} 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

Table 26: Area of the plume at different levels of TRO concentration (from BEEMS Technical report TR303 Edition 4).

Model run	µg l^{-1}	95th percentile surface (ha)	95th percentile seabed (ha)	mean surface (ha)	mean seabed (ha)
TRO_2outf_May - Chlorination of Sizewell B + Sizewell C	1	5450.62	3662.9	1704.96	579.31
	2	3302.04	1415.19	869.52	234.26
	4	1710.23	428.1	412.22	129.41
	6	1214.69	251.52	238.07	64.03
	8	928.17	200.28	157.89	27.13
	EQS 10	**726.21**	**167.08**	112.81	16.82
	15	436.55	101.93	64.82	8.63
	20	289.87	52.03	44.07	4.93
TRO_2outf_MayTROB - Chlorination of Sizewell B only	1	1652.14	1136.86	756.49	363.32
	2	1206.05	559.79	460.55	226.40
	4	821.86	332.71	257.02	126.72
	6	617.99	244.23	168.21	63.02
	8	483.09	197.14	122.90	27.03
	EQS 10	**388.56**	**164.96**	94.98	16.59
	15	264.98	101.26	60.11	8.41
	20	192.32	51.69	42.50	5.15
Sizewell C only	1	3798.48	2526.04	948.47	215.99
	2	2095.99	855.4	408.97	7.86
	4	888.37	95.39	155.2	2.69
	6	596.7	7.29	69.86	1.01
	8	445.08	3.14	34.99	0.1
	EQS 10	**337.65**	**2.13**-	17.83	0.23
	15	171.57	0.67	4.71	0.22
	20	97.55	0.34	1.57	-

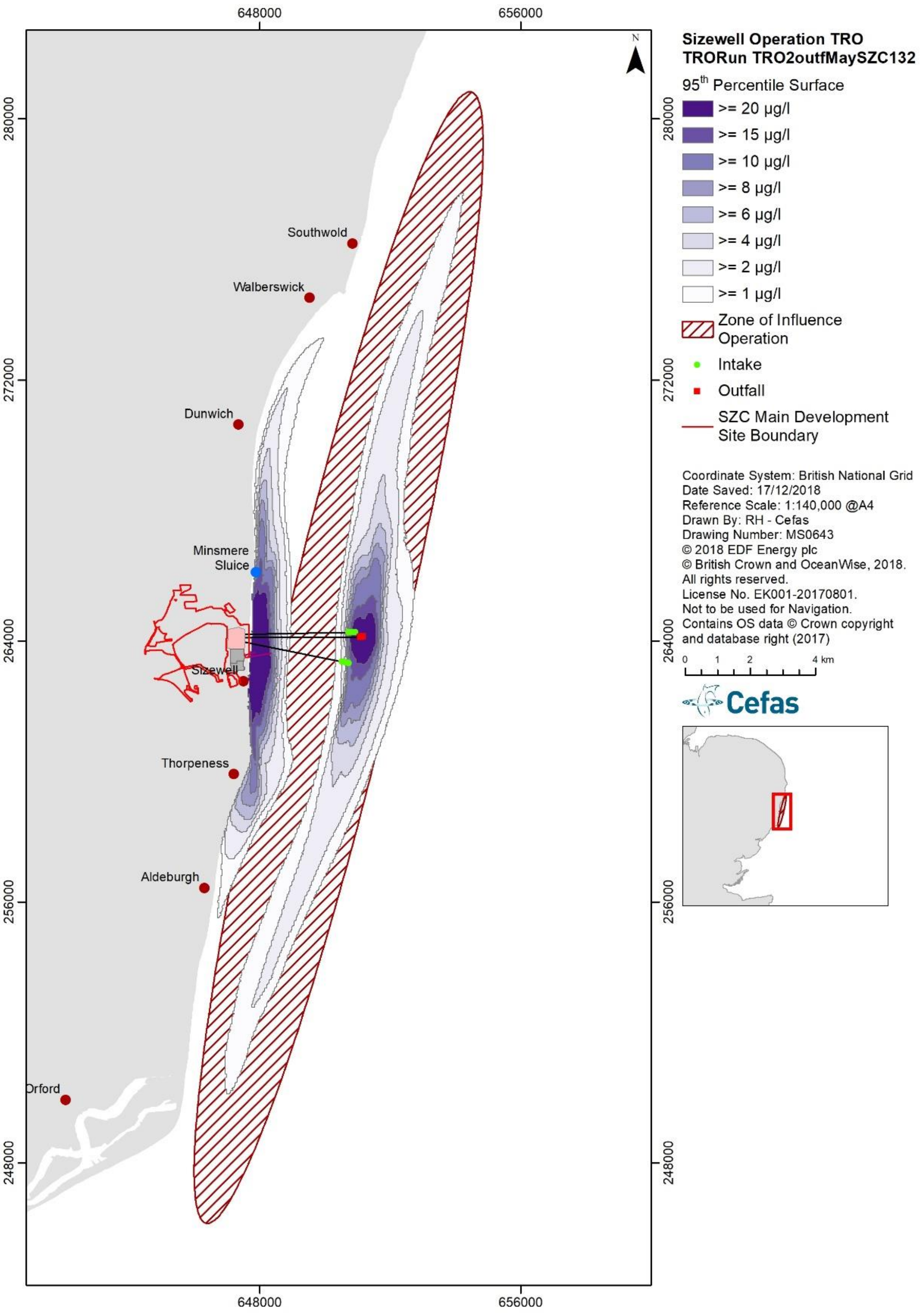

Figure 13: Sizewell B + Sizewell C modelling: 95th percentile of the TRO concentration at the surface (µgl^{-1}). The hatched area shows the outer tidal excursion.

7.3.3 Chlorination byproducts (bromoform) modelling assessment

Another consequence of the chlorination of the power station is the formation of chlorination by-products (CBP’s) 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 (BEEMS Technical Report TR217). Bromoform is lost through volatilization to the atmosphere, with the loss rate a function of the thermal stratification and values obtained from the literature (Mackay and Leinonen, 1975) 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 5µgl^{-1} as a 95%ile has been used (Taylor 2006). 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 HPC WDA permit application). Figure 14 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 also on the amount of mixing. In laboratory experiments (BEEMS Technical Report TR217), 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. Unstirred replicate samples following addition of 0.5mgl^{-1} Cl_2 had 19µgl^{-1} of bromoform compared to the much higher value of 29µgl^{-1} 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 overlap with the Sizewell C plume that is outside the Bank (Figure 14). Both plumes are strongly stratified with larger areas at the surface than at the seabed. The Sizewell C plume is generally smaller and narrower than that due to Sizewell B; the exception is at the 1µgl^{-1} contour for the 95th percentile where the Sizewell C plume has a longer extent but at higher concentrations the Sizewell C plume is always smaller. This is due to the lower initial discharge concentration and greater water depth at the Sizewell C outfall location (16m vs. 5m for Sizewell B outfall).

The Bromoform plume areas that exceed the PNEC (5µgl^{-1} as a 95%ile) have been calculated and are shown in Table 27. For Sizewell C only, the area exceeding the applied EQS at the seabed is 0.67ha and 52.14ha at the sea surface.

Table 27: Absolute areas exceeding the Bromoform PNEC.

Model		PNEC = 5µgl^{-1} as a 95th percentile Surface ha	Seabed ha
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

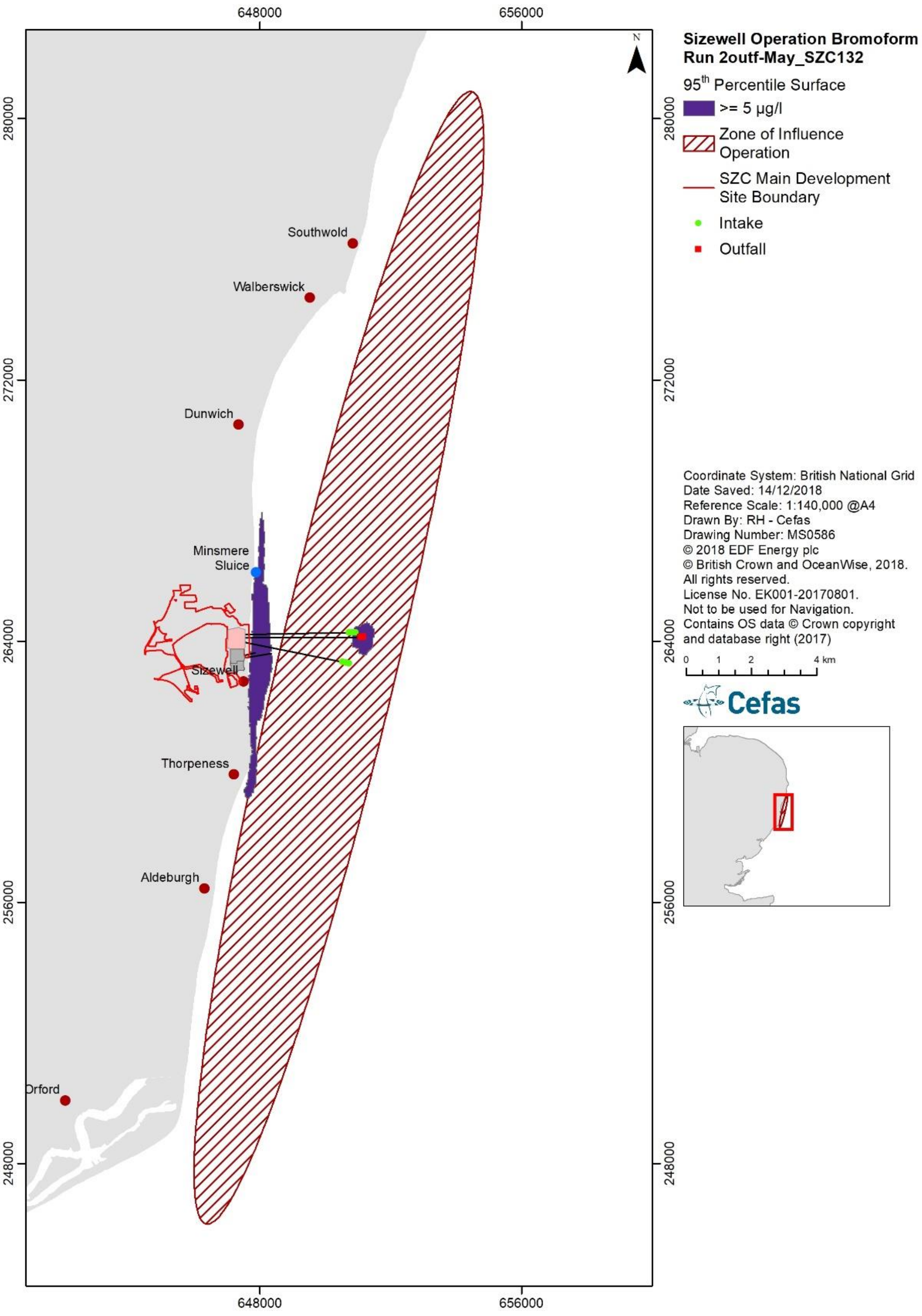

Figure 14: 95th percentile of the Bromoform concentration at the surface for chlorination from Sizewell B and Sizewell C (run Brom_2outf_May). The dark shaded area delineates the PNEC of 5µgl^{-1}. The hatched area shows the outer tidal excursion.

7.3.4 Hydrazine modelling assessment

There is evidence that hydrazine is harmful to aquatic organisms at low concentrations with the lowest acute six-day EC50 of 0.4µgl^{-1} for growth inhibition of a marine alga, *Dunaliella tertiolecta*. Hydrazine persistence in the marine environment is low to moderate dependent upon its concentration and the water quality. There is no established EQS for hydrazine and so a chronic PNEC (Predicted No-Effect Concentration) of 0.4ngl^{-1} has been calculated for long term discharges (calculated as the mean of the concentration values) and an acute PNEC of 4ngl^{-1} for short term discharges (represented by the 95th percentile).

In this report the daily discharges from the Sizewell C secondary circuit have been modelled corresponding to an annual hydrazine discharge of 24kg per annum into the cooling water flow of 125m^{3}s^{-1}. Sizewell B has no permitted hydrazine discharge so was not included in the scenario tested. 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 69ngl^{-1} in daily pulses of 2.32h starting at 12pm, and the second one of 34.5ngl^{-1} of hydrazine discharged in daily pulses of 4.63h duration starting at 12pm. The amount of mass that is released in each of these scenarios is the same. Due to the pulse-like discharge, the interpretation of the short-term results (daily) is biased to the moment of the tidal cycle when hydrazine has been released. In order to minimize this aliasing with the tidal signal, the simulation period has been fixed to 28 days (from the 1st of May to the 29th of May), which corresponds to two complete tidal cycles.

Hydrazine is modelled by using an empirical decay formulation derived in the laboratory and coupled into the GETM Sizewell model (BEEMS Technical Report TR145). The derivation of this decay constant has proved problematic in the past because of limitations in the stability and sensitivity of analytical methods for the measurement of hydrazine in seawater. The experiments described in TR145 used an analytical method with a limit of detection of approximately 10µgl^{-1} and therefore had to perform decay experiments using initial hydrazine concentrations of 50 – 300µgl^{-1} which are considerably greater than the estimated concentration of the daily discharges from Sizewell C. These experiments produced an estimated hydrazine half-life of 12-35 hrs which in agreement with previous reported work and was used in the modelling reported in Technical Report TR303 Edition 4. Previous work by Cefas and others has obtained indications that the half-life of hydrazine in seawater is concentration dependent however it has previously not been possible to confirm that the half-life continues to fall at concentrations of less than 100ngl^{-1}. More recent work has been conducted using a proven method developed by Cefas that has a Limit of Detection of 5ngl^{-1}. A more extensive set of studies has now shown that for concentrations of hydrazine between 30-3000 ng l^{-1}, the decay rate of hydrazine in Sizewell sea water follows first-order kinetics and has a half-life of 38 minutes. This work is reported in TR352. However, the assessment made here is based on the earlier more conservative modelling derived from the data in TR145 (Half-life 32 hours).

In BEEMS Technical Report TR303 each hydrazine model run was for 28 days (two tidal cycles) and the mean and 95th percentile of the hydrazine concentrations was extracted. Table 28 presents the area of the plume that exceeds both concentration thresholds. To provide an indication of the hydrazine concentration profile with depth not only the chronic and acute PNEC values were included, but also other values between 0.1 and 0.5ngl^{-1} for the chronic concentrations and between 1 and 5ngl^{-1} for the acute concentrations.

Table 28: Area of the plume at different levels of Hydrazine concentration.

Model run		**ngl^{-1}**	**95th percentile surface (ha)**	**95th percentile seabed (ha)**	**Mean surface (ha)**	**Mean seabed (ha)**
Hydrazine_SZC_34ng_May – release of hydrazine in pulses of 4.63h a day starting at 12pm. SZC only	Chronic PNEC	0.1			3914.09	3364.50
		0.2			1269.19	795.85
		0.3			389.46	1.46
		0.4			**156.88**	**0.34**
		0.5			66.16	0.11
	Acute PNEC	1	446.42	15.14		
		2	132.54	0.78		
		3	54.72	0		
		4	**17.38**	**0.00**		
		5	1.23	0.00		
Hydrazine_SZC_69ng_May- release of hydrazine in pulses of 2.32h a day starting at 12pm. SZC only	Chronic PNEC	0.1			4399.32	3788.72
		0.2			1477.99	942.53
		0.3			441.04	2.24
		0.4			**158.12**	**0.56**
		0.5			60.55	0.11
	Acute PNEC	1	329.35	2.8		
		2	49.11	0.67		
		3	22.5	0.22		
		4	**13.79**	**0.22**		
		5	3.58	0.11		

The hydrazine plume areas at the chronic PNEC (0.4ngl^{-1} as an average) and the acute PNEC (4ngl^{-1} as the 95th percentile have been calculated and are shown in Table 29.

Table 29: Absolute areas exceeding the Hydrazine PNEC.

Model	**PNEC**		Absolute area of exceedance	
			surface	seabed
Hydrazine_SZC_69ng_May mean	Chronic 0.4 ng l^{-1}	ha	158.11	0.56
Hydrazine_SZC_34ng_May mean	Chronic 0.4 ng l^{-1}	ha	156.88	0.336
Hydrazine_SZC_69ng_May 95th percentile	Acute 4 ng l^{-1}	ha	13.79	0.22
Hydrazine_SZC_34ng_May 95th percentile	Acute 4 ng l^{-1}	ha	17.38	0.00

The chronic PNEC is exceeded at the surface and at the seabed, although for the seabed, an area of less than 1ha is affected 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 69ngl^{-1} release for an area of 0.22ha.

BEEMS Technical report TR303 presents the predicted plume plots at the surface and the seabed from model runs of daily hydrazine discharges from Sizewell C. Figure 15 shows the predicted surface plume resulting from a daily hydrazine discharge from Sizewell C.

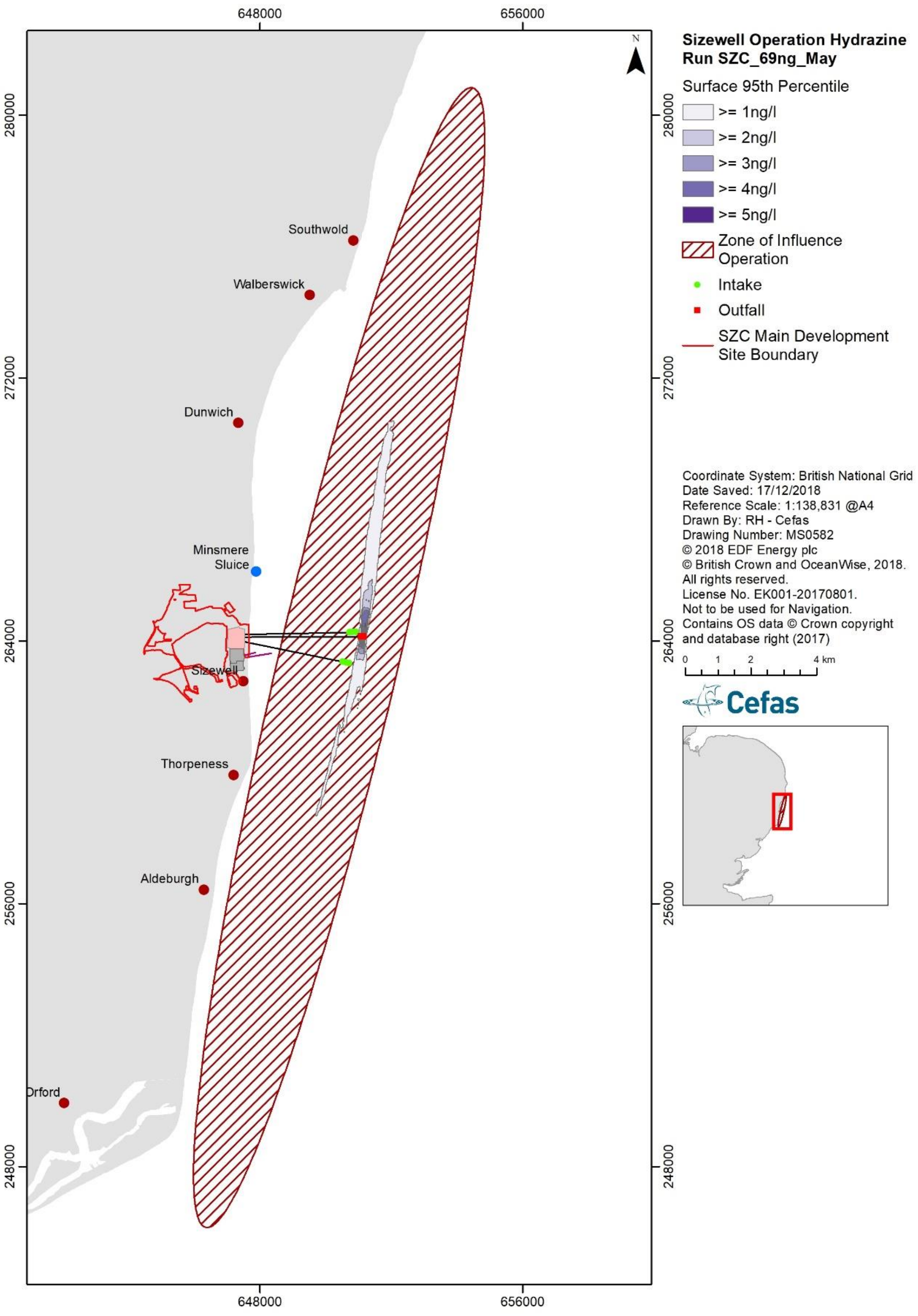

Figure 15: 95th percentile hydrazine concentration at the surface after release of 69ngl^{-1} in pulses of 2.32h from Sizewell C (run Hydrazine_SZC_69ng_May).

7.3.5 Dissolved oxygen modelling assessment

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 Water Framework Directive applies to 1 nm from the coast (approx. 1850m) 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.

Table 30 shows the area calculated from the GETM runs that is beneath various DO concentrations for the entire model domain. 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.

Table 30: Area in hectares below various waterbody quality status boundaries for dissolved oxygen for the entire model domain (Standards and Classification) Directions (England and Wales, 2015).

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

7.3.6 Relative proportion of un-ionised ammonia due to thermal elevation of cooling water and influence on wider environment

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 worst case ammonia discharge of 14,396kg (BEEMS Technical Report TR193) which gives a calculated mean ammonia discharge concentration of 3.9µgl^{-1} NH_4 (3.06 µgl^{-1} NH_4-N) at the outfall assuming a worst case cooling water discharge rate of 116m^{3}s^{-1}. (This is the lowest volume of water abstracted under normal operating conditions and represent a worst-case scenario in terms of dilution of contaminants in the CW stream). 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 32. All cases (including worst cases) for un-ionised ammonia show that no areas exceed the EQS of 21µgl^{-1} as an annual mean and the predicted mean increase in un-ionised ammonia was at maximum 13 times below the EQS of 21µgl^{-1}. Assessment of potential inputs of ammonia from breakdown of hydrazine, ethanolamine/morpholine indicate that this would be at a maximum an additional 4% increase to the annual loading. Relative to the assessment results Table 32 this is considered of negligible influence.

Table 31: Summary of un-ionised ammonia concentration (EQS is 21µgl^{-1} as an annual mean) at the surface

Un-ionised ammonia for mean temperature, mean ammonia, 50th percentile pH, salinity (The regulatory standard)		
	Sizewell B + C	Sizewell B
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 percentile temperature, mean ammonia, 50th percentile salinity, pH.		
	Sizewell B + C	Sizewell B
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 percentile pH, ammonia , 5th percentile salinity		
50th centile	0.8	0.81
95th centile	0.8	0.83
99th centile	0.9	0.88
Maximum	1.61	1.55
50th centile	0.8	0.81

7.3.7 DIN in operational discharges

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 332kg and the maximum annual loading 11725 kg per year (32.12kg d^{-1}). During the operational phase, maximum daily loading for nitrogen therefore reach approximately 2% of the daily exchange for Sizewell Bay, but the average daily value is low at 0.2% (again indistinguishable from background levels) (BEEMS TR385). 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. 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 showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.11%. During operation the use of hydrazine, morpholine and/or ethanolamine have the potential to contribute to the nitrogen input to the marine environment. An assumption of maximum potential inputs not accounting for atmospheric nitrogen loss or incomplete breakdown, results in a small potential addition of 1.3kg/day. This addition is small relative to operational values of 32kg/day and would be insignificant relative to the daily exchange and would not be expected to influence phytoplankton growth above that predicted for other operational inputs of nitrogen.

7.3.8 Phosphate in operational discharges

Phosphorus also passed the screening assessment but had one of the higher values in screening test 1 based on 24-hour loadings (352.5kg 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 (BEEMS TR385) 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^{-1}$$PO_4$-P and is below the site background value of 33.5µgl^{-1} (Table 21). 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 (Foden *et al*., 2009). Incorporation of the operational phosphorus load together with that of the DIN was modelled in BEEMS TR385 as described in the 7.2.8 above and showed a negligible increase in carbon levels at 0.11%.

7.3.9 Biochemical oxygen demand (BOD) assessment for operational discharges

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 $m^{-2}d^{-1}$ (Hull, 2016) or 3.2g$m^{-2}d^{-1}$. The maximum daily BOD loading based on 1900 staff on site is 3.8kg. 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.

7.3.10 Coliforms and intestinal enterococci assessment for operational discharges

During operation the maximum number of staff on site is estimated at 1900 (with 100l^{-1} per head per day effluent production) based on HPC and on numbers present during an outage. Mixing of the treated sewage effluent with the cooling water flow from one EPR (66m^3 s^{-1}) will achieve a dilution of ~33000. Assuming the same level of treatment is achieved during operation as for the construction period then application of either secondary treatment only and with UV treatment will achieve compliance with the bathing water standards at the point of discharge.

7.3.11 Fish Recovery and Return assessment

A Fish Recovery and Return system (FRR) is planned to provide a safe return of the more robust organisms from the drum screens directly into the marine environment. An initial assessment of discharge of chlorinated seawater from this system was made in BEEMS TR333 and all the potential tunnel locations passed the assessment. However, intakes and tunnels will not be chlorinated. Chlorination first occurs after the drum and band screens but routing of the water sources that supply the FRR will mean that it is not chlorinated.

This section describes the impacts associated with the operation of the unmitigated FRR (alternative head designs are being evaluated and these would reduce impingement numbers, so the present assessment is very conservative). The FRR 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 by impingement on the screens and incur high mortality rates. The return of dead and moribund biota retains biomass within the local food web 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, un-ionised ammonia concentration and reductions in dissolved oxygen are considered.

The total biomass of moribund biota predicted to be discharged from the FRR 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 for the existing Sizewell B station (BEEMS TR193). The biomass predictions are used to derive nitrogen and phosphorus contributions to the marine environment and to assess the affect upon dissolved oxygen and un-ionised ammonia levels due to decomposing tissues. Three biomass values are used in the assessment:

(i) During the period April to September increasing light and temperature mean that phytoplankton growth is increasing so this is a period when elevated nutrient levels can exert most impact.

(ii) Annual average biomass is derived to take account of the variability of species abundance throughout the year and is used to provide a more precautionary input for the phytoplankton modelling.

(iii) The maximum daily loading of biomass occurs during March and this is used to derive the most precautionary estimates of un-ionised ammonia and biochemical oxygen demand

Highest discharged biomass occur during the winter when it would have least influence on phytoplankton growth but to provide a more conservative assessment annual average biomass value was used to derive predicted nitrogen and phosphorus loadings which were 37.3kg per day N and 5.3kg per day P (Loadings for April to September were lower at ca., 14kg N and ca., 2kg P). These derived annual values for the FRR 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 (BEEMS TR385) of carbon and this level of change would not be discriminated above natural background variation.

An assessment was also made for un-ionised ammonia. Studies on cod tissue were shown to contribute 125mg kg^{-1} NH_4 (Timm and Jorgensen, 2002) so this value was used together with Sizewell monitoring data for pH, temperature and salinity to derive an equivalent un-ionised ammonia concentration (BEEMS TR193). The average daily biomass loading from the Sizewell FRR over the April to September period and relevant pH, temperature and salinity during this period were used to derive an equivalent un-ionised ammonia loading. Based on a minimum depth at the FRR discharge point of 4m the volume of water (defined by surface area) that would be required to dilute the calculated load of un-ionised ammonia to the level of the EQS was derived. Considering extreme summer pH, temperature and salinity an area of 3.8ha would exceed the un-ionised ammonia EQS (21µg l^{-1} NH3-N, expressed as an annual average). For March when the predicted fish biomass loading discharged from the FRR is at a maximum (adjusting for appropriate seasonal temperature, pH, salinity) an area of 6.7ha would exceed the un-ionised ammonia EQS.

The effect of biomass decay on dissolved oxygen was also derived. The source biochemical oxygen demand values associated with a given unit biomass were calculated based on annual mean value (BEEMS TR193).

An oxygen deficit was calculated since 1.5mgl^{-1} deviation in BOD from background is expected to generate less than 0.5mgl^{-1} impact/reduction on dissolved oxygen (OSPAR Comprehensive studies report, 1997). The calculated annual mean daily biomass oxygen demand (447.5kg/day) represents 0.2% of the oxygen available in the volume of water exchange across the Greater Sizewell Bay (BEEMs TR385). Reaeration at the surface would also resupply oxygen with typical values of surface exchange for this area providing an equivalent loading to that consumed by the biomass discharge over an area of ca., 14ha. For the maximum predicted discharge of biomass during March oxygen demand would increase to 0.6% of that available from daily exchange and would be equivalent to reaeration over 45.2ha.

Each of the biomass impact assessments assumes direct breakdown of all tissue with no losses through scavenging and predation of the discharged fish. The high exchange rate for this area and the fact that the water is well mixed vertically indicate that the calculated impacts related to nutrient inputs, un-ionised ammonia and biochemical oxygen demand would affect a relatively small area and would not be significant. These assessments are made against the background contribution from Sizewell B.

7.4 Cooling water discharge and the influence Climate change

Under future climate change predictions various environmental changes would influence the behaviour, fate and effects of operational discharges from Sizewell C. The following sections consider the most likely effects that could occur and consider these in the context of the current impact assessment.

7.4.1 Thermal elevation influence on chlorination

Cooling water chlorination and hence TRO discharges would occur for the operational life of the proposed development and would be continuous when water temperatures exceed 10ºC. In 2030, water temperatures at the Sizewell C intakes are predicted to exceed 10ºC from the beginning of May until the start of December. Future climate change may extend the period of the year seawater temperatures exceed 10ºC, and by proxy, the seasonal duration of chlorination under the current strategy. 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 unlikely to extend considerably.

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.

7.4.2 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 (Orr, 2011). 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 (Blackford and Gilbert, 2007). Other projections suggest a reduction 0.14 units below present values by 2050 and 0.3–0.4 below present units in 2100 (Nakicenovic, N, and Swart, R. 2000. Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios).

The ratio of oxidant chemicals formed upon chlorination of seawater is influenced by pH (Jolley and Carpenter, 1981): 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 (BEEMS TR217).

TRO discharges would occur for the operational life of the proposed development and would be continuous when water temperatures exceed 10ºC. CBP production would occur following chlorination. In 2030, water temperatures at the Sizewell C intakes are predicted to exceed 10ºC from the beginning of May until the start of December. Future climate change may extend the period of the year seawater temperatures exceed 10ºC, and by proxy, the seasonal duration of chlorination and CBP formation under the current strategy. 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 and presence of CBPs is unlikely to extend considerably

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

7.4.3 Climate change influences on other operational discharges

Hydrazine discharges would occur for the operational life of the proposed development. In 2030, water temperatures at the Sizewell C intakes are predicted to exceed 10ºC from the beginning of May until the start of December.

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 e.g. copper (MacNaughton et al., 1978) and other factors such as ionic strength, temperature and pH (Environment Canada, 2011). 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 (Environment Canada, 2011) and future climate baseline predictions for regions such as the North Sea are ca., 7.8 - 7.6.

The proportion of un-ionised ammonia would change relative to the ionised form with increased temperatures increasing the proportion in the un-ionised form and decreasing pH, so reducing the un-ionised ammonia. However, 24-hour cooling water discharge assessments already take account of thermal extremes that occur within the cooling water system and even under these 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 (Table 45 and BEEMS TR193). In the wider discharge plume temperature uplift would be more modest and even during peak predicted future summer temperatures (see Appendix F) 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.

7.5 Inter-relationship effects Operation

This section provides a description of the identified inter-relationship effects that are anticipated to occur on marine water quality between the individual environmental effects arising from operation of the proposed development. **Figure 16** shows the extent and overlap at the seabed and surface of various operational discharges.

7.5.1 Synergistic effects of chlorinated discharges and treated sewage effluent in the cooling water system

During the operational phase, seasonal chlorination would be applied to protect critical plant from biofouling. Chlorination of seawater results in the liberation of a range of TROs and CBPs depending on the water chemistry.

Ammonia discharges from plant conditioning chemicals and the on-site sewage treatment would also be discharged via the cooling water outfalls. The level of total ammonia discharged including current background levels is low and represents an increase of ca.30% of the present mean background total ammonia. The synergistic effects of chlorination and ammonia discharges may result in the formation of additional combined products.

Seawater chlorination with 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 that uncombined oxidants of chlorine or bromine (Capuzzo, 1979, Fisher et al., 1999) although it is of very low persistence. However, total ammonia in the discharge is very low at around one third of the background ammonia, any increase in toxicity above that due to chlorination alone is expected to be insignificant.

The synergistic effects of chlorination and ammonia discharges are therefore not predicted to alter the assessment of toxicological effects of the discharge.

In addition to the potential reaction of ammonia and chlorinated seawater the thermal uplift of the seawater has the potential to influence the sensitivity of exposed organisms to residual oxidants. The main potential for synergistic effects of temperature and toxicity of the chlorinated seawater is to species experiencing primary entrainment in the cooling water system and these are considered as part of the entrainment impact assessment. However, for organisms experiencing secondary entrainment in the thermal plume (beyond ca.,10 -20m) the residual oxidant exposure would be low at a few 10s of micrograms/litre and the thermal elevation would be a few degrees above background. Under these conditions the effects of this exposure would 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 of the plume beyond the immediate discharge point in combination with the toxicological effects of chlorination is therefore not expected to change the assessment of the chlorinated seawater discharge or thermal plume considered separately.

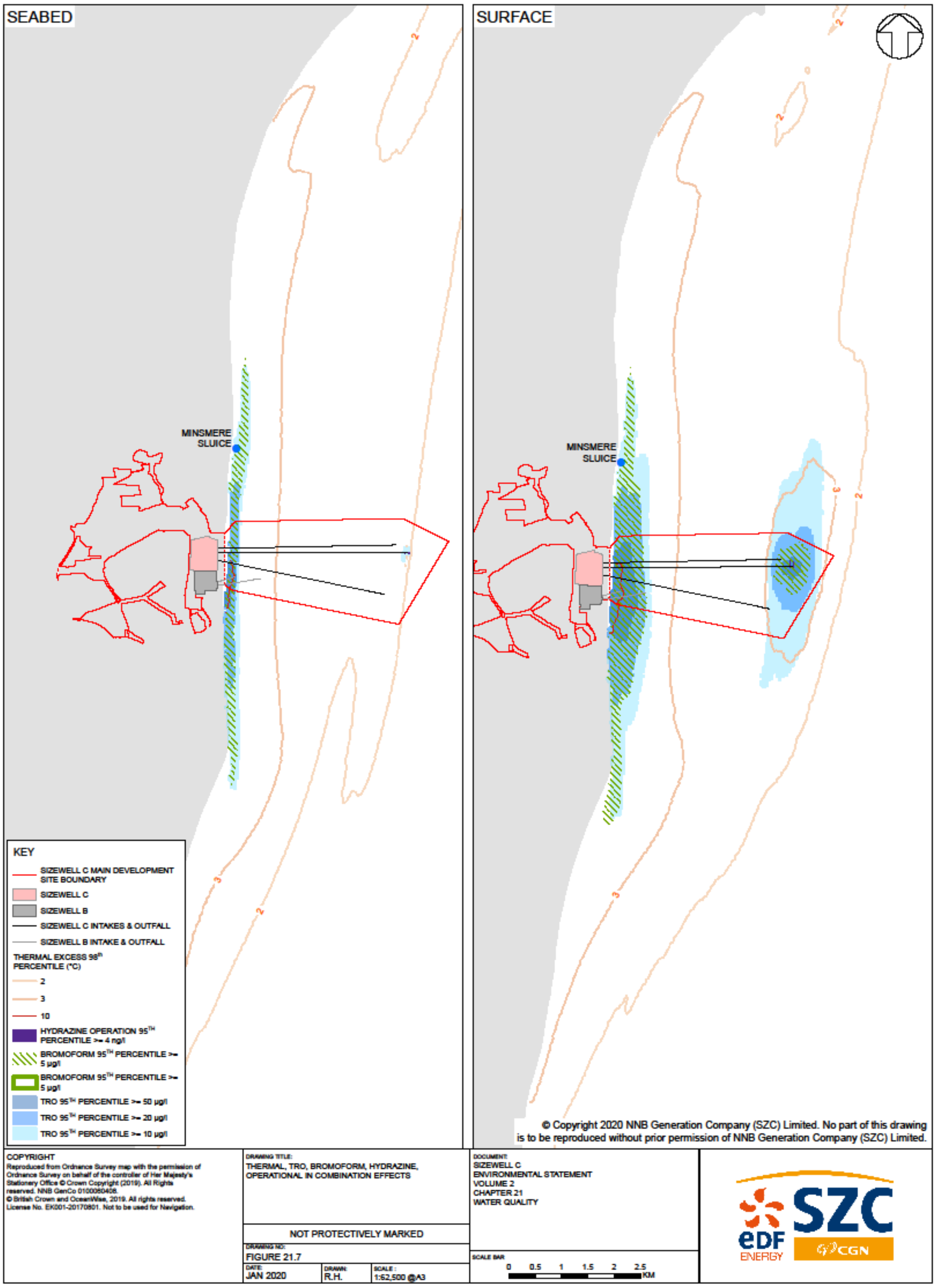

Figure 16: Overlap of thermal and chemical plumes during operation of Sizewell C and in combination with Sizewell B.

8 Summary assessment of main site activities

8.1 Background to assessment of main site activities

Table 32: Scale of construction activities in the marine environment with potential to influence sediment and water quality.

Structure	Activity	Influence of activity
Sediment	Disturbance	The sandy nature of the material and levels of contamination below Cefas Action Level 2 found in the marine sediment at Sizewell, there is a low risk of bioavailable contaminants. Sediments associated with dredging for the Planned Development are therefore considered to be uncontaminated and the effects of resuspension of contaminants on marine water quality and ecology receptors is not considered further.
Beach Landing Facility	Dredging	Capital dredging of the BLF would remove a total dredge volume of 4,600m^3. Modelling indicates sediment only settles on the bed over a relatively small area close inshore. Depth average location maximum SSC of more than 100mgl^{-1} above daily maximum background extend approximately 5 km north and south of the dredge site over an area of up to 108ha at the sea surface and 83ha as a depth averaged plume. Plume quickly disperses after dredge – low concentrations 20mgl^{-1} above background over three days. For maintenance dredging plumes of SSC of 100mg/l would affect an area of 108ha at the surface and 28ha at the bed but this elevation in SSC would relatively short-lived. Changes in SSC are not of sufficient duration and magnitude to alter the SSC status of the Suffolk Coastal Waterbody
Cooling water intake and outfall	Dredging	For intakes elongate area 13km north, 22km south ~2 km east-west affected by increases in SSC >100mgl^{-1}, depth averaged peak at >1,000mgl^{-1} above background. Elevated concentrations are short lived, with more typical SSC of 100mgl^{-1}. Following dredging, the plume quickly dissipates –ca., two days until at background. Dredging for outfall similar SSC elevation and time to return to background. Changes in SSC not significant for marine water quality.
	Drilling and shaft insertion	During the drilling of the bedrock at the intake structures, a very diffuse plume with SSC of around 5mgl^{-1} relative to background may occur– Changes in SSC not significant for marine water quality
	Installation head	Head is lowered into place, not cast in-situ so no predicted foreign material release effects to the water and sediment quality of the local area
FRR and CDO	Dredging	No areas are subjected to increased surface SSC of more than 50mg/l for more than 6 hours.
	Drilling	Tunnel approximately 0.8m diameter directionally drilled from onshore with drill cuttings returned to land no predicted sediment resuspension effects to the water. There are no details available for chemical selection and quantities required for tunnelling but conservative values for products assessed for use at HPC are evaluated for Sizewell. Changes in SSC not significant for marine water quality
	Installation of head	Head lowered into place, not being cast in-situ so negligible predicted foreign material release effects to the water and sediment

Table 33: Construction discharges via the CDO with potential to influence marine sediment and water quality.

Determinand	Influence of discharge
Metals load	Combined discharges for groundwater were assessed for contribution against the annual load limits for the priority hazardous substances cadmium and mercury of 5kg and 1kg cumulative loads. These values are not exceeded by the discharges during any phases of construction. Consideration also made of potential additional inputs from trace metal contamination of water treatment chemicals used for demineralisation of water and these additions did not result in exceedance of the annual load limits.
Metals thresholds	Several metals are present in groundwater. Chromium and zinc fail screening and were modelled. Chromium plume is below EQS at<25m and zinc is undetectable above background at<3m from the CDO outfall. Not significant.
Ammonia	Maximum ammoniacal nitrogen contributions from groundwater and sewage for the construction period were evaluated. Exceedance of the EQS for un-ionised ammonia (21µgl^{-1}) maximum only occurs within 6.3m of the point of discharge. Not significant
Nutrients DIN and phosphorus	Maximum dissolved inorganic nitrogen and phosphorus contributions from groundwater and sewage were combined with the nitrogen and phosphorus loading used during commissioning. These loadings provided source terms for input to a combined phytoplankton and macroalgae model. Run over an annual cycle the model showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.13% for maximum construction and commissioning inputs of DIN and phosphorus. Not Significant
BOD	Using 13.3ls^{-1} and BOD of 40mgl^{-1} and taking account of groundwater contributions a maximum daily BOD of 121kg was calculated. This represents an oxygen requirement of 40.6kg/day. This amount of oxygen would be transferred across 1.2ha in a day and reaeration at the sea surface would also contribute. There is therefore considered negligible impact on the well mixed and well oxygenated waters off Sizewell from this discharge. Not Significant
Microbiological	*E.coli* meets bathing water standards <1m of the outfall with UV treatment and intestinal enterococci are ≤200 cfu/100ml at discharge the nearest Bathing water is 10k North of the discharge. No impact.
Tunneling wastewater and chemicals	The offshore cooling water infrastructure consists of two subterranean intake tunnels and one outfall tunnel. Tunnels would be excavated by tunnel boring machines (TBMs) from land. Three chemicals used to facilitate tunnelling and that might be discharged at Sizewell were evaluated in terms of significance of discharge concentration. Conservative scenarios were modelled for a clay mineral (bentonite) that may be required at Sizewell and based on Hinkley Point information for two surfactant chemicals. The low toxicity of bentonite, the small areas affected (concentrations of 10µgl^{-1} restricted to sea surface areas of mean 1.35ha and a 95th percentile area of 10.8ha) and the low discharge concentrations are likely to have negligible effects on water quality. For both surfactants assessed no exceedance of the EQS occurred at the seabed and the maximum area of exceedance at the surface was small with highest mean exceedance of 3.14ha and 25ha as a 95th percentile. Not significant for marine water quality.

Table 34: Commissioning discharges via the CDO with potential to influence marine sediment and water quality.

Determinand	Influence of discharge
Commissioning discharges	For commissioning the predicted discharge concentrations of phosphate were already assessed in combination with construction discharges. The circuit conditioning chemical ethanolamine passed the H1 test 5 dilution screening test and hydrazine and un-ionised ammonia were evaluated using GETM discharge modelling via the CDO. Hydrazine would be treated to achieve a maximum discharge concentration of 15µgl^{-1}. This discharge was assessed in terms of areas of exceedance for the acute and chronic hydrazine PNEC and intersection with the Minsmere sluice, the Coralline Crag and the foraging area for three SPA breeding colonies of birds. Hydrazine only intersects the sluice on the ebbing tide when it is likely to be closed. Passage of species like Eel that move to and from the saltmarsh via the sluice are not expected to have a significant affect as the peak concentrations are 800,000-fold less than levels shown to cause sublethal effects in fish. Peak hydrazine concentrations over the coralline crag do not exceed the precautionary chronic PNEC. The hydrazine plume never intersects foraging areas for two of the three SPA breeding colonies of birds. The hydrazine plume intersects foraging areas for the Minsmere Little Tern colony. Whilst the plume intersection with 15µgl^{-1} release concentration regularly exceeds 1% of the foraging range, the duration of the plume is short, with concentrations exceeding the acute PNEC for no longer than 4 hours a day. These changes are evaluated not significant for marine water quality, but further assessment is relevant for specific receptors. The un-ionised ammonia discharge during commissioning is rapidly reduced by the changing pH and salinity as well as by dilution as it mixes with seawater. Exceedance of the annual average EQS for un-ionised ammonia is predicted to only to occur in the direct vicinity of the discharge point and to be below the EQS 25m from the point of discharge. This change is not considered significant for marine water quality. As for the construction discharge assessment the total ammonium concentration at the point of mixing described above is at background for total ammonia and well below levels of concern.

Table 35: Inter-relationship effects during construction period

Determinand	Influence of discharge
Overview	This section provides a description of the identified inter-relationships that have the potential to affect marine water quality and sediment from construction and cold commissioning of the proposed development. Activities include potential for overlapping dredging for different infrastructure. Assessment of the construction discharges have already accounted for maximum potential inputs of the same substances from different phases of construction and cold commissioning. Here the interaction of the effects of the discharge from the CDO and the Sizewell B cooling water discharge plume are also considered.
Dredging activity	Simultaneous dredging activities may occur for some elements of the development. The suspended sediment plumes from the BLF maintenance dredge and the cooling water infrastructure do not interact, forming two discrete plumes. Therefore, the concurrent activities result in a greater spatial area of impacts rather than interactive effects. Increases in the total size of the instantaneous SSC plume are minimal. The suspended sediment plume from the BLF maintenance dredge and the FRR dredge plume do interact. At the sea surface the maximum instantaneous area exceeding 100mg/l increases to 111ha. The plume is highly transient and the total duration of increases in SSC would be reduced due to the temporal overlap. Simultaneous overlap of BLF maintenance, CWS intake and FRR outfalls would represent an area equivalent to 5% of the Suffolk Coastal waterbody this area of exceedance would occur for <5% of the year assuming e.g. monthly maintenance dredging and dredging of six CWS intakes and outfalls.
CDO chemical discharge and thermal elevation Sizewell B	CDO chemical discharges have a small area of exceedance at EQS levels <25m so the influence of thermal elevation at ca. 5°C above background would be very limited and insignificant.
Chlorinated discharge Sizewell B and ammonia input CDO	Chlorine and ammonia at similar molar concentrations and at low concentration can react in full strength seawater to form, predominantly, dibromamine which has higher toxicity than TRO alone. However, TRO typically at ca 20µg/l and ammonia NH4-N rapidly decreases to ca., 11µg/l at around 25 metres of the discharge meaning that the concentration of any combination products would be at very low concentrations and within a limited area around the CDO.

Table 36: Operation activities and discharges (cooling water thermal input) with potential to influence marine temperature and dissolved oxygen saturation.

Type of discharge	Influence of discharge
Cooling water – Thermal SPA	The absolute areas of exceedance for each thermal standard that applies to the SPA were assessed: For the 2˚C uplift threshold based on a maximum excess (100th percentile) the absolute areas of exceedance range between a minimum area of 5,219ha at the seabed for Sizewell B to 22,464ha at the surface for Sizewell B + Sizewell C. The second criteria for SPAs concern the 98th percentile of the absolute temperature. The predicted absolute areas where the plume temperatures exceed 28˚C are all below 1ha based on a calculated mean excess of >8.6˚C added to the 98%ile for Sizewell. In some cases, large areas are influenced by the thermal change but the magnitude is not evaluated as significant for marine water quality, but individual receptor assessments are further considered in the Marine Ecology Environmental Statement Chapter.
Cooling Water Thermal WFD	The absolute areas of exceedance for each thermal standard that applies to the WFD waterbodies was assessed: For the 2˚C uplift threshold based on a 98%ile of >23˚C the absolute areas of exceedance range between a minimum area of 8.75ha at the seabed for Sizewell B to 89.6ha at the surface for Sizewell B + Sizewell C. For excess temperatures of 2˚C as a 98th percentile this was exceeded for a minimum of 2126.71ha at the seabed for Sizewell B and 7899.17ha at the surface for Sizewell B +Sizewell C In some cases, large areas are influenced by the thermal change but the magnitude is not evaluated as significant for marine water quality but individual receptor assessments are further considered in the Marine Ecology Environmental Statement Chapter.
Cooling water – Thermal effect on Oxygen WFD	The effect of the thermal discharge on the oxygen saturation of the surrounding area has been derived using modelling. GETM runs show the area calculated that is beneath various DO concentrations for the entire model domain. The derived average DO concentration for the model domain for both Sizewell B and Sizewell C and Sizewell B alone is>5.77mgl^{-1} as a 5th percentile which is at or above the WFD threshold for High Status of 5.7mgl^{-1}. The influence of this change on marine water quality is not evaluated as significant
Cooling water – Thermal effect on percentage un-ionised ammonia WFD	The calculated mean ammonia discharge concentration was added to either the mean or 95th percentile un-ionised ammonia regional background value derived using the temperature fields generated by GETM and the relevant physicochemical data and total ammonia concentration for each scenario to derive the un-ionised ammonia calculation. The predicted mean increase in un-ionised ammonia was at maximum 13 times below the EQS of 21μgl^{-1}. The influence of this change on marine water quality is not evaluated as significant

Table 37: Operation activities and discharges (cooling water chemical input) with potential to influence marine sediment and water quality.

Type of discharge	Influence of discharge
Cooling water - TRO	For the Sizewell C discharge plume there is a small area of 2.13ha that exceeds the TRO EQS 95th percentile of 10µgl^{-1} for Sizewell C at the seabed and over ca., 337ha at the sea surface. The Sizewell C plume does not mix with the Sizewell B plume. (The absolute values for Sizewell B and Sizewell C in combination exceed the TRO EQS 95%ile of 10µgl^{-1} over 726ha at the surface and 167ha at the seabed. In some cases, large areas are influenced by TRO concentrations above the EQS but as TRO is not persistent the effects are not evaluated as significant for marine water quality but this is further considered in the Marine Ecology Environmental Statement Chapter.
FRR - TRO	An initial assessment of discharge of chlorinated seawater from this system was made in BEEMS TR333 and all the potential tunnel locations passed the assessment. However, intakes and tunnels will not be chlorinated.
Cooling water – CBP's	The Bromoform discharge was modelled for 132m^{3}s^{-1}. The Bromoform plume area that exceeds the applied EQS (PNEC 5µgl^{-1} as a 95th percentile) for Sizewell C only at the seabed is ca.,0.15ha and ca.,52ha at the sea surface. The Sizewell C plume does not mix with the Sizewell B plume. The combined plumes for Sizewell B and Sizewell C result in an area of ca.,357ha at the surface and ca.,130ha at the seabed. In some cases, large areas are influenced by bromoform concentrations above the EQS but based on toxicity and persistence the effects are not evaluated as significant for marine water quality but individual receptor assessments are further considered in the Marine Ecology Environmental Statement Chapter.
Cooling water - Hydrazine	Hydrazine discharges exceed the acute and chronic quality standard (PNEC) values for discharge concentrations derived from both 24-hour and annual loadings. The chronic PNEC 0.4ngl^{-1} is exceeded at the surface and at the seabed, although in the latter case, an area of less than 1ha is affected for both discharge scenarios. The acute PNEC 4ngl^{-1} is exceeded at the surface (for less than 18ha) and at the seabed, but only in the case of the 69ngl^{-1} release for an area of 0.13ha. Relatively small areas are influenced by hydrazine concentrations above the acute or chronic EQS. These values are precautionary and so the effects are evaluated as not significant for marine water quality but individual receptor assessments are further considered in the Marine Ecology Environmental Statement Chapter.
Various substances screened out	Various substances (copper, zinc, chromium) exceeded the 24 hour or annual discharge assessment but this resulted from high background concentrations and predicted discharge concentration for these substances would be below detection limits, so they were screened out. Other substances that have no PNEC and reference site background cannot be effectively assessed but again most are below detection limits so again are screened out of further assessment

Table 38: Operation activities and discharges (Un-ionised ammonia, dissolved inorganic nitrogen, phosphorus and microbiological parameters) with potential to influence marine sediment and water quality.

Type of discharge	Influence of discharge
Un-ionised ammonia	During operation the concentration of ammonia predicted in the discharge has been added to the site background and predictions of un-ionised ammonia concentrations derived for the discharge to Sizewell Bay. All cases (including worst cases) for un-ionised ammonia show that no areas exceed the EQS of 21µgl^{-1} NH_3-N as an annual mean. Evaluated as not significant for marine water quality.
DIN	The predicted DIN loading during operation 332kg represents ca., 2% of the exchange per day in summer between Sizewell Bay, the outer tidal excursion and the wider area. Based on these values and combined with PO_4-P a phytoplankton and macroalgal growth Box model run over an annual cycle showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.11%. Evaluated as not significant for marine water quality but further receptor evaluations are considered in the Marine Ecology Environmental Statement Chapter 21.
Phosphorus	The predicted phosphorus loading during operation PO_4-P gives a value of 114.8kg. This loading represents ~5% of the PO_4-P exchange per day in summer between Sizewell Bay, the outer tidal excursion and the wider area. Based on these values and combined with DIN a phytoplankton growth Box model run over an annual cycle showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.11%. Evaluated as not significant for marine water quality but further receptor evaluation is considered in the Marine Ecology Environmental Statement Chapter 21..
Microbiological parameters	During operation the maximum number of staff on site is estimated at 1900 based on HPC. If UV treatment is applied to the predicted sewage effluent volume discharge and assuming a 5.4 log reduction in specific microorganisms compliance would be achieved at the point of discharge. Evaluated as not significant for marine water quality.

Table 39: Discharges of moribund fish from the FRR with potential to influence marine sediment and water quality.

Type of discharge	Influence of discharge
FRR moribund fish influence on nutrient status	Nitrogen and phosphorus concentrations from decaying fish biomass predicted to be discharged from the FRR and based on annual average fish loadings were assessed in a model run in combination with operational inputs using a Combined Phytoplankton and Macroalgae Model. A model run over an annual cycle predicts a less than 0.29% difference in annual gross production of carbon and this level of change would not be discriminated above natural background variation. Evaluated as not significant for marine water quality but further receptor evaluation is considered in the Marine Ecology Environmental Statement Chapter 21.
FRR moribund fish influence on un-ionised ammonia	The un-ionised ammonia input from decaying biomass from the FRR was derived for the maximum annual biomass loading. Relevant seasonal pH and temperature which influence the proportion of un-ionised ammonia were also accounted for an equivalent area of 6.7ha would potentially exceed the un-ionised ammonia annual average EQS. This area of exceedance is considered to be low relative to the potential for mixing and exchange of water across the GSB. Evaluated as not significant for marine water quality but further receptor evaluation is considered in the Marine Ecology Environmental Statement Chapter 21.
FRR moribund fish influence on dissolved oxygen	The effect of biomass decay on dissolved oxygen was also derived. The calculated annual mean daily biomass oxygen demand represents 0.2% of the oxygen available in the volume of water exchange across the Greater Sizewell Bay. Reaeration at the surface would also resupply oxygen with typical values of surface exchange for this area providing an equivalent loading to that consumed by the biomass discharge over an area of ca., 14ha. For the maximum predicted discharge of biomass during March oxygen demand would increase to 0.6% of that available from daily exchange and would be equivalent to reaeration over 45.2ha. Evaluated as not significant for marine water quality but further receptor evaluation is considered in the Marine Ecology Environmental Statement Chapter 21.

Table 40: Influence of climate change on Operational discharges.

Type of discharge	Influence of discharge
Cooling water – Thermal	Thermal uplifts above ambient are predicted to be largely independent of the background sea temperature. Therefore, thermal uplift areas are predicted to remain largely unchanged under future climate scenarios. The results indicate that future climate change is not predicted to significantly increase the absolute areas in exceedance of 28ºC, which remain under 1ha for all scenarios tested. Following the decommissioning of Sizewell B, 28ºC as an absolute temperature is not predicted to be exceeded as a 98th percentile even under the extreme climate case of the proposed development operating in 2110. Therefore, thermal effects in the receiving waters are predicted to remain minimal. Whilst climate change would act in-combination with the proposed development to increase areas of exceedance, receptors exposed would be acclimated to a modified thermal baseline. Furthermore, changes in species composition may have occurred independently of the proposed development. For species exposed to the thermal plume, effects would be like those predicted for the current baseline.
Cooling water - TRO	TRO decay will increase at elevated temperatures, but dosing is adjusted to ensure that the target TRO of 0.2mgl^{-1} is achieved in critical sections of the CW plant. The residual oxidant level at the point of discharge is therefore unlikely to be reduced under climate change. The ratio of oxidant chemicals formed upon chlorination of seawater is influenced by pH. Lowering pH could in theory reduce toxicity but the pH change and influence on ratio of hypobromous and hypochlorous acid is not considered significant so the assessment remains the same as for current conditions.
Cooling water – CBP's	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
Cooling water - Hydrazine	Hydrazine half-life 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.

Table 41: Inter relationship effects Operation

Type of discharge	**Influence of discharge**
Synergistic effects chlorinated discharge and treated sewage effluent	Seasonal chlorination and un-ionised ammonia from treated sewage discharge have the potential to interact in the cooling water discharge. The level of total ammonia discharged including current background levels is low and represents an increase of ca.30% of the present mean background total ammonia. The synergistic effects of chlorination and ammonia discharges may result in the formation of additional combined products. However, the low level of ammonia available to interact with chlorinated seawater would limit the byproduct formation to below levels of significance in terms of change to toxicological influence of the chlorinated seawater alone.
Synergistic effects of temperature and toxicity of chlorinated seawater	Beyond the immediate point of discharge ca 10-20m the residual oxidant exposure would be low at a few 10s of micrograms/litre and the thermal elevation would be a few degrees above background. Beyond this point the low level of thermal elevation and its influence on the toxicity of residual oxidants would be insignificant. The area affected with potential for synergistic effects of temperature on chlorinated seawater toxicity would therefore be very limited.

9 Potential in-combination and cumulative effects from Sizewell C development

The Sizewell C Environmental Statement will assess the potential in-combination (activities associated with the Sizewell C project) and cumulative effects (activities associated with Sizewell C plus activities from other relevant developments). Zones of Influence (ZoI) will be established for these assessments and the Planning Inspectorate guidance will be adhered to.

The activities and associated pressures relevant to water and sediment quality that will be included in these assessments are as follows:

- Increases in suspended sediment concentration from dredging activities (in-combination and cumulatively);
- Increases in temperature from the thermal discharge (in-combination and cumulatively). Interaction of the Sizewell C and Sizewell B discharge have been considered in this report; and;
- Contamination from the chemical and microbiological discharge (in-combination and cumulatively)

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11 Appendix A Zone of Influence

To determine the effects of entrainment on phytoplankton populations, from Sizewell B and C, BEEMS Technical Report TR385, determined the approximate volume of water within the influence of the power station during a tidal cycle. Based upon a current meter (S2) deployed near the proposed Sizewell C intake locations, a progressive vector diagram (PVD) method indicated that the north – south excursion is approximately 15.9 km in each direction, and 1.4km east – west during spring tides. The trajectory of the tide flows both north and south, thus the tidal volume represents a body of water 31.8 km long and approximately 2.8km wide. The average depth was calculated at 12.5m giving a total volume of 1209.7 x 106 (Table 43) and (Figure 17).

Table 42: The volume of water associated with the Greater Sizewell Bay and the tidal excursion originally reported in BEEMS Technical Report TR385.

Body of water defined in TR385	Surface area (ha)	Average depth (m)	Volume (x10^6 m^3)
GSB	4120	8.8	363.8
GSB + tidal excursion beyond the Sizewell-Dunwich Bank	9670	12.5	1209.7

The tidal excursion is dependent on the stage within the spring-neap cycle but provides an estimate for the zone of influence. The method applied to determine the tidal excursion has a bearing on the calculation of the estimated area and volume. The following section details several methods applied to estimate the body of water potentially influenced by the power station.

For comparison, a harmonic analysis was conducted on the same current meter (BEEMS Technical Report TR233) and provided similar results to the PVD method. The tidal ellipse indicates that the north – south excursion is approximately 17.2km, and 1.8km east – west during spring tides. The trajectory of the tide flows both north and south, thus the tidal volume represents a body of water 34.4 km long and approximately 3.6km wide.

Further analysis was undertaken to support the estimate of the tidal water volumes reported in BEEMS Technical Report TR385. To determine the Outer Tidal Excursion, a particle tracking study was considered but the trajectories exceeded the hydrodynamic model domain. Instead, without running a new model set-up, two alternative methods have been considered: a PVD and a harmonic analysis. The PVD method estimates the potential transport based upon measured velocity time-series (at a fixed location). The distance travelled between each time step of the record, is determined from using the U and V velocity components, and its trajectory plotted from the original starting point (i.e. the outfalls). The tidal excursion is then determined from an area encompassing the total trajectory path. For the harmonic analysis method, an idealised tidal curve was reconstructed, using the M2, S2 and N2 tidal constituents, to determine the major and minor axis of the tidal ellipse. This provides a maximum theoretical tidal excursion, excluding any meteorological forcing. The area and volume based upon the average depth, of the associated ZoIs are shown in Table 44.

To determine the volume of water that may be influenced by the CDO and FRR discharges, within the Sizewell-Dunwich Bank particle tracking associated with the FRR was completed (BEEMS Technical Report TR333). Particles were released from FRR Position 5 over a spring-flood tide and a neap-flood tide for May 2009. This is representative of the mean conditions for the area of Sizewell. The tidal excursion within the Sizewell-Dunwich Bank was then determined by defining an area encompassing every particle position at each time step of both runs combined. This indicates that the total tidal excursion is approximately 20.8km North-South and approximately 3.5km east-west.

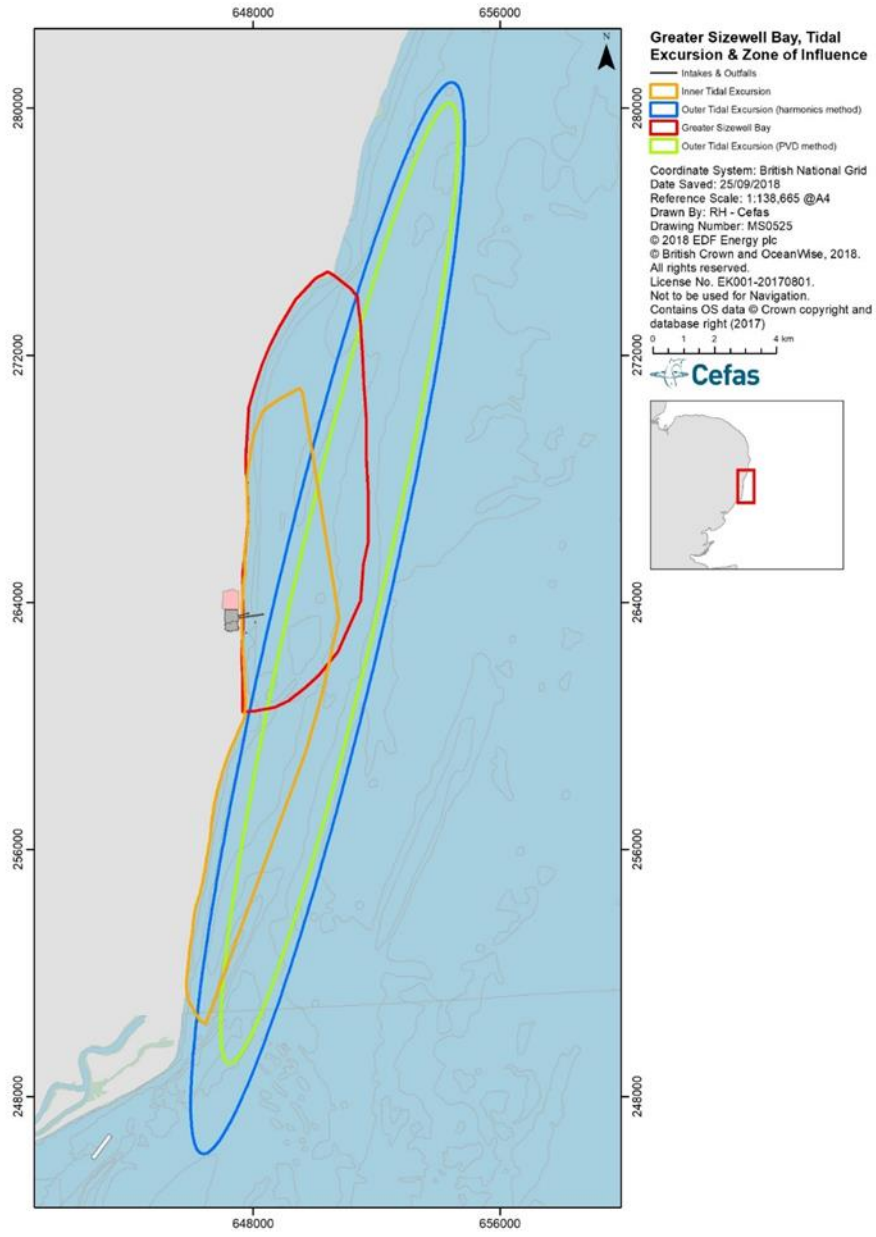


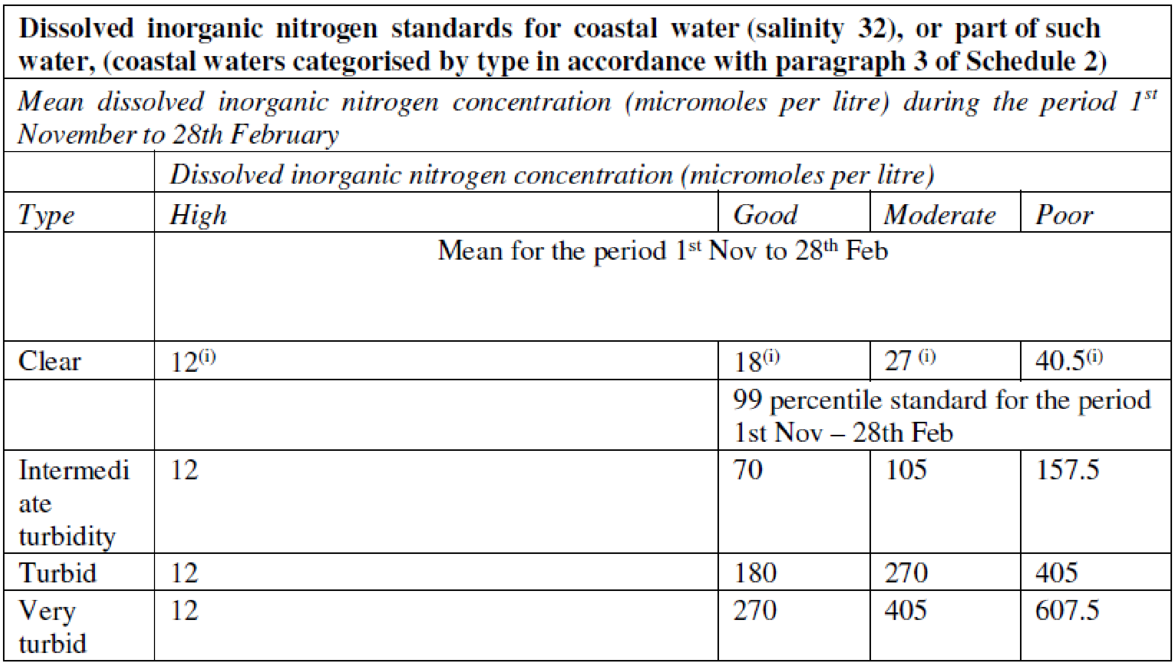
Figure 17: The area of the tidal excursion from the Sizewell C CDO/FRR and outfall during spring tides, the outer tidal ellipse and the Greater Sizewell Bay body of water.

Table 43: Approximate surface area and volume of the Zones of Influence based on the areas delineated in Figure 14.

Body of water	Surface area (ha)	Average depth (m)	Volume (x10^6 m^3)
GSB (geomorphic extent)	4577.5	8.73	399.7
Inner Tidal Excursion	4323.2	8.49	367.0
Outer Tidal Excursion			
PVD method	7081.4	13.91	985.0
Harmonics method	10129.1	13.84	1401.9
***GSB + tidal excursion**	9906.7	12.14	1202.9

12 Appendix B Extract from Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015

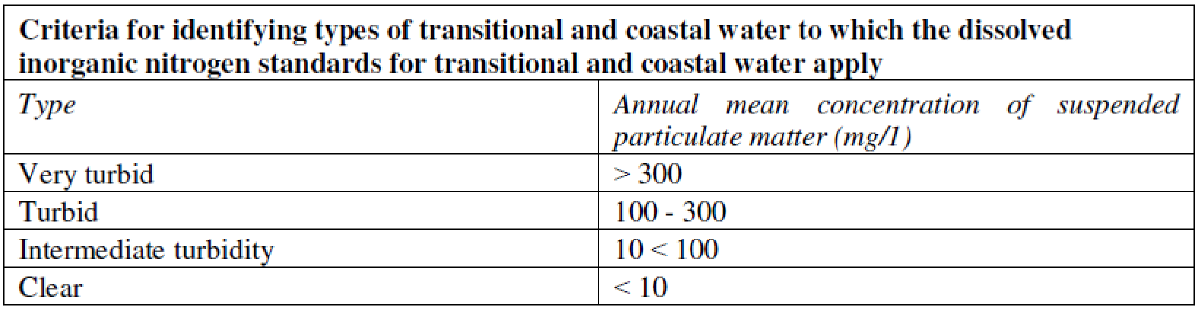
Table 16



Dissolved inorganic nitrogen standards for coastal water (salinity 32), or part of such water, (coastal waters categorised by type in accordance with paragraph 3 of Schedule 2)				
Mean dissolved inorganic nitrogen concentration (micromoles per litre) during the period 1st November to 28th February				
	Dissolved inorganic nitrogen concentration (micromoles per litre)			
Type	*High*	*Good*	*Moderate*	*Poor*
	Mean for the period 1st Nov to 28th Feb			
Clear	12(i)	18(i)	27 (i)	40.5(i)
		99 percentile standard for the period 1st Nov – 28th Feb		
Intermediate turbidity	12	70	105	157.5
Turbid	12	180	270	405
Very turbid	12	270	405	607.5

(i) The standard refers to the concentration of dissolved inorganic nitrogen at a mean salinity of 32 for the period of 1st November to 28th February.

Table 6



Criteria for identifying types of transitional and coastal water to which the dissolved inorganic nitrogen standards for transitional and coastal water apply	
Type	*Annual mean concentration of suspended particulate matter (mg/l)*
Very turbid	> 300
Turbid	100 - 300
Intermediate turbidity	10 < 100
Clear	< 10

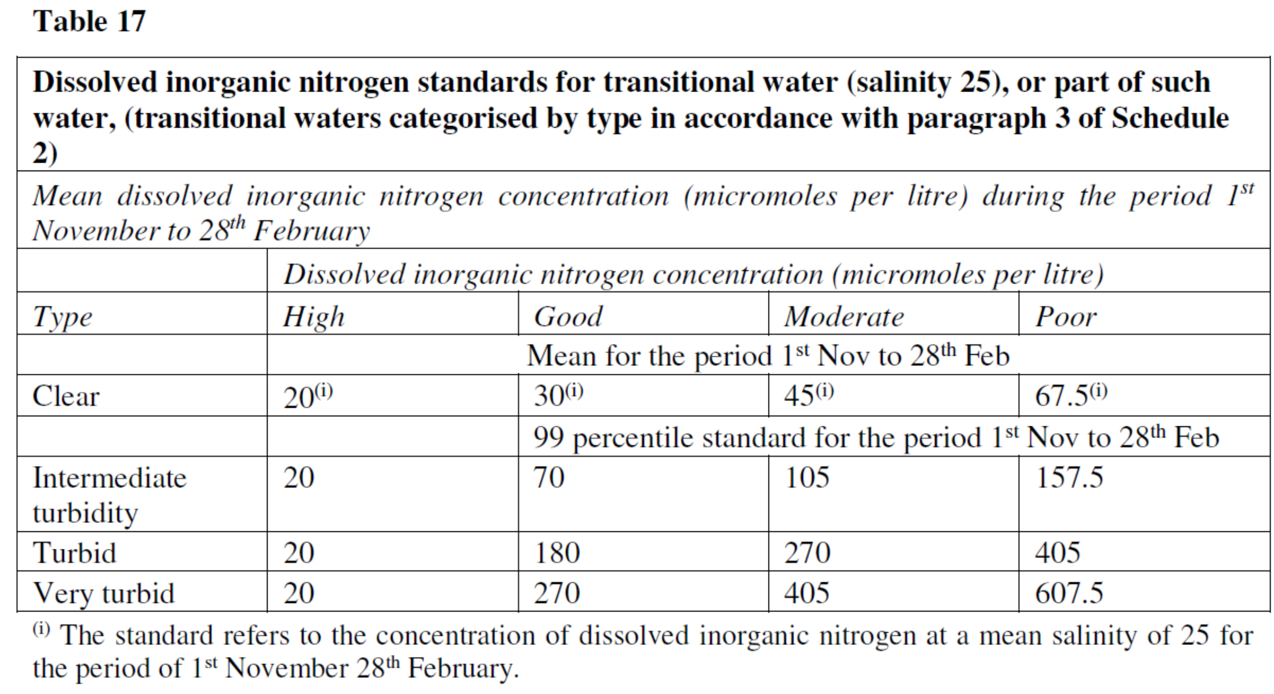


Table 17

Dissolved inorganic nitrogen standards for transitional water (salinity 25), or part of such water, (transitional waters categorised by type in accordance with paragraph 3 of Schedule 2)				
Mean dissolved inorganic nitrogen concentration (micromoles per litre) during the period 1st November to 28th February				
	Dissolved inorganic nitrogen concentration (micromoles per litre)			
Type	*High*	*Good*	*Moderate*	*Poor*
	Mean for the period 1st Nov to 28th Feb			
Clear	20(i)	30(i)	45(i)	67.5(i)
		99 percentile standard for the period 1st Nov to 28th Feb		
Intermediate turbidity	20	70	105	157.5
Turbid	20	180	270	405
Very turbid	20	270	405	607.5

(i) The standard refers to the concentration of dissolved inorganic nitrogen at a mean salinity of 25 for the period of 1st November 28th February.

13 Appendix C Microbiological assessment of sewage discharges

For the construction discharge following either sewage treatment at a secondary or tertiary (UV) level the distance from the discharge point, at which enough dilution occurs to be below relevant microbiological standard levels, has been estimated using CORMIX for Case D (30ls^{-1}) sewage discharge and Case D1 (72ls^{-1}). Results are shown below in Table 45.

Table 44 Estimate of minimum distance from point of discharge at which microbiological standards for bathing waters are met following different levels of sewage treatment for the construction discharge from SZC

Species	**Standard cells/ 100ml**	**Discharge concentration cells / 100ml**	**2^{ndry} treatment 2 log reduction**	**Dilution required to meet bathing water standard**	**Maximum potential distance from the discharge at which meets bathing water standard**		**UV treatment reduction 5.4 log reduction**	**Dilution factor required for discharge to meet bathing water standard**	**Maximum distance from the discharge at which it meets bathing water standard**
					30 l s^{-1}	**72 l s^{-1}**			
E.coli	500	240,000,000[1]	2400000	4800	~1.7 km	~3.1 km	955.5	1.9	<1 m pass immediately on discharge, for both cases.
Entero-cocci	200	13,600,000	136000	680	~66 m	~460 m	54.1	0.3	<1 m pass immediately on discharge, for both cases.

[1] Cell numbers/100ml are based on data in support of the Hinkley Point C development (pers. Comm. EDF);

14 Appendix D Screening of Operational discharges

Operational phase chemical discharges for 2 EPR units based on EDF, 2011 and subsequent modifications incorporated in EDECME120678). For the Operational discharge assessment, it has been assumed that all metals within the effluent are present 100% in the dissolved state and therefore biologically available. This provides a worst-case scenario in terms of the modelling assessment. In the following sections Table 46 shows the loading of different chemicals used during operation as 24-hour and annual load.

Thereafter two tables Table 47 and 48 show the screening test results for maximum 24-hour and average annual loadings respectively during operation:

Table 47 shows Screening Test for large cooling water discharges to TraC waterbodies for the maximum 24 hour loadings predicted for operational phase chemical discharges (this includes sanitary waste for 1900 staff and demineralised water additives for two UK EPR units) for SZC – bold underlined values indicate failure of the relevant test. Table 48 shows Screening Tests for large cooling water discharges to TraC waterbodies for the average annual loadings predicted for operational phase discharges for 2 EPR units at SZC – bold underlined values also indicate failure of the relevant test.

Table 45: Loading of different chemicals used during operation as 24-hour and annual loading for 2 EPR units based on EDF, 2011 2014 and subsequent modifications incorporated in HPC-EDECME-XX-000-RET-000061120678)

Substance	Circuit conditioning (kg yr^{-1})	Sanitary waste discharge (kg yr^{-1})	Producing demineralised water (kg yr^{-1})	Maximum annual loading (kg yr^{-1})	Maximum 24-hour loading (kg d^{-1})
Boric acid (H_3BO_3)[1]	14000	-	-	14000	5625
Boron	2448	-	-	2448	984
Lithium hydroxide	8.8	-	-	8.	4.4
Hydrazine	24.3			24.3	3
Morpholine	1680	-	-	1674	92.25
Ethanolamine	920	-	-	919	24.75
Nitrogen as N	10130	1595	-	11725	332
Un-ionised Ammonia (NH_3)	-	-	-	958	27
Phosphates	800	-	-	790	352.5
Detergents	-	-	624	624	-
Suspended solids	2800	2080	88000	92879	870
BOD	-	1278	-	1387	3.8
COD	5050	-	-	5050	330
Aluminium	5.26	-	-	5.26	1.1
Cadmium[2]	-	-	0.37	0.37	0.005
Copper	0.42	-	-	0.42	0.08
Chromium	8.37	-	-	8.37	1.7
Iron	34.97		46000	46035	257
Manganese	3.33			3.33	0.67
Mercury[2]			0.099	0.099	0.0011
Nickel	0.44			0.44	0.09
Lead	0.3			0.3	0.07
Zinc	5.6			6.0	1.2
Chloride			87100	87100	450
Sulphates			98400	98400	2000
Sodium			52400	52400	855
ATMP			9100	9100	45
HEDP			890	890	4.5
Acetic Acid			14	14	0.1
Phosphoric acid			12	12	0.1
Sodium polyacrylate			8030	8030	40

Acrylic acid			165	165	1

1 Dissociation boric acid in seawater so equivalent boron concentration in discharge is presented and assessed 2 Cadmium and mercury loadings are derived from estimates based on trace contamination of raw material chemical use in water treatment systems based on Hinkley Point C data

Table 46: Screening Test for large cooling water discharges to TraC waterbodies for the maximum 24 hour loadings Operation.

Substance	EQS/surrogate value µg l^{-1}	Derivation of surrogate	Discharge concentration + background (µg l^{-1})	Annual Discharge/EQS <1
Boron[1]	7000	Pre WFD EQS	4656	0.67
Lithium hydroxide	65[2]	Mean background	90.2[2]	**1.39**[3]
Hydrazine	0.0004	Chronic PNEC	0.53[4 5]	**131.5**
Morpholine	17	Chronic PNEC	16.2	0.58
Ethanolamine	160	Acute PNEC	4.34[5]	0.03
Nitrogen as N	980[6]	WFD 99th percentile	484.3[7]	0.49
Un-ionised Ammonia (NH$_3$-N)	21	WFD AA-EQS	7.34[8]	0.35
Phosphates(PO$_4$-P)	33	Mean background	127	**3.79**
Suspended solids	74000[3]	Mean background	154[5]	0.002
BOD	2000	Mean background	0.67[5,9]	0.0003
COD	239000	Mean background	57.87[5]	0.00024
Aluminium	12	Mean background	20.19	**1.68**
Cadmium	1.5	WFD MAC-EQS	0.13	0.09
Copper	3.76	WFD AA-EQS	4.76	**1.27**
Chromium	0.6	WFD AA-EQS	2.48	0.08
Iron	1000	WFD AA-EQS	302	0.3
Manganese	2	Mean background	-	-
Mercury	0.07	WFD MAC-EQS	0.02[10]	0.29
Nickel	34	WFD AA-EQS	1.17	0.03
Lead	1.3	WFD AA-EQS	3.94	0.28
Zinc	6.8	WFD AA-EQS	46	**6.77**
Chloride	14128000	Mean background	78.9[5]	0.00
Sulphates	2778000	Mean background	350.7[5]	0.00
Sodium	10400000	Mean background	150[5]	0.00
ATMP	74	NOEC 96h fw[11] algae	7.89[5]	0.11
HEDP	13	EC$_{50}$ 96h algae	0.79[5]	0.06
Acetic Acid	301	LC$_{50}$ 48h fw crust	0.02[5]	0.00006
Phosphoric acid	200	LC$_{50}$ 72h algae	0.02[5]	0.0001
Sodium polyacrylate	180	LC$_{50}$ 96h fw fish	7.01[5]	0.04
Acrylic acid	1.7	LC$_{50}$ 96h fw fish	0.18[5]	**0.1**
Chlorine (TRO) bromoform	(10) 5	MAC-EQS	(150), 190	**(15)38**

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 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 NH4 concentration that results from the combined sanitary and conditioning inputs [69] 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.10 The mean is used in place of the 95th percentile as values below detection result in lower 95th percentile value 11 fw represents freshwater species toxicity test data which determines PNEC

Table 47: Screening Test for large cooling water discharge to TraC waterbodies for the average annual loadings during Operation.

Substance	EQS/surrogate value µg l^{-1}	Derivation of surrogate	Discharge concentration including background (µg l^{-1})	Annual Discharge/EQS <1
Boron[1]	7000	Pre WFD EQS	4145.67	0.59
Lithium hydroxide	65[2]	Mean background	65[2]	**1.00**[3]
Hydrazine	0.0004	Chronic PNEC	0.01[4]	**16.6**
Morpholine	17	Chronic PNEC	0.46[5]	0.03
Ethanolamine	160	Acute PNEC	0.25[5]	0.001
Nitrogen as N	980[6]	WFD 99%	360.12[7]	0.37
Un-ionised Ammonia (NH_3-N)	21	WFD AA-EQS	0.96[8]	0.05
Phosphates	33	Mean background	33.57	**1.00**
Detergents	-	-	0.17[5]	0.2
Suspended solids	74000[3]	Mean background	25.4[5]	0.0003
BOD	2000	Mean background	0.38[5,9]	0.0002
COD	239000	Mean background	1.38[5]	0.00001
Aluminium	12	Mean background	12	**1.00**
Cadmium	0.2	WFD AA-EQS	0.05	0.25
Copper	3.76	WFD AA-EQS	2.15	0.57
Chromium	0.6	WFD AA-EQS	0.57	0.95
Iron	1000	WFD AA-EQS	132.58	0.13
Manganese	2	Mean background	-	-
Mercury	0.07	WFD MAC-EQS	0.02	0.29
Nickel	8.6	WFD AA-EQS	0.79	0.09
Lead	1.3	WFD AA-EQS	1.0	**0.76**
Zinc	6.8	WFD AA-EQS	14.7	**2.16**
Chloride	14128000	Mean background	23.81[5]	-
Sulphates	2778000	Mean background	26.90[5]	-
Sodium	10400000	Mean background	14.32[5]	-
ATMP	74	NOEC 96h fw[10] algae	2.49	0.03
HEDP	13	NOEC 96h algae	0.24	0.02
Acetic Acid	62.8	NOEC 21d fw crust	0.004	0.0001
Phosphoric acid	20	LC_{50} 72h algae	0.003	0.0002
Sodium polyacrylate	11.2	NOEC 72h fw crust	2.20	0.20
Acrylic acid	0.34	NOEC 72 h fw algae	0.05	**0.13**

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 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 1595kg/y 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 NH4 concentration that results from the combined sanitary and conditioning inputs 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 (0.38µgl-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 10 fw represents freshwater species toxicity test data which determines PNEC

15 Appendix E Thermal modelling extremes(100 percentiles)

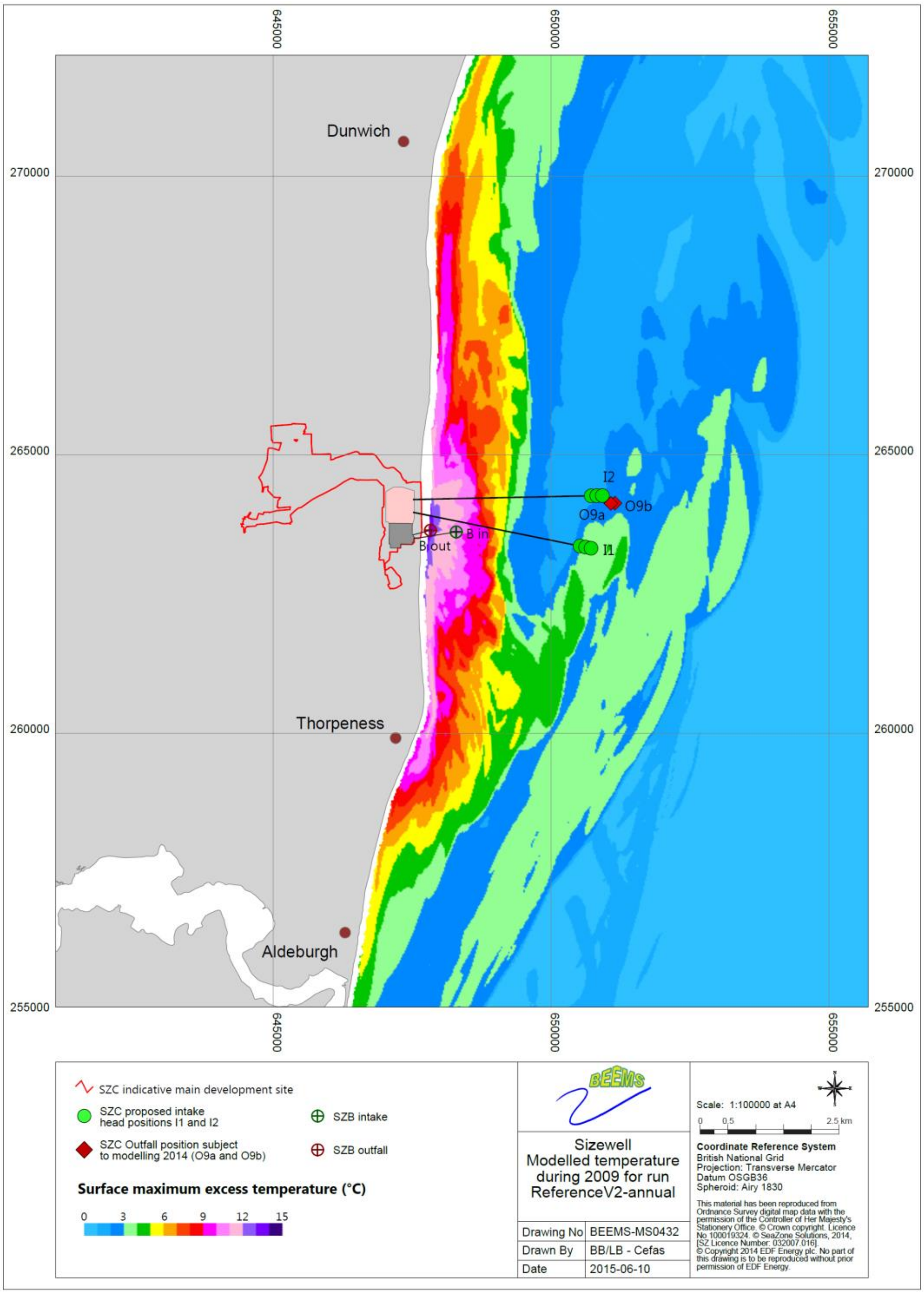


Figure 18: Surface annual maximum excess temperature for SZB only (100%iles).

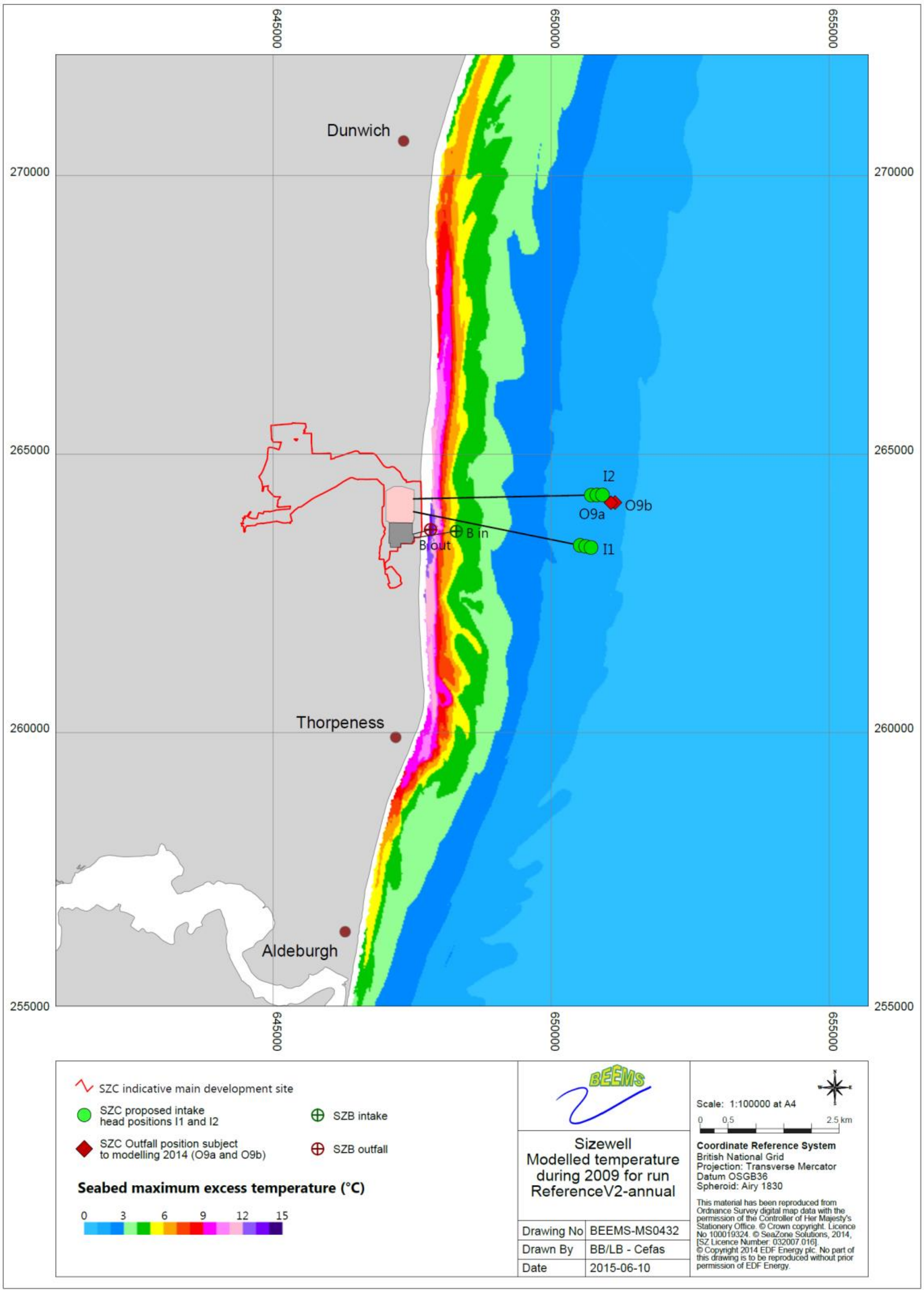


Figure 19: Seabed annual maximum excess temperature for SZB only (100%iles).

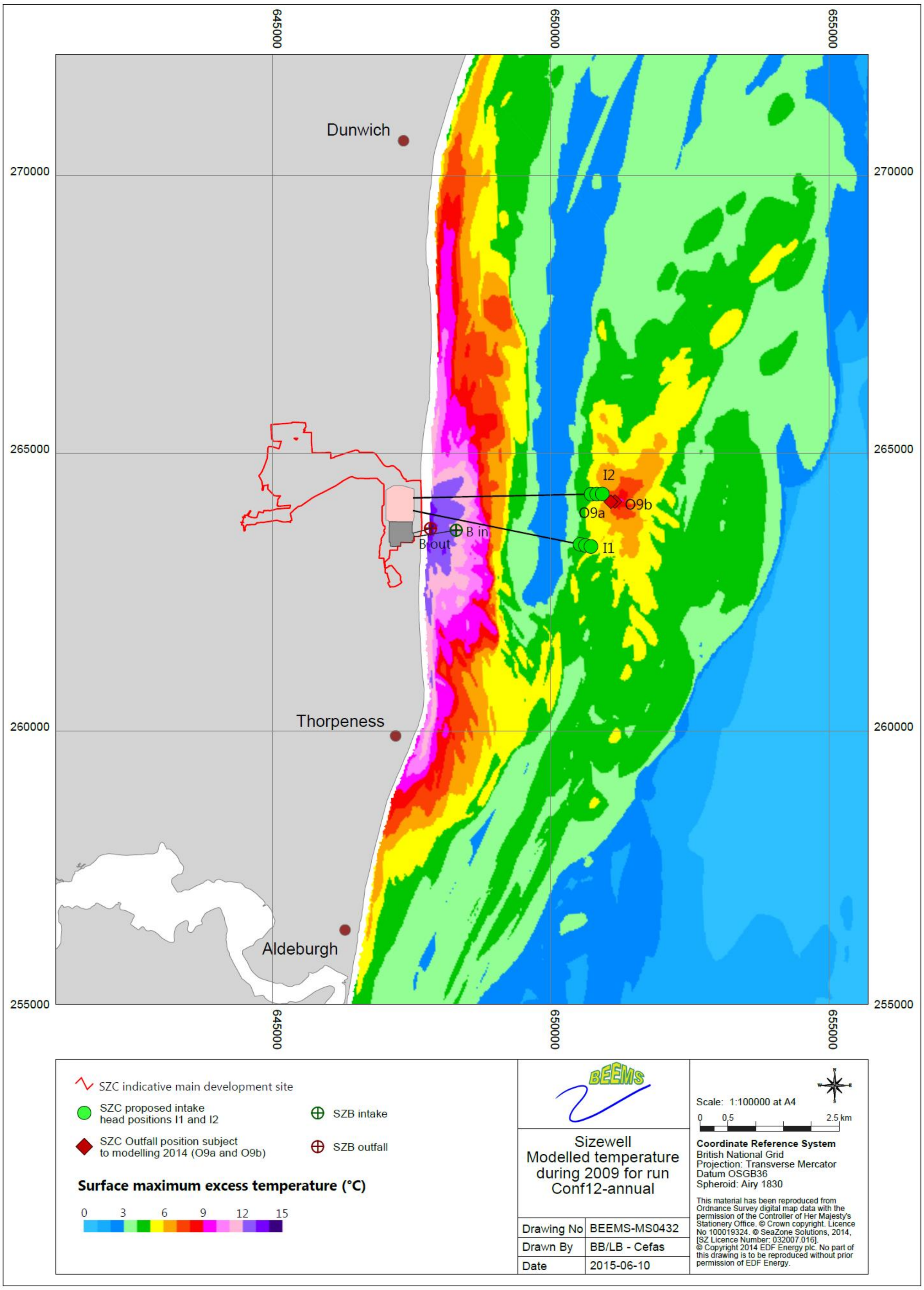


Figure 20: Surface annual maximum excess temperature for SZB + SZC.

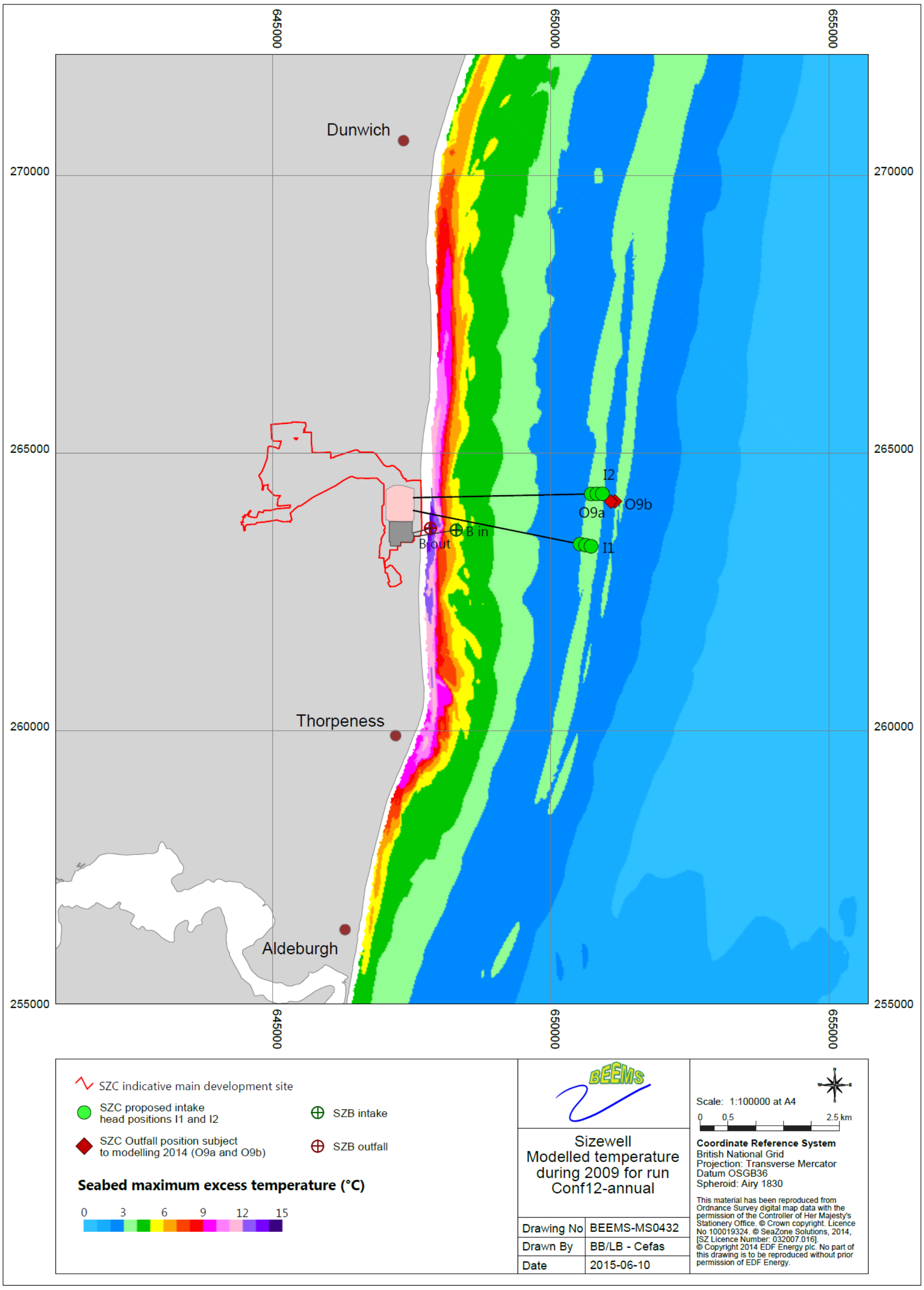


Figure 21: Seabed annual maximum excess temperature for SZB + SZC

16 Appendix E Future Climate and Thermal Considerations

This section considers the influence of climate change on future thermal parameters in relation to the operation of Sizewell C and Sizewell B. At the time of writing the recently updated UKCP18[3] marine climate predictions (November 2018) do not include sea temperature data. Future climate scenarios for Sizewell are based on UKCP09 data, which provides predictions of future climate for 2070-2100 relative to a baseline of 1961-1999 for the broad Sizewell area.

Whilst the UKCP09 air temperature predictions provided three emissions scenarios: High, Medium and Low, sea temperature is only provided for the medium emissions scenario (SRES A1B). In addition to the medium emissions, the UKCP09 provides data on daily variability including predictions of the maximum daily mean temperatures within a month. This data can be used to represent extreme maximum values (99.9%tiles) for each month based on 30 years of data (BEEMS Technical Report TR231).

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;
- The influence of future climate change on (contemporary) thermal standards.

Temperature records from Sizewell A and Sizewell B, collected between 1967 and 2017, were used to estimate monthly mean intake temperatures (with an associated standard deviation).). In addition, recently hourly temperature data from SZ B has become available from 1994 – 2018 with monthly values shown in Table 44. These temperatures were centred on the year 2006 to provide a basis for future intake temperature and entrainment predictions. This higher frequency record has been used in subsequent analysis

The average monthly UK baseline (1961-1999) were subtracted from the UKCP09 projected temperatures for 2070-2100. The differential was applied to calculate future thermal baselines at Sizewell using linear interpolation. Predications for Sizewell were centred on 2006. Therefore, climate predictions assume a linear increase in temperature which will be subject to increased uncertainty further into the future.

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 (BEEMS Technical Report TR302).

To incorporate a range of future intake temperatures the following scenarios were investigated:

1. **2030:** The earliest potential date for Sizewell C to be operational. The scenario includes both stations running simultaneously.
2. **2055:** The hypothetical last likely date for Sizewell B to be operational. The scenario includes both stations running simultaneously and SZC running in isolation.
3. **2085:** Towards the end of the operational life of Sizewell C.

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[3] https://www.metoffice.gov.uk/research/collaboration/ukcp (last accessed 03/03/2019)

4. **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.

Future intake temperatures

Mean monthly temperatures at the Sizewell B and Sizewell C intakes are provided in Table 48 and illustrated in (Figure 22. Predicted mean monthly temperatures at the location of the Sizewell B intakes (± s.d.) for 2030 and 2055, with both Sizewell B and Sizewell C operating.Figure 22 and Figure 233). Predicted mean monthly temperatures at the location of the Sizewell B intakes (± s.d.) for 2030 and 2055, with both Sizewell B and Sizewell C operating (Figure 22 and 23). Intake temperatures peak in August at 20.4ºC at 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 21.9ºC at 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.

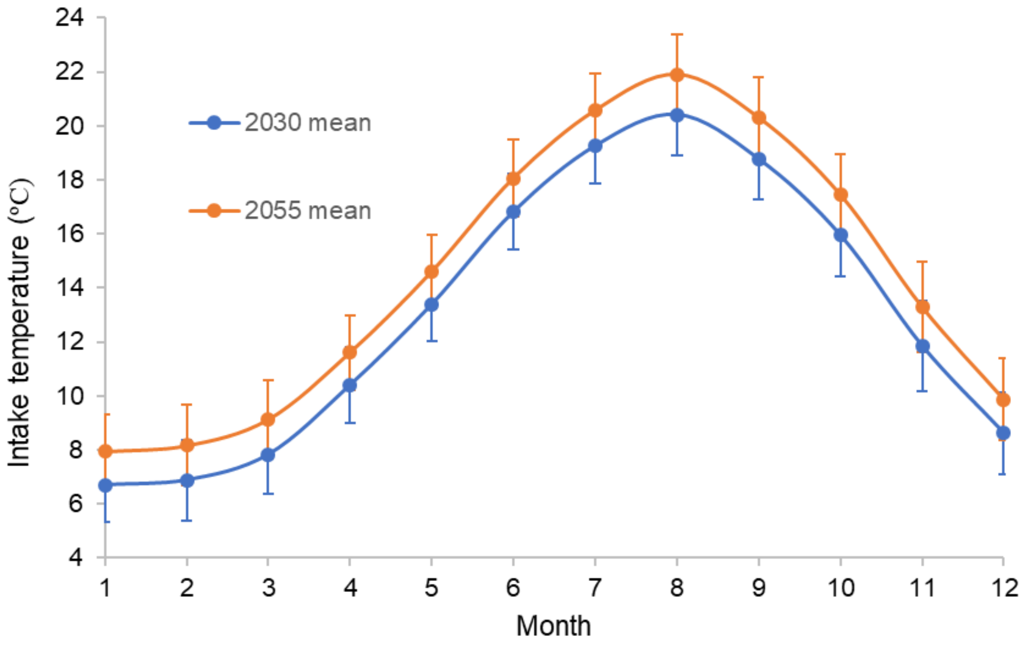

Figure 22. Predicted mean monthly temperatures at the location of the Sizewell B intakes (± s.d.) for 2030 and 2055, with both Sizewell B and Sizewell C operating.

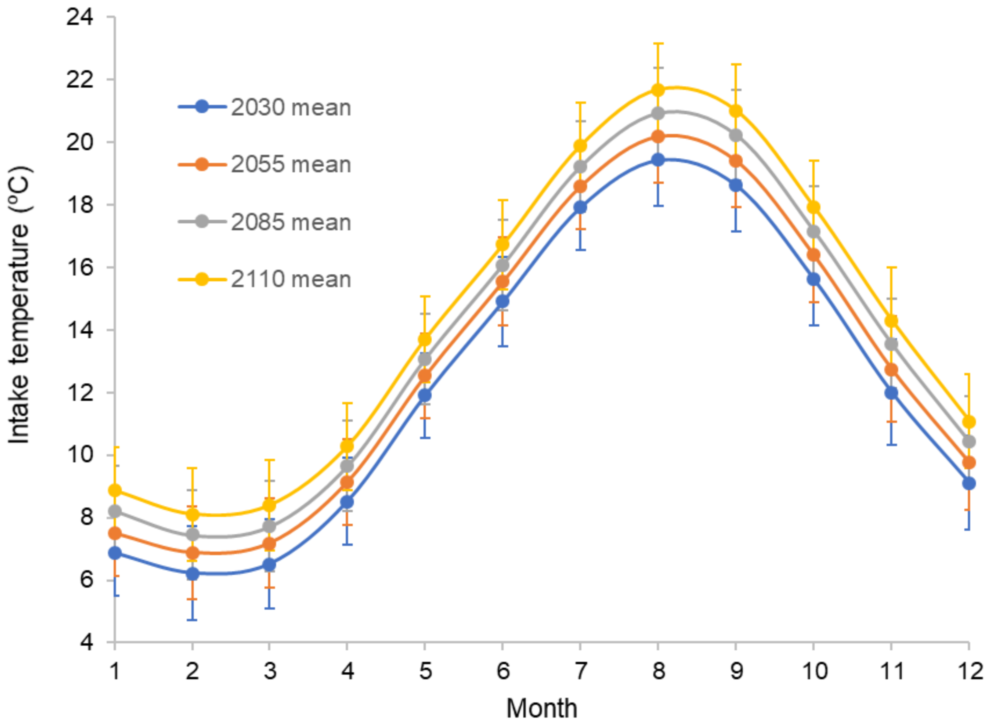

Figure 23 Predicted mean monthly temperatures at the location of the Sizewell C intakes (± s.d.) for 2030 and 2055, 2085 and 2110.

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. Table 49 details the future maximum daily temperature at the Sizewell B and Sizewell C intakes for each month. 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 (Table 49).

Table 48 Predicted monthly mean temperatures (°C) at the location of the Sizewell B and Sizewell C intakes. Assessments are based on mean daily temperatures from the UKCP09 medium emissions scenario (SRES A1B).

Month	UKCP09 (Baseline)	UKCP09 Projected	UKCP09 Increase in mean temp (°C)	1967-2017 SZA_SZB	Hourly data 1994 - 2018	Recirculation component		Daily mean SZB		Daily mean SZC				Standard deviation between years of monthly values
	1961-1999	2070-2100			Centre 2006	Estimated temp. at SZC intakes, if SZC were operating	Estimated temp. at SZB intakes if SZC were operating	2030	2055	2030	2055	2085	2110	
January	4.6	7.3	2.7	6.0	5.9	6.3	6.1	6.7	7.9	6.9	7.5	8.2	8.9	1.4
February	4	6.8	2.8	5.4	5.4	5.6	6.3	6.9	8.2	6.2	6.9	7.4	8.1	1.5
March	4.5	7.4	2.8	6.2	6.4	5.9	7.2	7.8	9.1	6.5	7.2	7.7	8.4	1.4
April	6.7	9.3	2.6	8.6	8.9	7.9	9.8	10.4	11.6	8.5	9.1	9.7	10.3	1.4
May	9.8	12.5	2.6	11.7	12.2	11.3	12.8	13.4	14.6	11.9	12.5	13.1	13.7	1.4
June	13.5	16.2	2.7	15.2	15.6	14.3	16.2	16.8	18.1	14.9	15.5	16.1	16.7	1.4
July	16.5	19.4	2.8	18.1	18.1	17.3	18.6	19.3	20.6	17.9	18.6	19.2	19.9	1.4
August	17.9	21.1	3.2	19.1	19.1	18.7	19.7	20.4	21.9	19.4	20.2	20.9	21.7	1.5
September	16.3	19.6	3.3	17.8	17.6	17.9	18.0	18.8	20.3	18.6	19.4	20.2	21.0	1.5
October	13.3	16.5	3.2	14.8	14.5	14.9	15.2	15.9	17.4	15.6	16.4	17.2	17.9	1.5
November	9.6	12.7	3.1	11.4	10.9	11.3	11.1	11.8	13.3	12.0	12.7	13.6	14.3	1.7
December	6.5	9.2	2.7	7.9	7.6	8.5	8.0	8.6	9.9	9.1	9.7	10.4	11.1	1.5
Average	10.3	13.2	2.9	11.8	11.8	11.7	12.4	13.1	14.4	12.3	13.0	13.6	14.3	

Table 49 Predicted maximum daily temperatures (°C) for each month at the location of the Sizewell B and Sizewell C intakes. Assessments are based on UKCP09 medium emissions scenario (SRES A1B).

Month	Max Daily Mean Sea Temperature 1961-1999_(UKCP09)	Max Daily Mean Sea Temperature 2070-2100_(UKCP09)	Increase	Maximums at hourly interval (1994 – 2018)	Maximum daily average at SZB (1994 – 2018)	Estimated daily max temp at SZC intakes, if SZC were operating	Estimated daily max temp at SZB if SZC were operating	Maximum daily value SZB		Maximum daily value SZC			
								2030	2055	2030	2055	2085	2110
January	8.3	9.8	1.5	**9.6**	9.3	10.0	9.5	9.9	10.2	10.4	10.7	11.2	11.5
February	6.8	10.1	3.3	**9.2**	8.1	7.6	8.8	9.6	10.4	8.3	9.1	10.1	10.9
March	7.7	10.9	3.2	**15.7**	12.9	11.5	13.5	14.2	15.0	12.3	13.0	13.9	14.7
April	9.7	12.4	2.7	**17.5**	16.4	14.3	17.2	17.8	18.5	14.9	15.5	16.3	17.0
May	12.8	15.9	3.1	**18.9**	18.2	16.3	18.7	19.4	20.2	17.0	17.7	18.6	19.4
June	17.2	19.4	2.2	**19.8**	18.6	16.7	19.2	19.7	20.3	17.2	17.8	18.4	18.9
July	19.2	22.5	3.3	**24.4**	23.4	21.5	24.0	24.7	25.5	22.3	23.1	24.0	24.8
August	20.3	23.2	2.9	**23.2**	22.1	21.1	22.7	23.3	24.0	21.7	22.4	23.2	23.9
September	19.1	22.8	3.7	**23.2**	22.5	22.5	22.8	23.6	24.5	23.4	24.3	25.3	26.2
October	17.2	20.3	3.1	**20.8**	20.1	19.7	20.8	21.6	22.3	20.4	21.2	22.1	22.8
November	13.5	17.2	3.7	**17.2**	16.8	16.5	17.5	18.4	19.3	17.4	18.3	19.4	20.3
December	10.5	13.7	3.2	**11.7**	10.8	10.6	10.8	11.6	12.3	11.4	12.1	13.1	13.8

Entrainment temperatures

Following passage of cooling water through the condensers at the Sizewell B power station thermal inputs result in temperature increases of approximately 11°C above ambient. At the Sizewell C entrainment temperatures are predicted to be approximately 11.6°C above ambient intake temperatures. Mean monthly entrainment temperatures under future climate conditions are provided in Table 50.

Elevated temperatures can cause lethal effects to a range of invertebrates, fish eggs and larvae entrained in the cooling water flow. 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 (see BEEMS Technical Report TR081). The thermal death point or upper incipient lethal temperature (UILT) has not commonly been calculated for invertebrates or primary producers, however, UILT of 30 to 33°C (regardless of latitude) are typical (Bamber 1990). Welch and Lindell (1980) found that the statistical mode for the lethal temperatures for many invertebrate species, lay between 35°C and 40°C (see BEEMS Scientific Advisory Report SAR008 for further information of UILT). The monthly distribution of mean entrainment temperatures are shown for Sizewell B (Figure 24) and Sizewell C (Figure 25).

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 (Table 51). 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. Temperatures above 33 ºC are predicted to occur throughout much of August and into September (41 days) reaching a maximum of 33.6 ºC.

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 (BEEMS Scientific Advisory Report SAR008). Furthermore, the peak in abundance of ichthyoplankton occurs prior to the hottest periods of the year, between May and July, with May being the peak for invertebrate zooplankton (BEEMS Technical Report TR315). The most abundant component of the ichthyoplankton off Sizewell was anchovies, which are becoming increasingly abundant in the southern North Sea. Anchovy eggs and larvae peak in June and July. The timings of the commercially important finfish species with high egg and larvae abundance at Sizewell are as follows:

- Dover sole; eggs and larvae peak in May.
- Seabass; eggs peak in May, larvae peak in June.
- Plaice; eggs peak in May, larvae peak in June.
- Herring; eggs and larvae peak in May

Table 50 Predicted monthly mean entrainment temperatures (°C) for Sizewell B (ambient + 11°C) and Sizewell C (ambient + 11.6°C). Assessments are based on mean daily temperatures from the UKCP09 medium emissions scenario (SRES A1B). Month with mean temperatures above 30°C are shaded pink.

Month	Sizewell B		Sizewell C			
	2030 Entrainment	2055 Entrainment	2030 Entrainment	2055 Entrainment	2085 Entrainment	2110 Entrainment
January	17.7	18.9	18.5	19.1	19.8	20.5
February	17.9	19.2	17.8	18.5	19.0	19.7
March	18.8	20.1	18.1	18.8	19.3	20.0
April	21.4	22.6	20.1	20.7	21.3	21.9
May	24.4	25.6	23.5	24.1	24.7	25.3
June	27.8	29.1	26.5	27.1	27.7	28.3
July	30.3	31.6	29.5	30.2	30.8	31.5
August	31.4	32.9	31.0	31.8	32.5	33.3
September	29.8	31.3	30.2	31.0	31.8	32.6
October	26.9	28.4	27.2	28.0	28.8	29.5
November	22.8	24.3	23.6	24.3	25.2	25.9
December	19.6	20.9	20.7	21.3	22.0	22.7

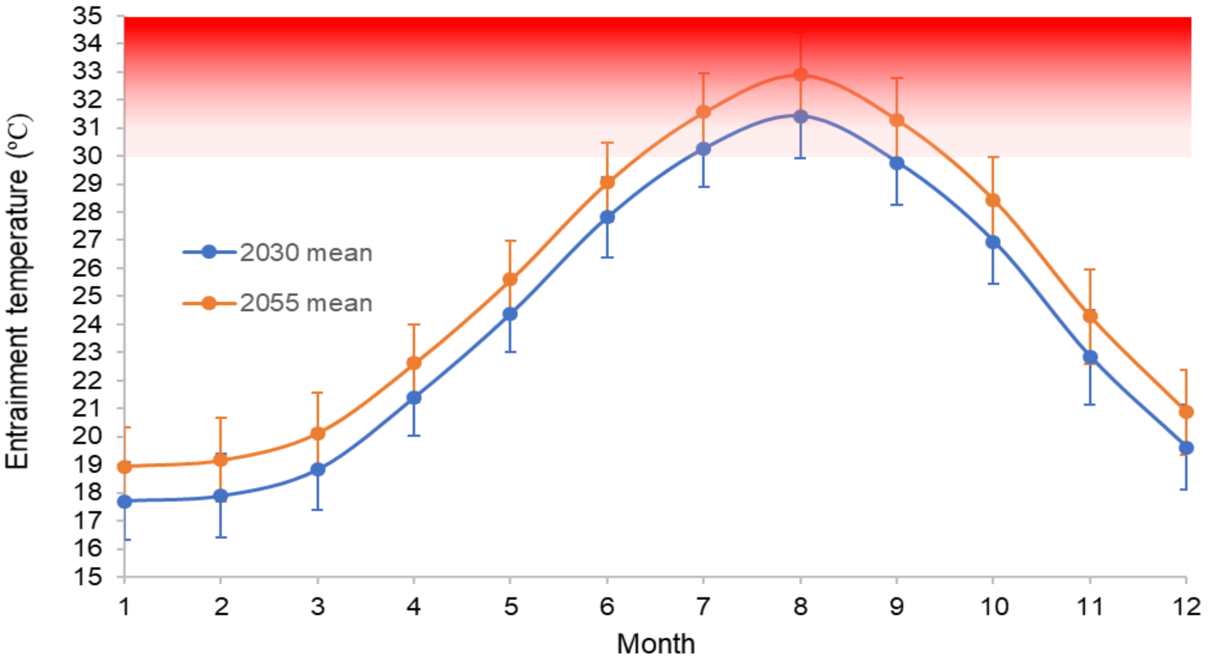

Figure 24. Mean monthly entrainment temperatures (± s.d.) under future climate predictions for Sizewell B. Shaded areas depict periods where typical UILT may be exceeded.

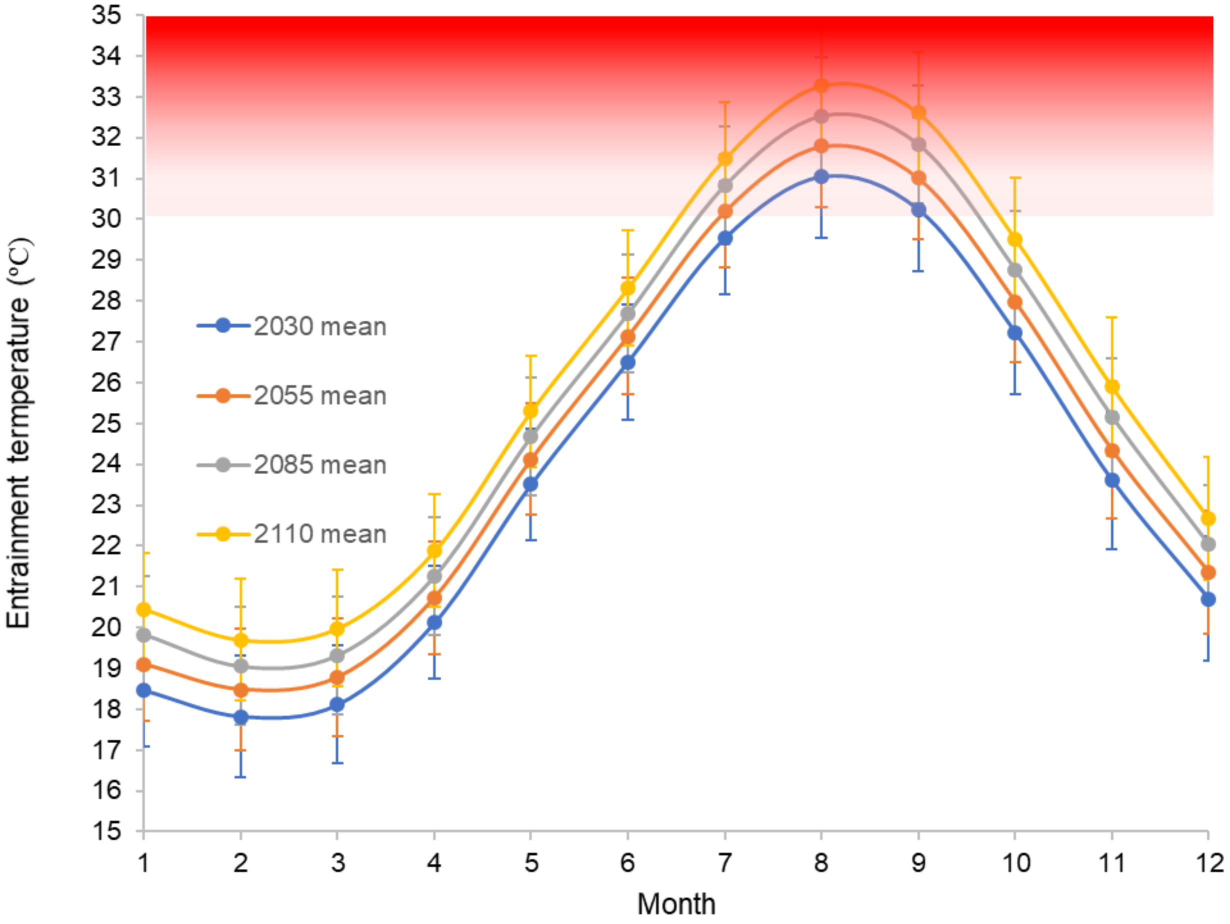

Figure 25 Mean monthly entrainment temperatures (± s.d.) under future climate predictions for Sizewell C. Shaded areas depict periods where typical UILT may be exceeded.

Table 51 Number of days the mean month entrainment temperatures are predicted to exceeds given levels with future climate change at Sizewell C. Predictions account for the recirculation of Sizewell B thermal discharges up until and including 2055 (hence the reduction in 2085).

Month	2030			2055			2085			2110		
	28ºC	**30 ºC**	**33 ºC**	**28 ºC**	**30 ºC**	**33 ºC**	**28 ºC**	**30 ºC**	**33 ºC**	**28 ºC**	**30 ºC**	**33 ºC**
January	0	0	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0
June	0	0	0	17	0	0	12	0	0	17	0	0
July	31	9	0	31	29	0	31	27	0	31	31	0
August	31	31	0	31	31	11	31	31	0	31	31	28
September	30	17	0	30	30	2	30	30	0	30	30	13
October	10	0	0	25	10	0	21	4	0	30	13	0
November	0	0	0	0	0	0	0	0	0	1	0	0
December	0	0	0	0	0	0	0	0	0	0	0	0
Total	**102**	**57**	**0**	**134**	**100**	**13**	**125**	**92**	**0**	**140**	**105**	**41**

Implications of climate on chlorination strategy

Chlorine would be applied seasonally to achieve protection of critical plant (essential cooling water systems for the nuclear island and the turbine hall, and the condensers). However, spot-chlorination may be required to protect critical plant outside these periods. Chlorination would be applied at a dose level to produce a total residual oxidant (TRO) concentration of $0.2 mgl^{-1}$ after the drum screens. The TRO discharge concentration from the CW systems at the outfall would be $0.15 mgl^{-1}$.

The seasonal chlorination strategy for the proposed development involves chlorination during the period of the year when water temperatures exceed 10ºC. At the earliest time of operation of the proposed development (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 (Table 52). 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.

Shifts in plankton phenology have been observed in the North Sea. Since the 1960s, peaks in dinoflagellates have occurred 23 days earlier, diatoms 22 days earlier, copepods 10 days earlier, and other holozooplankton groups 10 days earlier (Richardson 2008). Whilst the duration of the growing season is likely to extend in the future, temperature driven changes in phenology would be moderated by day length and solar elevation thus restricting the total growth period. When photosynthesis is light limited, increases in temperature are not predicted to enhance productivity (Underwood and Kromkamp 1999). 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.

Table 52. Duration of the year intake temperatures at SZC are predicted to exceed 10ºC, accounting for recirculation and future climate change.

Month	**Days per month average daily temperature exceeds 10ºC at SZC intakes**				
	1994-2018 average at SZB	**2030**	**2055**	**2085**	**2110**
January	0	0	0	0	0
February	0	0	0	0	0
March	0	0	0	0	0
April	0	0	6	10	17
May	26	31	31	31	31
June	30	30	30	30	30
July	31	31	31	31	31
August	31	31	31	31	31
September	30	30	30	30	30
October	31	31	31	31	31
November	24	30	30	30	30
December	0	5	13	20	28
Total	203	219	233	244	259

Thermal Standards

Thermal standards for TraC waterbodies are detailed in Section 1.2.2. 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. Therefore, the following sections should be considered as indicative.

Thermal uplifts above ambient

Thermal uplifts above ambient are predicted to be largely independent of the background sea temperature (BEEMS Technical Report TR302). Therefore, thermal uplift areas predicted for in section 7.1 would remain largely unchanged under future climate scenarios. The results for the different model scenarios are summarised in Table 53 below.

Table 53. Absolute areas of thermal uplifts in exceedance of HRA and WFD criteria. The scenario of SZB and SZC operating in-combination (bold) represents the worst-case scenario and is considered as the primary assessment scenario.

Model run	Position	unit	Max Excess temp. >2°C (100%ile) HRA threshold	Excess temp. >2°C (98%ile) WFD assessment (area above 'good' status)	Excess temp. >3°C (98%ile) WFD assessment (area above 'moderate' status)
ReferenceV2 annual SZB	Surface	ha	9,375	2,433	1,263
	Seabed	ha	5,219	2,127	667.7
Conf12 annual **SZB+SZC**	**Surface**	**ha**	**22,464**	**7,899**	**2,200**
	Seabed	**ha**	**16,451**	**6,241**	**1,553**
SZC only	*Surface*	*ha*	*16,777*	*1,550.5*	*305.7*
	Seabed	*ha*	*12,244*	*170.6*	*0.0*

Maximum absolute temperatures

There are currently no uniform regulatory standards in place to control thermal loads in transitional and coastal waters (BEEMS Science Advisory Report SAR008). 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. Recommended absolute thermal standards exist for SACs, SPAs and Water Framework Directive (WFD) waterbodies. The receiving waters adjacent to the proposed development are within the Southern North Sea SAC and the Outer Thames SPA. SAC absolute thermal criteria are more conservative and therefore considered in the first instance.

SACs designated for estuarine or embayment habitat and/or cold-water salmonid species, apply absolute temperature thresholds of 21.5°C as a 98th percentile (Wither et al. 2012). These criteria are not applicable to the Southern North Sea SAC is designated for harbour porpoise. Therefore, absolute temperature assessments consider SPA thresholds (28°C as a 98th percentile).

In addition, to SPA thresholds the EIA will consider WFD standards which have thresholds of <23°C as a 98th percentile for 'good' status and <28°C as a 98th percentile for 'moderate' status.

Absolute exceedances for relevant standards are detailed in Section 7.1. Here the influence of climate change is added to the thermal uplifts to ascertain absolute temperatures in the future. The method considered SZB and SZC operating in 2030 and 2055 as a worst-case. Sizewell C operating alone is also considered in 2055, 2085 and 2110 to represent an extreme hypothetical scenario.

The 98th percentile temperature for the five year period from 2009-2013 is 19.4°C and forms the basis for absolute temperature calculations. Exceedance of the relevant WFD and SPA thresholds is calculated as follows:

a) at or above 28˚C as a 98th percentile is calculated as the area where the mean excess temperature (+ the influence of climatic warming) is >8.6˚C (i.e. 28˚C -19.4˚C).
b) at or above 23˚C as a 98th percentile is calculated as the area where the mean excess temperature (+ the influence of climatic warming) is >3.6˚C (i.e. 23˚C -19.4˚C).

To calculate the uplift due to climate change, the UKCP09 monthly increase in mean temperature, as shown in Table 49, were applied to the daily mean temperatures of SZC intake temperatures. The SZC daily mean intake temperatures over a full year were derived from the observed hourly SZB intake temperatures from 1994 – 2018 and adjusted to the offshore location using the GETM model results, as described in BEEMS Technical Report TR302. The thermal uplift due to the UKCP09 monthly increase in mean temperature, centred on 2006, was applied to this contemporary annual baseline projecting forward to 2030, 2055, 2085 and 2110. The average and 98th percentile uplift over the year, for each projected scenario, was calculated and presented in Table 55.

Table 54. Annual thermal uplift due to climate change

	Annual thermal uplift due to climate change (°C)			
	2030	**2055**	**2085**	**2110**
Annual average	+0.660	+1.347	+2.014	+2.701
Annual 98th percentile	+0.737	+1.508	+2.263	+3.045

The annual 98th percentile thermal uplift for climate change was applied in calculation of future absolute temperature scenarios as the largest annual uplifts coincided with the same month of the year (August) as the observed 98th percentile background temperatures.

This climate uplift (98th percentile) and the 98th percentile ambient temperature was then applied to the mean excess temperature rise due to the power stations. This is considered precautionary as the mean uplifts due to thermal discharges tend to be lower in the summer months (BEEMS Technical Report TR302). Whilst the thermal uplift was calculated using the SZC intake temperatures, the thermal uplift due to climate change is independent of the location and is applied uniformly to the GETM model results to calculate areas of exceedance above the thresholds.

The results in Table 55 indicate:

i. 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.

ii. Following the decommissioning of SZB, 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.

iii. During the operation of both stations, absolute temperatures of 23˚C increase from 198.2 ha at the surface in 2030 to 506.2 ha at the surface in 2055. At the seabed absolute temperatures of 23˚C are 92.3 ha and 264.4 ha in 2030 and 2055, respectively.

In the event SZB is decommissioned prior to 2055, leaving SZC operating alone, the exceedance of the absolute 23˚C threshold is predicted to be just 5.38 ha at the surface and 0 ha at the seabed (Figure 28). Warming effects result in larger areas exceeding 23°C as a 98th percentile (7,080 ha at the surface, and 6,540 ha at the seabed) in the extreme operational scenario of 2110 (Figure 29).

However, the influence by 2110 the 98th percentile uplift due to climate change is estimated to be +3.045 across the model domain, hence a station uplift of just 0.56°C is sufficient to exceed contemporary thermal standards.

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 (Figure 28 and Figure 29).

Table 55. Total areas where absolute temperatures are exceeded accounting for climate change. Contemporary results are provided for comparison. It should be noted that applying contemporary standards to future climate scenarios ignores responses to climate change in regulations and should be considered as comparative only.

Model run	**Year**	**Position**	**Units**	**>23°C (98th %ile)** **Calculated from mean excess temperature (+climatic warming) >3.6°C** **(WFD 'good' status)**	**>28°C 98th %ile)** **Calculated from mean excess temperature (+climatic warming) >8.6°C** **(WFD 'moderate' status and SPA threshold)**
ReferenceV2 annual **SZB**	**Contem-porary**	**Surface**	**ha**	**44.9**	**0**
		Seabed	**ha**	**8.75**	**0**
Conf12 annual **SZB+SZC**	**Contem-porary**	**Surface**	**ha**	**89.60**	**0.11**
		Seabed	**ha**	**25.6**	**0**
SZC only	**Contem-porary**	**Surface**	**ha**	**0***	**0**
		Seabed	**ha**	**0**	**0**
Conf12 annual *SZB+SZC*	*2030*	*Surface*	*ha*	*198.2*	*0.11*
		Seabed	*ha*	*92.3*	*0*
Conf12 annual *SZB+SZC*	*2055*	*Surface*	*ha*	*506.2*	*0.90*
		Seabed	*ha*	*264.4*	*0*
SZC only	*2055*	*Surface*	*ha*	*5.38*	*0*
		Seabed	*ha*	*0*	*0*
SZC only	*2085*	*Surface*	*ha*	*69.1*	*0*
		Seabed	*ha*	*0.22*	*0*
SZC only	*2110*	*Surface*	*ha*	*7,080*	*0*
		Seabed	*ha*	*6,540*	*0*

* Mean exceedance temperatures were 3.52°C marginally below the 3.6°C threshold

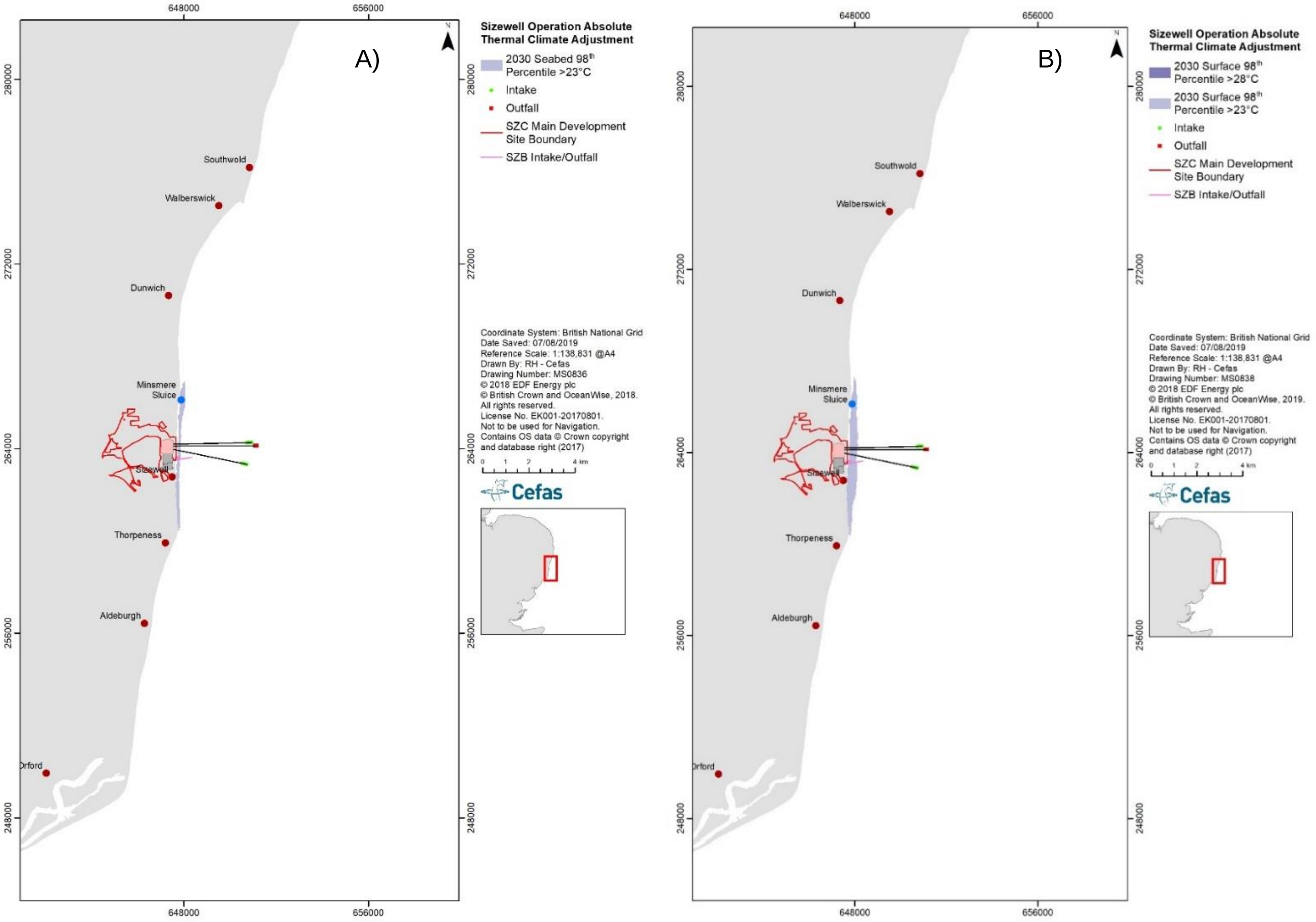

Figure 26. Predicted areas where absolute temperature thresholds are exceeded at A) the seabed, and B) the surface as a 98th percentile due to the combined Sizewell B and Sizewell C thermal plumes and accounting for climate change in the year 2030.

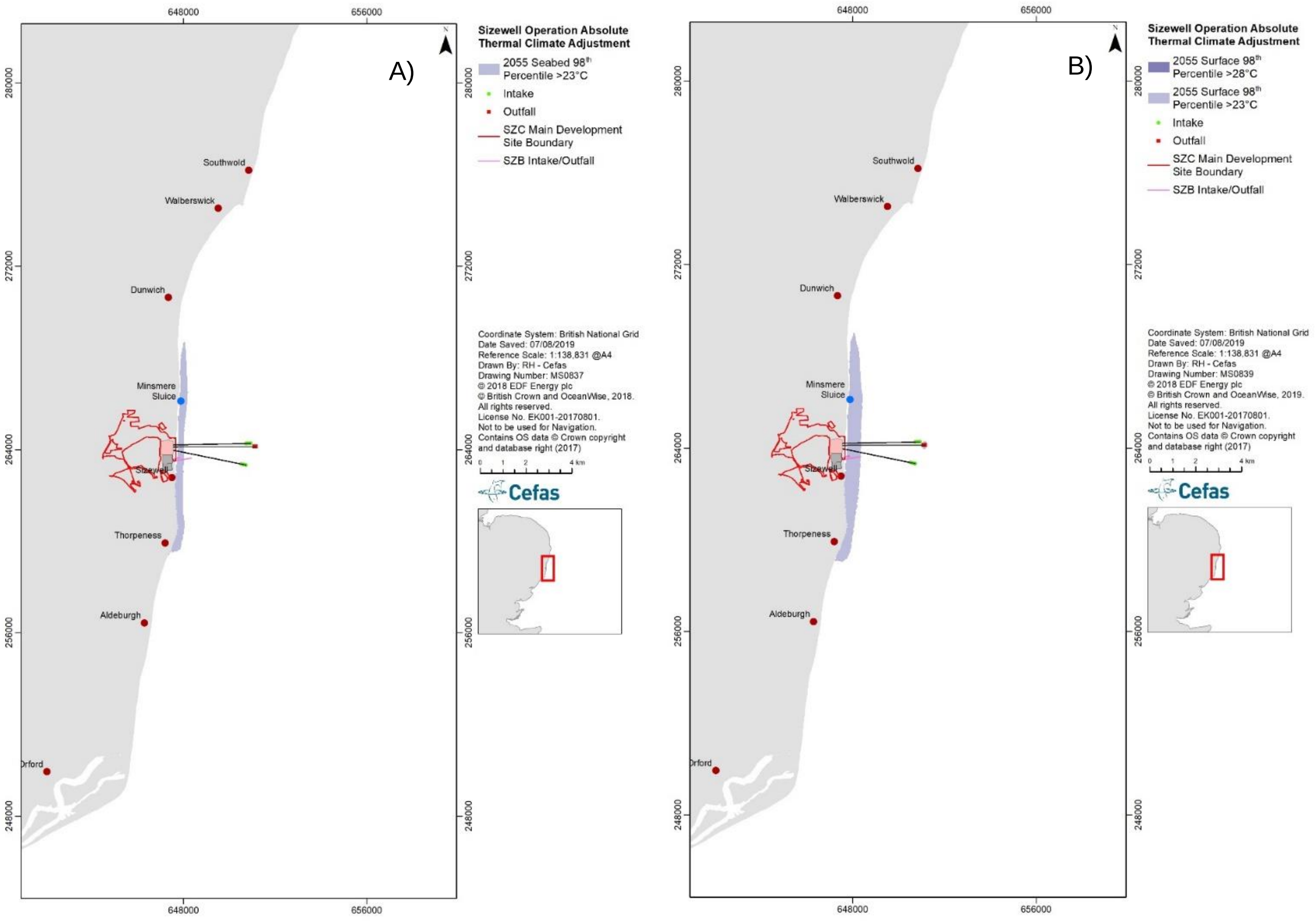

Figure 27. Predicted areas where absolute temperature thresholds are exceeded at A) the seabed, and B) the surface as a 98th percentile due to the combined Sizewell B and Sizewell C thermal plumes and accounting for climate change in the year 2055.

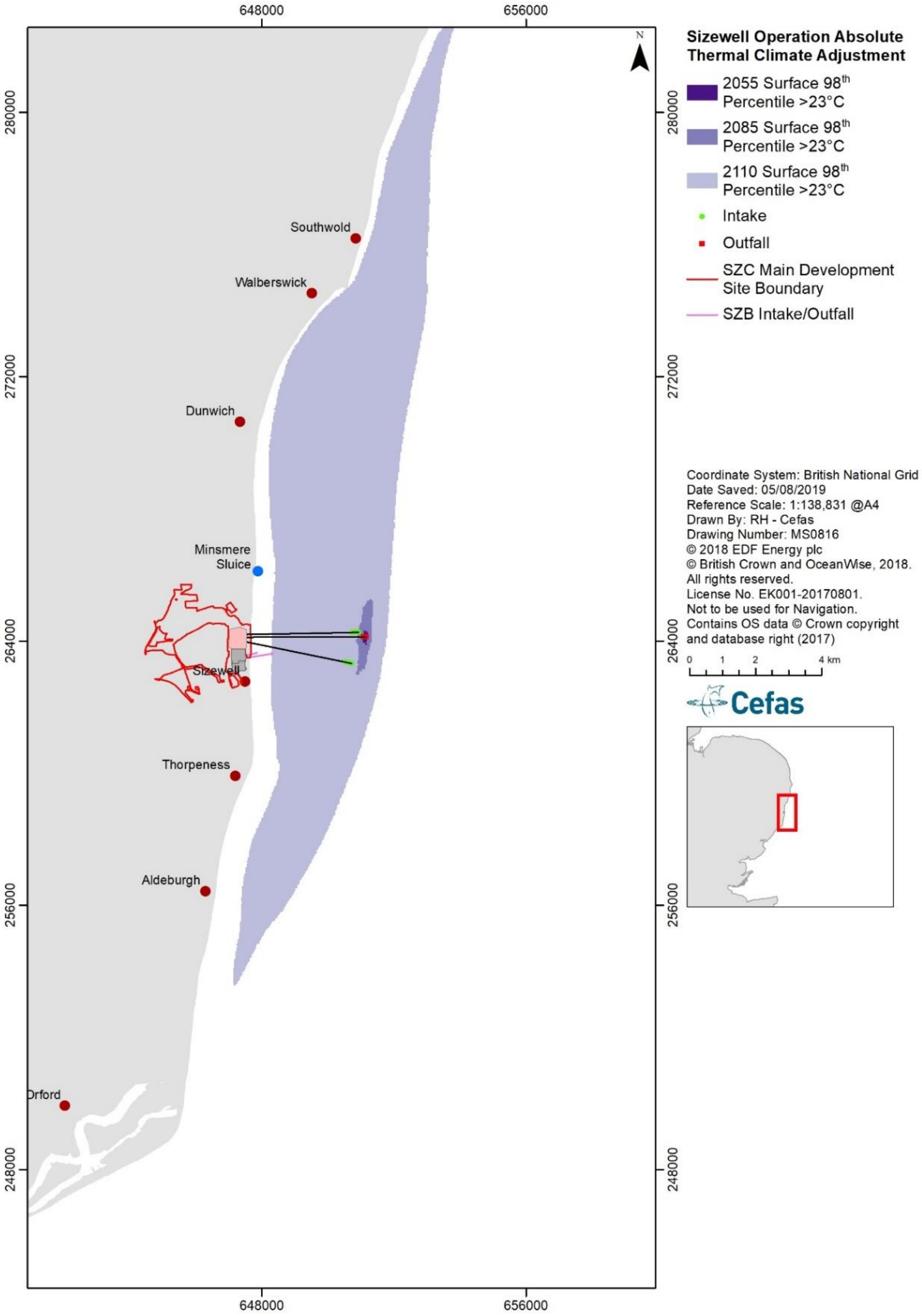

Figure 28. Predicted areas where the absolute temperature of 23°C is exceeded at the surface as a 98th percentile due to the Sizewell C thermal plume and accounting for climate change in 2055, 2085 and 2110.

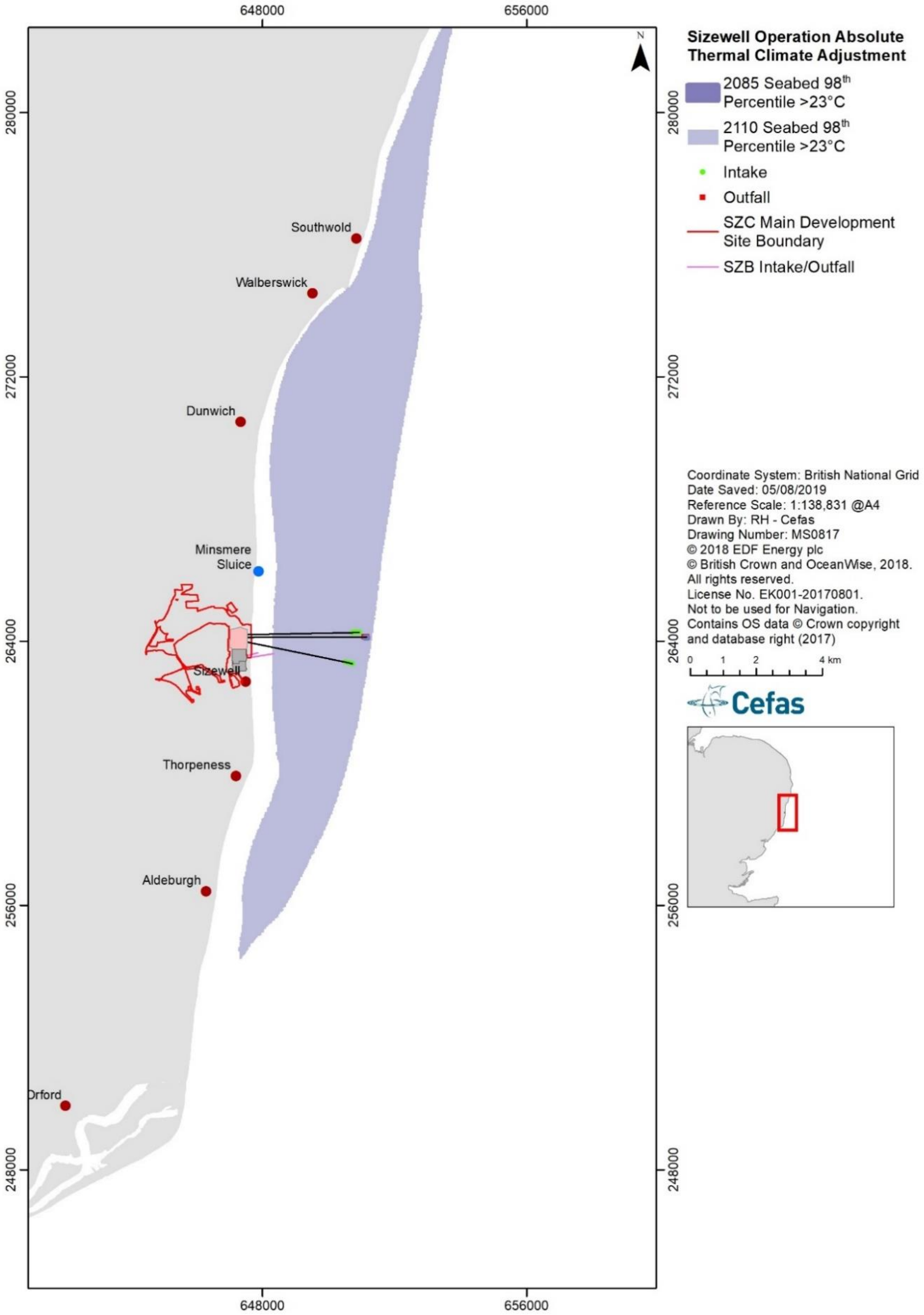

Figure 29. Predicted areas where the absolute temperature of 23ºC is exceeded at the seabed as a 98th percentile due to the Sizewell C thermal plume and accounting for climate change in 2055 (no exceedance), 2085 and 2110.

VOLUME 2 APPENDIX 21F

SIZEWELL C H1 ASSESSMENT EDITION 5 – SUPPORTING DATA REPORT.

2020. BEEMS TECHNICAL REPORT TR193 EDITION 5

Sizewell C Discharges H1 type assessment – supporting data report Edition 5

BEEMS Technical Report TR193 Edition 5

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List of Tables and Figures

Please note that the red line boundary used in the figures within this document was amended after this document was finalised, and therefore does not reflect the boundaries in respect of which development consent has been sought in this application. However, the amendment to the red line boundary does not have any impact on the findings set out in this document and all other information remains correct.

Tables

Figures

Executive summary

This report aims to assess the potential impacts of the Sizewell C (SZC) planned New Nuclear Build on the water quality within the local marine environment and to provide information that will support the assessment and setting of a discharge consent by the statutory regulator (Environment Agency) under the Environmental Permitting Regulations.

For marine discharges, the standard approach for determining the potential impacts to water quality from industrial aqueous discharges is to apply the Environment Agency/Defra screening of contaminant contributions from surface drainage sources (Defra and Environment Agency Guidance, 2016) Environment Agency’s H1 Environmental Risk Assessment.

The H1 screening methodology is applied here to identify any proposed chemical discharges that represent a potential risk to the marine environment including those which are then subject to detailed modelling to fully evaluate the acceptability of the discharge.

To assess the significance of specific chemical discharges the H1 methodology uses as its reference existing Environmental Quality Standards (EQSs). Where no EQS is available for a given substance then available toxicity test data are used to generate a Predicted No Effect Concentration (PNEC) as a reference for short term acute exposure and longer-term chronic exposure. Where insufficient or no toxicity data can be sourced then the marine background concentration for a substance from monitoring conducted adjacent to the Sizewell site is used as a point of reference.

The Greater Sizewell Bay (GSB) is considered as the initial reference area for the study site extending to Walberswick in the north with the southerly extent 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 on the bank. Sizewell C site discharges from the combined drainage outfall (CDO) which would include those from the construction site and potentially those during commissioning and from the Fish Recovery and Returns (FRRs) would also occur within the GSB. Sizewell B intakes and outfalls are also located within the Sizewell-Dunwich Bank and discharge into the receiving waters of the GSB.

Construction discharges prior to the availability of the combined drainage outfall

Prior to establishment of the CDO and sewage treatment plant, wastewater would be tankered off site for appropriate disposal. Groundwater discharge volumes during tunnelling have been incorporated into the assessment based on those identified for Hinkley Point C.

Construction discharge assessment

Temporary and variable discharges to marine water will form part of the surface drainage strategy during the construction phase. The main expected contaminants in these discharges are suspended solids, hydrocarbons, Biochemical Oxygen Demand (BOD), some metals from groundwater sources and ammonia. Sediment and hydrocarbons in site drainage water will be managed with appropriate technology and good site management so that these discharges from the construction site are unlikely to affect the water quality status.

The groundwater metals contamination across the construction site varies so monitoring data are used to derive the 95th percentile concentration and these values are used in the initial screening assessment. Groundwater discharge volumes vary and are highest in the first 28 days so screening is conducted for this period. After the first 28 days of the construction schedule various overlapping processes lead to a combination of wastewater sources and different substance concentrations and therefore several time points (Cases) during the schedule that are deemed worst case for different substance inputs are screened using H1 methodology.

For first 28 days of the construction period - groundwater dewatering

Chromium, copper, zinc and iron in the groundwater exceed EQS or equivalent values and fail the initial Test 1 of screening. Taking account of subsequent dilution upon discharge (Test 5) chromium fails and zinc is present at high background concentrations and so, as a precaution, was also considered in more detailed assessment.

Both chromium and zinc were modelled using the CORMIX US EPA supported mixing zone model and the validated Sizewell GETM model. CORMIX is used to predict the rate of chemical plume dilution and plume geometry from the Combined Discharge Outfall (CDO). The GETM model is a 3D hydrodynamic model with an inbuilt passive tracer to represent zinc and chromium. As a worst case, it was assumed that there was no loss of dissolved metals due to sediment absorption or biological uptake. Using these assumptions, concentrations were scaled, as the modelled concentration was simply a function of dilution.
Both zinc and chromium were modelled for the first 28 days of maximum groundwater discharge.

CORMIX shows that for zinc the outfall plume would no longer be detectable above background concentrations within 3m. For chromium the outfall plume would fall below the EQS within 25m. GETM was also used in support of modelling this discharge and slightly under-predicts the initial dilution and shows a 40-fold dilution in the first 25m, meaning the plume extends slightly further. The mean surface area in exceedance of the EQS for Chromium, predicted by GETM, is 5.49ha and for zinc, the total surface area for which the influence of the discharge plume would be detectable above background is 0.11ha

For both chromium and zinc the discharge concentrations predicted above EQS are localised and represent a negligible influence on water quality.

From 28 days onwards in the construction period

Once sewage treatment is available on site to treat sanitary waste from the workforce the treated effluent will contribute to a discharge via the CDO of ammoniacal nitrogen and nutrients as well as Biochemical Oxygen Demand (BOD), faecal indicator organisms Escherichia coli and Intestinal Enterococci and suspended solids.

Ammoniacal nitrogen inputs to the construction discharge are from groundwater and treated sewage effluent. The percentage of un-ionised form of ammonia is important to assess as this has a relatively high toxicity and as such has a derived annual average EQS of 21µgl^{-1} NH_3-N. Various water quality parameters influence the proportion of ammonia that is un-ionised in seawater and so must be considered in any assessment i.e. higher pH, temperature elevation and reduced salinity all increase the relative proportion of un-ionised ammonia. The percentage of ammonia in the un-ionised form in the construction discharge was calculated for worst case discharge scenarios during the construction period and under mean and most extreme site values. The CORMIX model was used to determine the maximum distance required to achieve un-ionised ammonia concentrations below the EQS which was 6.3m.

Nitrogen in site discharges can contribute to nutrient enrichment in the marine environment therefore the input loadings during construction were assessed together with phosphorus loadings using a phytoplankton box model. The effect of chlorination at Sizewell B (SZB) and the proposed Sizewell C (SZC) on phytoplankton that pass through the power station was simulated with an emphasis on the spring bloom and summertime production using the phytoplankton box model. The combined loadings of nitrogen and phosphorus as described (section 5.4 and 5.5) from the construction and cold commissioning inputs together with relevant inputs from SZB resulting from the use of conditioning chemicals and the discharge of treated sewage were assessed. 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 construction and commissioning combined, so that no change in phytoplankton growth beyond natural variability would be observed. A model run over an annual cycle predicts a less than 0.13% difference in annual gross production of carbon and this level of change could not be discriminated above natural background variation and overall the effect observed would be a modest reduction in phytoplankton growth due to entrainment effects.

The background Biochemical Oxygen Demand (BOD) near to the Sizewell B cooling water discharge based on monitoring has a mean value of 2mg l^{-1}. Dissolved oxygen levels at the site are 'high' with a mean DO concentration of 6.27mgl^{-1} when adjusted to an equivalent salinity of 35. 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 that which is exchanged across GSB together with the oxygen transfer across the water surface. Indicative values of maximum oxygen demand of 40.6kg were calculated and this amount of oxygen would be transferred across 1.2ha in a day. Therefore, DO is likely to remain at high status. The discharges of BOD during construction are therefore considered to be of negligible significance for dissolved oxygen modification.

Under bathing water regulations discharges containing faecal bacteria must be treated to ensure that the concentration of key indicator organisms will meet a designated standard for coastal and transitional waters for which Good status for Transitional and Coastal waters requires that the colony forming unit (cfu) counts for intestinal enterococci are ≤200 cfu/100ml and for *Escherichia coli* are ≤500 cfu/100ml. The predicted numbers of *Escherichia coli* and intestinal enterococci in sewage effluent was calculated following different stages of sewage treatment and used in a modelling assessment taking account of dilution. CORMIX estimates show that the concentration of Intestinal Enterococci is likely to exceed the bathing water standard (200 cfu/100ml) only within 66m of the discharge for the maximum 30ls^{-1} case for secondary treatment. With UV treatment, even at the higher discharge volume, exceedance would be limited to within less than 1 metre of the discharge.

As the microbiological modelling assessment indicates a relatively small distance over which indicator organism numbers would exceed the good bathing water standard and the nearest designated bathing waters are approximately 10km distant, there is a negligible risk to bathing water quality

Tunnelling Discharge Assessment

The offshore cooling water infrastructure consists of two subterranean intake tunnels and one outfall tunnel. Tunnels would be excavated by tunnel boring machines (TBMs) from land. In some TBM soil conditioning applications several different surfactant chemicals may be required. The use and discharge of two surfactant chemicals that are planned for use with the HPC tunnelling operation and that present higher risk quotients in terms of chemical properties are modelled for Sizewell (anti- clogging agent BASF Rheosoil 143 and the soil conditioning additive CLB F5 M). Both chemicals exceed their respective EQS and preliminary dilution assessment so were modelled using GETM. A third chemical bentonite a clay mineral may be employed in a slurry tunnelling method. Available data indicate that bentonite has very low toxicity and in its widespread use offshore in drilling processes it is classed as posing little or no effect. However, a modelling assessment was conducted to determine the 95th percentile and mean plume area to determine extent of any potential influence on water quality based on the limited effects dataset. For the soil conditioning chemical Rheosoil 143 there is no exceedance at the seabed and only very limited areas of exceedance at the surface of mean 1.01ha (5.83 as a 95th percentile). For CLB F5 M there was no exceedance at the seabed and the area at the surface exceeding the EQS was relatively small at 3.14ha for a mean assessment (25ha as a 95th percentile). A tunnelling discharge of bentonite at a concentration of 8.8mgl^{-1} was modelled using GETM and the 95th percentile concentration of 10μgl^{-1} was restricted to sea surface areas of <11ha (mean 1.35ha) with no influence on the bed. Limited data on survival of organisms exposed to bentonite suspensions indicate that the small areas affected, and the low discharge concentrations are likely to have negligible effects on water quality.

Commissioning Discharge Assessment

When the cooling water system is commissioned a range of tests will be conducted and conditioning of the entire plant will be undertaken with demineralised water and various chemical additives.

No operational cooling system will be available for the disposal and dilution of commissioning phase effluents during the cold flush testing stage during the phased development of the SZC site. Therefore, the only available discharge route for this wastewater stream will be through the CDO. During commissioning the input loading of phosphorus and nitrogen was assessed in combination with the construction discharge. In addition, the potential toxicity of three chemicals was also assessed during commissioning: hydrazine, ethanolamine (a water treatment chemical) and un-ionised ammonia. All three chemicals exceed their respective EQS in predicted commissioning discharges, but ethanolamine passed the initial dilution assessment (Test 5) and so hydrazine and un-ionised ammonia discharges were modelled using CORMIX and GETM. Using CORMIX the un-ionised ammonia discharge did not exceed its EQS after 25 metres and it was not possible to discriminate any areas of exceedance using GETM.

To assess the spatial extent of the hydrazine plume from a cold commissioning a upper bounding discharge concentration of 15 μgl^{-1} was modelled (discharge volume maximum 1500m^3 over a 5 hour period). The results were compared with relevant PNEC values (chronic and acute), the mean and 95th percentile of the hydrazine concentration was extracted from a 31-day model run. For hydrazine the chronic PNEC value is 0.4 ngl^{-1} for long term discharges (mean of the concentration values) and the acute PNEC value is 4ngl^{-1} for shorter term discharges (represented by the 95th percentile). In addition to these two precautionary PNEC values considered in this report, the area exceeding 200ngl^{-1} as a 95th percentile, as set by the Canadian Federal Water Quality Guidelines for hydrazine was evaluated.

The 95th percentile results show that the plume at the surface is shorter and thinner than the mean plume. The plume at the seabed shows a similar elongated narrow plume. The area exceeding the derived acute and chronic PNECs is less at the bed than the surface. The exceedance at the surface 12.9 and 30.5ha exceed the acute and chronic PNEC respectively. At the bed the exceedance is 2.92ha for both PNECs.

At the surface the exceedance for the 200ngl^{-1} Canadian standard is 0.34ha, which represents three model grid cells (25 x 25 m) around and including the hydrazine discharge from the CDO.

As the hydrazine chemical plume lies completely inside the Outer Thames Estuary SPA and inside the Suffolk Coastal Waters, the areas of exceedance for the chronic and acute PNECs are the same as for the whole plume and area of intersection with specific sensitivities are further considered. To investigate the potential interaction of the hydrazine discharge concentration with relevant environmental sensitivities the results of both simulations are compared against three criteria: The likelihood that hydrazine could enter the Minsmere Sluice; levels of hydrazine at the seabed over the Coralline Crag and the area of intersection of the acute hydrazine plume with Little Tern foraging areas.

The hydrazine plume is transported northward towards Minsmere during the falling tide, meaning that the sluice water supply that is periodically used to add additional saltwater to the Minsmere salt marshes is unlikely to be exposed to hydrazine. The likelihood of any hydrazine exposure in the sluice water would also be made considerably less likely due to rapid degradation of hydrazine with a half-life of ca.,30 minutes. Eels at different life stages may move into or out of the Minsmere salt marshes via the sluice. The peak hydrazine concentrations predicted at the sluice are around 800,000 times below chronic toxicity data available for fish. Also, the concentration peaks occur just before the sluice opens and are therefore diminishing when any Eels could move via the sluice. The wider area concentration plume of hydrazine and concentration peaks in proximity to the sluice are therefore considered of sufficiently low concentration (and in the latter case duration), to not represent a significant barrier to Eel movement.

In terms of the coralline crag, the peak hydrazine concentration at the seabed over the crag does not exceed the acute PNEC and only exceeds the chronic PNEC for 15 minutes a day. In the Greater Sizewell Bay, the hydrazine plume never intersects foraging areas for two of the three SPA breeding colonies of birds. Whilst the plume intersection with 15μgl^{-1} release concentration regularly exceeds 1% of the foraging range for the little Tern colony, the duration of the plume is short, with concentrations exceeding the acute PNEC for no longer than 4 hours.

During the latter stages of commissioning that is hot functional testing (HFT) the objective is to test the reactor and associated systems under realistic operating conditions therefore it would be expected that the assessment for operational discharges via the cooling water system would also apply to that during HFT.

Coastal power stations normally require a means of chlorine dosing for biofouling control in the cooling water (CW) systems. Based upon the known risk of biofouling at Sizewell, EDF Energy would need to chlorinate the SZC CW system to maintain control over biofouling of critical plant. Testing of this system will be undertaken during the commissioning phase, but it is assumed that this would only occur once the full cooling water system was in place and operational. This assessment is, therefore, covered under operation.

Operational Discharge Assessment

Potential discharges to the marine environment have been assessed for the operational phase of the planned SZC. For large cooling water discharges that are discharged to estuaries or coastal waters a specific screening assessment recommended by Defra and Environment Agency, (Clearing the Waters for All, 2016) is applied.

The annual and daily load of each of the chemicals used during operation is used to derive a predicted concentration in the cooling water discharge and this is compared to the relevant quality standard or other acceptable alternative reference for the substance. In the first phase of screening for operational chemicals chlorine and hydrazine fail screening and are assessed using more detailed modelling. As chlorination of seawater produces chlorination byproducts and bromoform was found to be the most dominant of those detected in laboratory simulations using Sizewell seawater it was also modelled in the cooling water discharge.

For the daily and annual discharge assessments of the cooling water inputs during operation several other substances including metals exceed the EQS screening criteria. However, in many cases these are screened out of further assessment as they are considered to have negligible likely effects as the actual discharge concentrations are below method detection limits, the concentrations are several orders of magnitude below their EQS (or PNEC or site background values) and/or the substances have low bioconcentration potential and are readily degradable. For phosphate and dissolved inorganic nitrogen further assessment of the contribution to nutrient status was made. Un-ionised ammonia passed initial screening for 24 hour and annual assessments but as temperature may influence the relative amount of un-ionised ammonia in the operational discharge a modelling assessment considering the influence of temperature elevation was also conducted.

As sewage effluent also contributes to the cooling water discharge during operation the influence of the biochemical oxygen demand and the numbers of intestinal enterococci and *Escherichia coli* likely to be present after treatment relative to the bathing water standard were also assessed.

During the operational phase biofouling of essential parts of the cooling water system results in the discharge of chlorine produced oxidants (or Total Residual Oxidants, TRO) at a predicted concentration of 150µgl^{-1} at the outfall heads. To provide protection to the marine environment chlorine has an EQS of 10µgl^{-1} TRO set as a maximum allowable concentration and expressed as a 95th percentile. The predicted TRO concentration in the cooling water discharge, based on an empirical demand/decay formulation derived from experiments with Sizewell seawater was modelled using the GETM Sizewell model. Two scenarios were considered: chlorination of SZB plus SZC operating in combination, and chlorination of SZB only. For each model run a month-long simulation was analysed and the mean and 95th percentile of the TRO concentrations were extracted. The total area of the plume that exceeds a concentration threshold of 10µgl^{-1} was at a maximum for SZB and SZC operating in combination covering an area of 726ha at the surface and 167ha at the bed. For SZC alone 338ha of the surface and only ca., 2ha at the seabed are affected at a 95th percentile TRO of 10µgl^{-1}.

A Fish Recovery and Return system (FRR) is planned to provide a safe return of the more robust organisms directly into the marine environment. The possibility of residual chlorination of this system was initially evaluated but chlorination will be avoided by engineering design and so no further assessment of residual oxidants or chlorination by-products (CBP's) via this discharge route are relevant.

Chlorination of seawater may result in the formation of chlorination by-products. Laboratory studies of chlorinated Sizewell seawater showed that the major CBP that was detected was bromoform, so this was modelled for the cooling water discharge plume. Since bromoform is a product of chlorination, the same scenarios as for TRO were considered: chlorination of SZB plus SZC operating in combination and chlorination of SZB 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 5µgl^{-1} as a 95th percentile was used.

A maximum of 358ha at the surface and 130ha at the seabed is affected by a bromoform concentration in the discharge plume from SZB and SZC in combination that exceeds the 5µgl^{-1} PNEC. For SZC alone a total area of 52ha at the surface and <1ha at the seabed exceeds the PNEC.

Hydrazine is an oxygen scavenger that is used in power plants to inhibit corrosion in steam generation circuits. Cooling water discharges exceed the acute and chronic quality standard (PNEC) values for both 24 hour and annual loadings. The worst-case daily discharges have been assessed in relation to an annual hydrazine discharge of 24kg per annum into the cooling water flow. Two discharge scenarios were studied for SZC: the first one considering a hydrazine discharge of 69ngl^{-1} in daily pulses of 2.32h, and the second one of 34.5ngl^{-1} of hydrazine discharged in daily pulses of 4.63h. The amount of mass that is released in each of these scenarios is the same. For each model run 28 days were analysed (two tidal cycles) and the mean and 95th percentile concentration for hydrazine were extracted. For hydrazine there is a chronic PNEC value of 0.4 ng l^{-1} for long term discharges (mean of the concentration values) and an acute PNEC value of 4ng l^{-1} for shorter term discharges (represented by the 95th percentile).

The total area exceeding the chronic PNEC at the seabed (0.4ng l^{-1} as an average) is less than 1ha if hydrazine is released in the short or longer pulse scenarios. At the surface the area of exceedance of the chronic PNEC is very similar for short or longer pulses (ca., 157 and 158ha, respectively).

The acute PNEC (4ngl^{-1} as the 95th percentile) is only exceeded at the seabed if hydrazine is released in short pulses and then for only for 0.22ha. At the surface, the area of exceedance for both scenarios is ca.,14ha if hydrazine is released in 2.3h pulses and ca.,17ha if hydrazine is released in 4.6h pulses.

Modelling that takes account of the site background un-ionised ammonia and the calculated additional input of un-ionised ammonia in the discharge was conducted. Average and worst-case combinations with respect to the percentage of un-ionised ammonia were simulated and show that no areas exceed the EQS of 21µg l^{-1} NH_3-N as an annual mean. The 24-hour discharge figure for un-ionised ammonia is just over a third of the EQS at 7.92µg l^{-1} but the site background concentration is low (maximum 5.2µgl^{-1}).

For annual discharges the screening assessment passed initial assessments but to provide more detailed assessment of the thermal influence on proportion of un-ionised ammonia the mean ammonia discharge at the outfall was added to regional background mean and 95th percentile values to predict the un-ionised ammonia level. All cases (including worst cases) for un-ionised ammonia show that all modelled areas are considerably below the EQS of 21µgl^{-1} as an annual mean.

Assessment of un-ionised ammonia during operation indicates that daily and annual discharges would have negligible effect on water quality.

During the operational phase, maximum daily loading for nitrogen reaches approximately 2% of the daily exchange for Sizewell Bay, but the average daily value is low at 0.2% of the daily exchange (again indistinguishable from background level).

For operational loadings phosphorus also passed the screening assessment but had one of the higher values in the screening test based on 24-hour loadings and would represent ca., 5% of the load present in the daily water exchange for the Greater Sizewell Bay. A more representative average daily value is very low at 0.03%. 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.

The effect of SZB and the proposed SZC during operation on phytoplankton that pass through the power station has been simulated using a phytoplankton box model. 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.

Based on the DIN and phosphorus loading during operation the phytoplankton growth box model run over an annual cycle showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.11%.

BOD loadings assessed during operation take account of maximum staff numbers on site during an outage and based upon Hinkley Point C this is estimated as 1900 staff. The waters off Sizewell are well mixed vertically and reduction of oxygen concentration will only occur if the rate of consumption due to BOD is greater than the oxygen transfer across the water surface. The maximum BOD loading is 3.8kg which is equivalent to an oxygen requirement of 1.26kg which would be present in a volume of 183m^3 which is very small relative to the daily exchange for GSB. An equivalent supply of oxygen to offset this demand would also be transferred across just over 1000m^2 in a day. 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.

Assessment of the sewage treatment level provided by secondary treatment and assuming dilution in the flow from a single operational EPR the estimated numbers of E.coli and intestinal enterococci in the discharge will meet the bathing water standard for Good status at the point of discharge.

The total biomass of moribund biota that potentially may be discharged from the FRR has been estimated. The additional loading of nutrients phosphorus and nitrogen added to the waters off Sizewell by the decaying biomass are considered low enough so as not to change an assessment of negligible influence on phytoplankton growth when considered in addition to the operational input of these nutrients.

Consideration is also made of the un-ionised ammonia contribution from decaying biomass. Calculated loadings for biomass produced from the FRR during April to September estimate that NH_3-N concentration could be at or above the EQS (NH_3-N, 21 μgl^{-1}) when accounting for natural background (and inputs from SZC operation) over an area of 1.2ha around the FRR. At maximum summer temperatures the area affected would increase to 3.8ha and for maximum loadings during March an area of 6.7ha would exceed the EQS.

The influence of biomass decay on the BOD was also assessed and daily re aeration over an area of ca., 14ha would be enough to meet this additional demand when considered with that of the operational discharge and this takes no account of water exchange for the Greater Sizewell Bay. For March when the highest discharge of moribund fish from the FRR is predicted the oxygen demand would increase to 0.6% of that available from daily exchange and would be equivalent to reaeration over 45.2 ha. Therefore, as waters off Sizewell are well mixed vertically facilitating reaeration at the surface, background dissolved oxygen levels are high 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 FRR is predicted to have a negligible effect on dissolved oxygen concentration which is not significant.

Conclusions

This report assesses the construction, commissioning and operation of two UKEPR units for the proposed SZC development.

A H1 type screening assessment together with more detailed modelling as required of the discharges during the construction, commissioning and operation periods has been completed. The assessment shows that resultant environmental concentrations of discharge chemicals during the construction period are likely to have a relatively localised and negligible influence on marine water quality. The influence of nitrogen and phosphorus inputs during construction combined with those during commissioning is considered to be insignificant for nutrient status of the Greater Sizewell Bay

Modelling of representative maximum scenarios for chemical release during tunnelling operations at Sizewell (based on information derived from Hinkley Point C) show small areas in which conditioning chemicals may exceed the respective EQS but the impact on water quality is considered negligible.

During the commissioning phase the cold flush discharges from EPR unit 1 and 2 would be made in a low volume flow via the construction drainage system to the marine environment. Inputs of nitrogen and phosphorus have been combined with construction inputs and used as source terms for a phytoplankton box model. Combined nutrient inputs were shown to have negligible effects on phytoplankton growth. A hydrazine discharge during commissioning results in relatively small areas in exceedance of the derived PNEC values and for relevant ecological receptors the potential for effects appears negligible but these are further discussed in the Marine Ecology Chapter 21 of the Environmental Statement. Only a very small area at the surface of 0.34ha exceeded the more recently derived Canadian marine standard for hydrazine.

During operation the larger volume discharges for example of chlorinated cooling water have more potential for larger scale influences on the water quality of the Greater Sizewell Bay. The areas of exceedance of relevant quality standards or equivalents for chlorination TROs, bromoform and hydrazine although unlikely to affect long term water quality objectives for marine waters will need to be considered for individual receptors where areas of exceedance intersect.

Assessment of un-ionised ammonia during operation indicates that daily and annual discharges would have negligible effect on water quality.

Nutrient inputs during operation were assessed using a phytoplankton box model and were shown to have negligible influence on water quality and this included an in-combination assessment with the potential loading from dead biomass discharged from the FRR. Biochemical oxygen demand of the operational discharge was also shown to be negligible again in combination with BOD arising from dead biomass from the FRR.

Microbiological input from sewage discharge during operation is indicated to be compliant with bathing water standards at the point of discharge based on secondary treatment and within system dilution.

Changes to this report

Edition 2. 3/5/2019

Included more detailed assessment and modelling of construction discharges based on the Hinkley Point C schedule but referencing expected groundwater contributions for the Sizewell C development. The screening assessment for the construction discharges was the same as for Edition 1 but Defra and Environment Agency, (Clearing the Waters for All, 2016) for large cooling water discharges was applied.

Edition 3. 15/8/2019

source data for several chemical inputs were updated by EDF Energy (based on information from HPC) and is incorporated into the assessments (Table 30). This applies to the phosphate and nitrogen loadings during operation based on higher numbers of staff present during an outage. The PNEC values have been updated for the demineralised water treatment (Sequestering) chemicals and this is reflected in the tabled values (Tables 5, 32 and 33). The nutrient inputs during construction and operation are assessed using a phytoplankton box model. Tunnelling chemicals are included, and their potential discharge assessed. Commissioning chemicals are also included and assessed. An additional assessment of the influence of potential biomass from dead organisms discharged by the Fish Recovery and Return is also included.

Edition 4. 29/10/2019

Some minor edits were made to the document and some additional supporting text related to the hydrazine habitats assessments was also added before this version was uploaded to the Aecom site.

Edition 5. 05/03/2020

Hydrazine cold commissioning discharge level has been revised to better reflect expected discharge level for permitting. An additional load assessment for trace metal contamination (cadmium and mercury) of raw materials used for water treatment has been added. Corrections have been made to some of the loading values for operational chemicals as more information has become available none of the changes has had significant implications for predicted impacts. This final version was uploaded to the Aecom site.

1 Background

1.1 Background to the site

NNB Generation Company (Sizewell C) Ltd is planning to build a new nuclear power station at Sizewell, Suffolk (SZC). The new power station will be located on the Suffolk coast, northeast of Ipswich and south of Lowestoft. The approximate National Grid reference for the centre of the proposed development is TM 4730 6410. The new power station will be built near and to the north of the Sizewell B station which will continue to operate after the commissioning of SZC. Sizewell A, which is located to the south of Sizewell B, ceased operation in 2006.

Any development at Sizewell that includes discharge to or operations in the adjacent marine environment must be considered in relation to its potential effect on coastal water quality.

Assessment is also made for Water Framework Directive (WFD) designations associated with the site which is in East Suffolk Zone (ESZ) of the Anglian River Basin District (RBD). Under WFD the Suffolk Waterbody is one of the main points of reference. The Suffolk Waterbody is designated as heavily modified based on coastal and flood protection and it is evaluated (2013 - 2016) as moderate status but must achieve good ecological potential by 2027. (https://environment.data.gov.uk/catchmentplanning/WaterBody/GB650503520002).

Associated with the Suffolk Waterbody are the Walberswick marshes, the transitional waterbodies the Blyth and Alde and Ore and designated Bathing Waters at Lowestoft north and south of Claremont pier and at Southwold the Denes and Southwold.

The primary habitats designations associated with the site are the Outer Thames Estuary Special Area of Protection (SPA) and the Southern North Sea SAC.

1.2 Designation of zone of influence for modelling assessment

The Greater Sizewell Bay (GSB) is considered as the initial reference area for the study site. For the purposes of the Environmental Impact Assessment (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 eastern side of the Bank. The landward limit of the marine study area is delineated by Mean High Water Springs (MHWS). However, the GSB is not a closed system and water exchanges with the rest of the southern North Sea. The Zone of Influence (ZoI) for development impacts is, therefore, dependent on hydrodynamic processes.

For the EIA, the potential ZoI is dependent on several factors including; the position and duration of the discharge, the behaviour and persistence and/or degradation rates of the discharge components, bathymetry, and the state of the tidal cycle. Construction and 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 inshore of the Sizewell-Dunwich Bank (Figure 1) and discharge into the receiving waters of the GSB. Sizewell C site discharges from the combined drainage outfall (CDO) (which would include those from the construction site and potentially those during commissioning) and from the Fish Recovery and Returns (FRRs) would also occur within the GSB and would be transported throughout the inner tidal excursion within the Sizewell-Dunwich Bank (Figure 1 and 2).

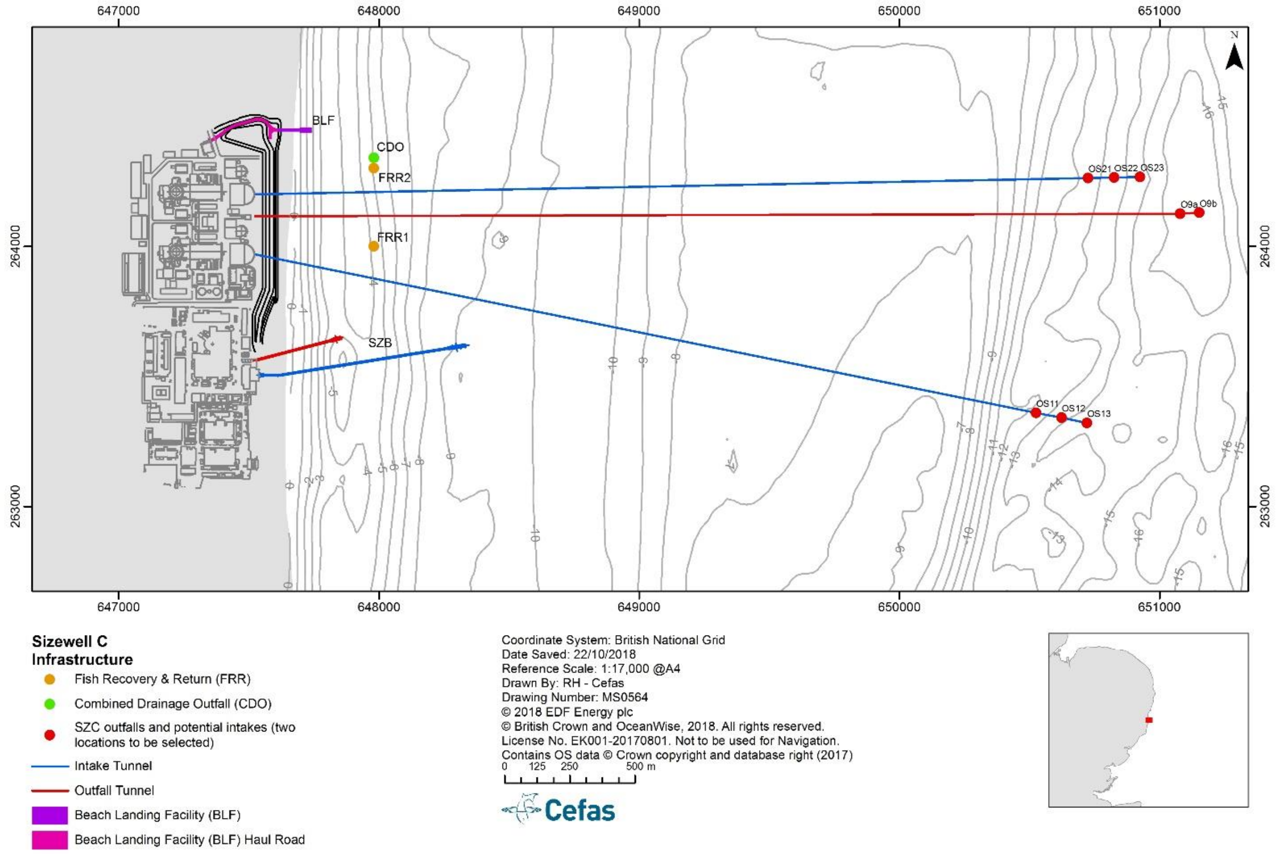

Figure 1: Schematic of development locations in the marine environment overlaid on bathymetry, blue indicates intake tunnels, red indicates outfall.

To determine the effects of entrainment on phytoplankton populations from Sizewell B and C, BEEMS Technical Report TR385 determined the approximate volume of water within the influence of the power station during a tidal cycle. Based upon a current meter (S2) deployed near the proposed Sizewell C intake locations, a progressive vector diagram (PVD) method indicated that the north – south excursion is approximately 15.9 km in each direction, and 1.4km east – west during spring tides. The trajectory of the tide flows both north and south, thus the tidal volume represents a body of water 31.8 km long and approximately 2.8km wide. The average depth was calculated at 12.5m giving a total volume of 1209.7 x 10^6 m^3 (Table 1).

Table 1 The volume of water associated with the Greater Sizewell Bay and the tidal excursion originally reported in BEEMS Technical Report TR385.

Body of water defined in TR385	Surface area (ha)	Average depth (m)	Volume (x10^6 m^3)
GSB	4120	8.8	363.8
GSB + tidal excursion beyond the Sizewell-Dunwich Bank	9670	12.5	1209.7

The volumetric exchange rate has not been measured at Sizewell. Typical exchange rates in partially mixed tidal estuaries are 5% volume exchange on each tide (Dyer, 1979), thus 0.1 per day. In the Southern North Sea, an open sea area, the exchange is expected to be greater. Calibration of a Sizewell phytoplankton model found a volumetric exchange rate of 10% corresponded well to observation data and has subsequently been adopted (BEEMS Technical Report TR385). The exchange rate will vary in accordance to a spring-neap cycle. Furthermore, velocity observations show a net westward exchange as well as a net southward exchange, meaning a 10% exchange is estimated to be the minimum water exchange rate.

The tidal excursion is dependent on the stage within the spring-neap cycle but provides an estimate for the zone of influence. The method applied to determine the tidal excursion has a bearing on the calculation of the estimated area and volume. The following section details several methods applied to estimate the body of water potentially influenced by the power station.

For comparison, a harmonic analysis was conducted on the same S2 current meter (BEEMS Technical Report TR233) and provided similar results to the PVD method. The tidal ellipse indicates that the north – south excursion is approximately 17.2km, and 1.8km east – west during spring tides. The trajectory of the tide flows both north and south, thus the tidal volume represents a body of water 34.4 km long and approximately 3.6km wide.

Further analysis was undertaken to support the estimate of the tidal water volumes reported in BEEMS Technical Report TR385. To determine the Outer Tidal Excursion, a particle tracking study was considered but the trajectories exceeded the hydrodynamic model domain. Instead, without running a new model set-up, two alternative methods have been considered: a PVD and a harmonic analysis. The PVD method estimates the potential transport based upon measured velocity time-series (at a fixed location). The distance travelled between each time step of the record, is determined from using the U and V velocity components, and its trajectory plotted from the original starting point (i.e. the outfalls). The tidal excursion is then determined from an area encompassing the total trajectory path. For the harmonic analysis method, an idealised tidal curve was reconstructed, using the M2, S2 and N2 tidal constituents, to determine the major and minor axis of the tidal ellipse. This provides a maximum theoretical tidal excursion, excluding any meteorological forcing. The area and volume based upon the average depth, of the associated ZoIs are shown in Table 2.

To determine the volume of water that may be influenced by the CDO and FRR discharges, within the Sizewell-Dunwich Bank particle tracking associated with the FRR was completed (BEEMS Technical Report TR333). Particles were released from FRR Position 5 over a spring-flood tide and a neap-flood tide for May 2009. This is representative of the mean conditions for the area of Sizewell. The tidal excursion within the Sizewell-Dunwich Bank was then determined by defining an area encompassing every particle position at each time step of both runs combined. This indicates that the total tidal excursion is approximately 20.8km North-South and approximately 3.5km east-west.

Table 2 Approximate surface area and volume of the Zones of Influence based on the areas delineated in Figure 2.

	Surface area (ha)	**Average depth (m)**	**Volume (x10^6 m^3)**
GSB	4577.5	8.73	399.7
Inner Tidal Excursion	4323.2	8.49	367.0
Outer Tidal Excursion			
PVD method	7081.4	13.91	985.0
Harmonics method	10129.1	13.84	1401.9
***GSB + tidal excursion**	9906.7	12.14	1202.9

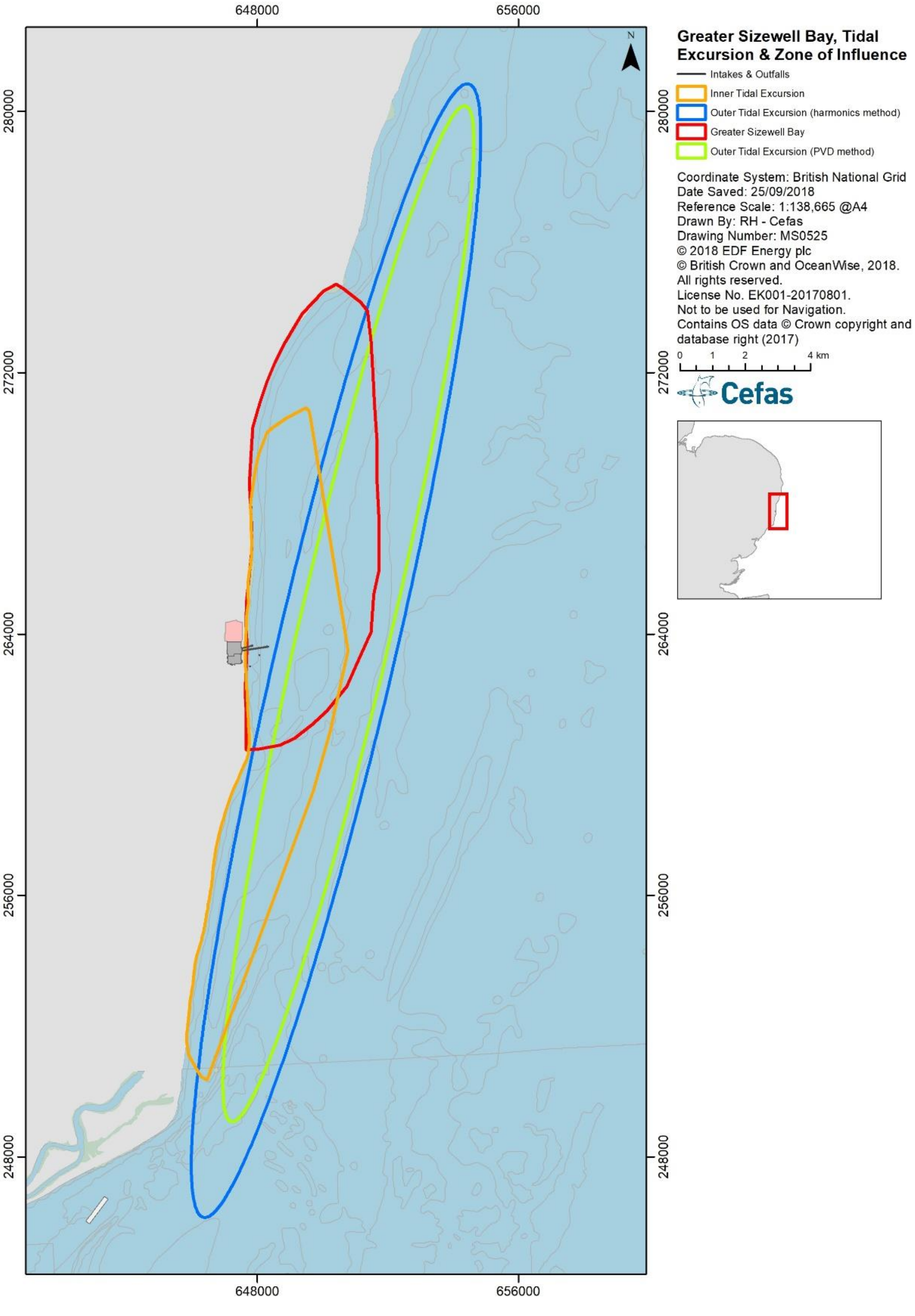

Figure 2 The area of the tidal excursion from the Sizewell C CDO/FRR and outfall during spring tides, the outer tidal ellipse and the Greater Sizewell Bay body of water.

1.3 Objectives

At each phase of the development (construction, commissioning, and operation) the potential and extent of any effects on water quality will be assessed. Assessment will take account of temporary and permanent discharges from the site and from the two proposed UKEPR units.

Sizewell C is a Nationally Significant Infrastructure Project (NSIP), therefore EDF Energy requires a Development Consent Order (DCO) to construct and operate the power station, and any associated development, under the Planning Act 2008. The application for development consent will comprise details of all development proposals and will be accompanied by an ES conforming to the Infrastructure Planning (Environmental Impact Assessment) Regulations 2009 (SI 2263) (as amended) (the EIA Regulations) and other relevant documents. In support of these requirements the main objective of this report is to assess the potential impacts on the water quality within the local marine environment and to provide information that will support the assessment and application for a Water Discharge Activity (WDA) environmental permit to the Environment Agency.

The WDA permit is determined based on the status of the receiving waterbody and upon existing pressures on water quality from other consented discharges. Once a permit is issued the operator must apply control measures to ensure compliance.

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”. The process consists of three stages (screening, scoping and impact assessment). For the planned Sizewell C this report considers each of the three assessment stages for the discharges to the marine environment during construction, commissioning and 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 Environmental Quality Standards (EQSs). Where no EQS is available approaches are described for derivation of an alternative reference value.

The focus of this report is the potential impact of activities upon water and sediment 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. This information is used to support the water quality assessment in BEEMS Technical Report TR306 (Water and Sediment Quality Synthesis). The same information but considering areas of overlap with the Water Framework waterbodies and Habitats are considered in BEEMS Technical Report TR483 or for individual biology receptors will be considered in the Marine Ecology section of the Environmental Statement.

2 Assessing potential concerns for marine water quality

2.1 Background

The water quality standards adopted for this assessment are those relevant to all expected discharges from the SZC site during all phases of the development. These mainly relate to Environmental Quality Standards (EQSs).

A detailed list of the currently available EQS values that have been assigned to water quality for both the freshwater and marine environments are described for other surface waters (Transitional and coastal waters, TraC Waters) for priority hazardous substances and other pollutants under Directive 2013/39/EU (implemented by the Water Framework Directive (Standards and Classification) Directions (England and Wales, 2015) which increased the list of chemicals to 45 and for substances classed as specific pollutants for which 29 substances are listed (Defra, 2014). Chemical status is recorded as 'good' or 'fail'. The chemical status classification for the water body is determined by the worst scoring chemical.

The water quality monitoring campaigns (defined periods of monitoring) for marine water quality are described in detail within BEEMS Technical Report TR189 and in BEEMS Technical Report TR314 (an update to TR189 that includes data on selected determinands from monitoring conducted in 2014/15). A Sizewell Water quality literature review TR131 provides historic information on background water quality for the Suffolk coastal waterbody. This document also provides details of all the relevant Screening EQS values for saltwater and the legislation and guidance documents from which they are derived.

2.2 Contaminants of concern for the combined drainage outfall (CDO)

Various chemical and physical standards for the protection of marine water may be affected by the discharges from SZC.

During construction and commissioning a CDO will be in place to collect and allow discharge of various wastewater streams to the marine environment. The discharge sources for contaminants of concern and flow rates used for the modelling at the CDO are:

1. Groundwater from the dewatering system which contains metals, ammoniacal nitrogen, dissolved inorganic nitrogen (DIN) and phosphate with a maximum flow rate of 124ls^{-1} in the first 28 days and thereafter at 15ls^{-1}.
2. Treated sewage discharge which contains, ammoniacal nitrogen, dissolved inorganic nitrogen (DIN) and phosphate from permanent treatment units with a total flow rate of 13.3ls^{-1}.
3. Effluent from tunnel excavations potentially containing residual amounts of Tunnel Boring Machine (TBM) soil conditioning chemicals and variable quantities of groundwater containing metals, ammoniacal nitrogen and DIN.

Dewatering is required during the construction of SZC. In this process, groundwater is pumped from a network of deep boreholes. Atkins Ltd (Atkins) was commissioned by EDF Energy to measure and assess groundwater chemistry underlying the site (Atkins, 2016). This groundwater chemistry dataset (referred to as the 2014-2016 dataset see Appendix A) is used to derive the 95th percentile concentration for each of the substances of concern. These 95th percentiles are used to assess the potential for effects of discharged groundwater on the marine environment. The use of 95th percentiles provides a conservative assessment and is more robust that using maximum values for which there is lower confidence.

Sewage treatment will be available on site to treat sanitary waste from the workforce and treated effluent will contribute to ammoniacal nitrogen and nutrients as well as Biochemical Oxygen Demand (BOD), faecal coliforms, Escherichia coli, Intestinal Enterococci and suspended solids.

The main bulk of the tunnelling material (potentially with associated soil conditioning chemicals) is returned with the spoil to the muck bay. The tunnelling spoil will be re-used on-site in accordance with the site materials management plan. Sources of water from the tunnelling operations will include groundwater entrained within the tunnelling spoil, groundwater from the shaft dewatering, very minor seepages of groundwater into the tunnel, water used for cleaning equipment and dust suppression, surface run-off from the muck bay and groundwater seepage into the launch pits and Spray Concrete Lined (SCL) tunnels.

Construction work at the site is also likely to contribute concrete wash water to site discharges and these will be assessed accordingly.

During the early part of the commissioning phase, conditioning chemicals will also be discharged through the CDO. The chemicals present may include hydrazine (antioxidant), metals, and various organic and inorganic chemicals.

One of the issues when considering all three discharge streams (sewage, groundwater and tunnelling wastewater) is to consider the timescale of the likely discharges and potential maximum discharges and loads. This report considers when loads of a contaminant are at maximum levels or are likely to persist as discharges for a reasonable period. To determine realistic worst-case contributions that need to be assessed for specific contaminants from different discharge sources combined in the CDO, several ‘Cases’ are described for different phases during the construction period when input sources overlap and combine.

2.3 Evaluation of contaminants of concern during operation

During the latter phase of commissioning and during operation various process effluents e.g. treated sanitary wastes from welfare facilities for operational staff, waste chemicals from boiler cooling circuits would be combined with the cooling water and discharged from the single offshore discharge point. The discharge would include chlorine produced oxidants from chlorination of the cooling water, residual hydrazine, metals, and various organic and inorganic chemicals.

2.4 Key contaminants of concern during operation

Various chemical and physical standards derived for the protection of marine water quality may be affected by the physical and chemical nature of site discharges. These standards may be for absolute concentrations or temperatures (where discharges are added to background concentrations), or uplifts above ambient conditions. There is a temporal component to EQS exceedance which is typically maximum (100th percentile), 98th percentile, 95th percentile, or sometimes the mean.

EQS thresholds are based on toxicity data for the most sensitive species with a safety factor applied depending on the confidence in the data. Typically, data is derived from representative examples of algae, crustacea and fish and safety factors range for 10-fold for good data to 1,000 or more for data poor chemicals (in some cases an EQS may not be formally established and BEEMS has used an ‘applied EQS’ based on available data, see section 2.5 and Appendix B).

The main standards referred to in this report are shown in Table 3. Under the Water Framework Directive assessment of nutrient status of a waterbody (Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015) there are four Waterbody ‘Types’ defined by annual mean concentration of suspended particulate matter (see Appendix C, Table 6).

The dissolved inorganic nitrogen (DIN) value referenced in Table 3 is based on the 99th percentile of the winter DIN values for ‘Intermediate turbidity’ waterbodies for classification of waterbodies as Good, Moderate, Poor, or Bad. The threshold value shown in Table 3 is derived based on the mean suspended particulate matter concentration at Sizewell. This would define Sizewell as of intermediate turbidity with associated threshold 99 percentile winter DIN values for coastal waters of 980µgl^{-1} and 1470µgl^{-1} for Good and Moderate respectively (Water Framework Directive Standards and Classification Directions 2015).

Table 3 Marine water quality standards applied in assessment of planned discharges during the SZC development – these represent Environmental Quality Standards (EQS) for other surface waters (TraC Waters) for priority hazardous substances and other pollutants (Directive 2013/39/EU); (Defra, 2014); microbiological standards from bathing water regulations (2013. No. 1675).

Determinands	**WFD EQS Annual average values (µg l^{-1})**	**WFD EQS Maximum Allowable Concentration (MAC) values (as 95 percentile) (µg l^{-1})**
Cadmium and its compounds (dissolved)	0.2	1.5
Lead and its compounds (dissolved)	1.3	14
Mercury and its compounds (dissolved)	-	0.07
Nickel and its compounds (dissolved)	8.6	34
Chromium VI (dissolved)	0.6	32
Arsenic (dissolved)	25	Not applicable
Copper (dissolved)	3.76 (2.677 x ((DOC/2) - 0.5)) µg/l dissolved, where dissolved organic carbon (DOC) > 1 mg l^{-1}	Not applicable
Iron (dissolved)	1000	Not applicable
Zinc (dissolved)	6.8 (plus ambient background 1.1 in salt water)	Not applicable
Boron (Total)	7000 (pre Water Framework recommended standard)[1]	-
Chlorine	-	10
Un-ionised ammonia (NH_3)[2]	21	-
Winter dissolved inorganic nitrogen		980[3]
Escherichia coli		≤500 colony forming units/100ml[4]
Intestinal enterococci		≤200 colony forming units/100ml[4]

[1] Mance et al, 1988; [2] Total ammonia values of 1100 (annual average) and 8000µg/l NH4-^{N} are also recommended for habitats consideration (WQTAG086, 2005) [3] EQS for nitrogen is based on WFD 99 percentile standard for Good status for an intermediate turbidity waterbody. 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 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.; [4] This assessment is from bathing water regulations (2013. No. 1675) for coastal and transitional waters and represents Good standard

2.5 Applied EQS values

In the absence of EQS values for some toxic chemicals, the use of Predicted No Effect Concentration (PNEC) values is proposed. PNEC values have only been used where there is no existing EQS standard and where a relevant saltwater PNEC standard has been determined by independent authorities (as recommended in European Chemicals Bureau Technical Guidance, 2003 (TGD) and CIS, 2011).

PNEC values are determined such that they ensure the protection of all organisms in the receptor environment and they represent the predicted concentration of a given chemical where there should be no effects on the aquatic biota. The determination of PNEC values follows the Technical Guidance Document (European Chemicals Bureau Technical Guidance, 2003) and CIS, 2011 on risk assessment of new and existing chemicals following a review of the ecotoxicological literature. Under the guidelines from the Water Framework Directive (WFD) and the EQS Directives, WFD EQS values are, for the most part, also based on PNEC values.

A review of PNEC values for several discharge chemicals has already been undertaken by EDF Energy based on PNEC values determined by independent research organisations (e.g. INERIS). This document proposes acute and chronic PNEC values for hydrazine, morpholine and ethanolamine (details Appendix B). These derived PNEC values have been adopted in the present assessment.

Because of the inherent uncertainty in the derivation of marine PNEC values, they are not directly comparable with the H1 methodology which is based on comparison with annual average and maximum allowable concentration EQSs. Therefore, to assess the environmental significance of chemicals where a PNEC value has been adopted, the approach presented in the Technical Guidance Document of comparing the ratio between the PNEC value and Predicted Environmental Concentration (PEC) is used. If the PNEC:PEC ratio is less than or equal to 1, the discharges will have no environmental impact (the PNEC is a concentration of no effect for all organisms). A PNEC:PEC ratio > 1 indicates that a potential impact cannot be excluded.

Depending on the release pattern of a chemical and its environmental fate, chemical exposure may occur over long periods - or even continuously - in biota, in sediments, and even in the water column. In the water column, exposure may also occur intermittently for short periods e.g. coinciding with storm events or short periods of chemical use.

In order to cover both long- and short-term effects resulting from exposure, two water column EQSs will normally be required:

i. a long-term standard, expressed as an annual average (AA) concentration and normally based on chronic toxicity data
ii. a short-term standard, referred to as a maximum acceptable concentration (MAC) which is based on acute toxicity data.

AA data are usually based on taking the lowest chronic ecotoxicological value. The values derived for chronic PNEC are usually based on a No Observed Effect Concentration (NOEC) and are the chemical concentrations for which it is predicted that there will be no effect on aquatic biota or where this is not available an effect concentration for 50% of the test individuals (EC50). A safety factor is then applied by dividing with an assessment factor (1 to 10,000) depending on the quality, quantity, diversity, and specificity of the ecotoxicological data available following TGD guidance and CIS, 2011. The assessment factor therefore reflects the confidence that the lowest ecotoxicological datum represents the greatest number of taxa possible, the environment in which they live (freshwater or marine) and the type of discharge in terms of frequency (chronic, duration typically months to years or acute shorter term, hours to days). For exposures resulting from shorter term (typically over 24 hours) exposures MAC values are derived from the lowest acute toxicity data and use 50% effect concentrations (EC_{50}) derived from studies of 24 - 96 hours duration.

As freshwater organisms are generally easier to obtain and test this has led to fewer marine toxicity datasets being available. This often leads to the development of marine PNEC values based on extrapolation from freshwater PNEC values or high assessment factors applied to marine ecotoxicological data (uncertainty regarding the sensitivity of other taxa). Because of the greater biological diversity in marine environments compared to freshwater environments and because of the general lack of marine ecotoxicological studies, it is often necessary to apply conservative assessment factors to the derived freshwater PNEC values to obtain a marine PNEC (unless there is justification that similar toxicity is seen in both environments).

For example, the derivation of PNEC values for hydrazine is based on the lowest valid ecotoxicological value: an EC_{50} (50% effect on test species) value of $0.4\mu gl^{-1}$ for the marine alga *Dunaliella tertiolecta*. To derive the chronic PNEC value an assessment factor of 1000 was applied because of the lack of studies available for other marine taxa. An assessment factor of 100 was applied to this EC_{50} value to obtain the acute PNEC value.

For the assessment of the proposed SZC discharges of hydrazine, morpholine and ethanolamine, the chronic PNEC value has been applied to annual chemical loadings and the acute PNEC values to 24-hour discharges and these are shown in Table 4.

Table 4 Proposed PNEC values for chemical parameters based on EDF R&D review of ecotoxicity studies (EDF, 2008) (more detail is provided in Appendix B).

Chemical Parameter	Acute Marine PNEC	Chronic Marine PNEC	Lowest ecotoxicological value used to derive PNEC values
Hydrazine	$0.004\mu gl^{-1}$	$0.0004\mu gl^{-1}$	$EC_{50} = 0.4\mu gl^{-1}$on *Dunaliella tertiolecta* (marine unicellular alga) – chronic and acute PNEC
Ethanolamine	$160\mu gl^{-1}$	$160\mu gl^{-1}$	NOEC = $1.6mgl^{-1}$on *Microcystis aeruginosa* (freshwater cyanobacteria) – chronic and acute PNEC
Morpholine	$28\mu gl^{-1}$	$17\mu gl^{-1}$	NOEC = $1.7mgl^{-1}$on *Microcystis aeruginosa* (freshwater cyanobacteria) – chronic PNEC EC_{50} (96h) = $28mgl^{-1}$on *Selenastrum capricornutum* (freshwater alga) – acute PNEC

2.6 Application of data from ecotoxicity studies

For potentially toxic chemicals where there are no EQS or PNEC values, then data from ecotoxicity studies have been used for assessing the environmental significance of discharges from SZC. This approach has been adopted for the following discharges of by-products from sequestering agents used with the demineralisation plant. Sequestering agents may be used for functions such as the prevention of scale formation by reacting with calcium salts present in water to prevent them reacting with other surfaces (see below).

2.6.1 Sequestering Agents

For the chemicals associated with the sequestering agents used in the demineralisation water plant (see Table 5), there are currently no saltwater EQS or EDF validated PNEC values available. Therefore, EDF validated ecotoxicity data (sourced from peer-reviewed publications and non-peer review literature such as industry reports) have been adopted for use in the H1 assessment. A precautionary approach has been adopted to determine the potential environmental significance of discharges of sequestering agent by-products, where the lowest concentration available in the ecotoxicity data is compared to the predicted concentration in the effluent following mixing of various process inputs. This approach has been used as the ecotoxicity data for most of the chemicals is only available for freshwater organisms. For annual discharges comparison has been made to chronic ecotoxicity concentrations and acute values used for 24-hour discharges.

A summary of the threshold values adopted for the H1 assessment is presented in Table 5. The footnotes indicate the reference sources for the dataset and application factors applied to these based on the CIS guidance, 2003. None of these substances have been analysed for in Sizewell seawater so there are no background concentration data to reference for the site.

Table 5 Derived PNEC values, and source and type of endpoint with application factor by which they were derived as used in the assessment of sequestering agents and by-products.

Chemical	Chronic Concentration (μgl^{-1})	Ecotoxicity Test Type	Test Species	Acute Concentration (μgl^{-1})	Ecotoxicity Test Type	Test Species
ATMP	74[a]	NOEC[1,2] (96h)	Freshwater alga (*Selenastrum capricornutum*)	74[1]	NOEC[2,3] (96h)	Freshwater alga (*Selenastrum capricornutum*)
HEDP	13[a]	NOEC(96h)[2,2]	Freshwater alga (*Selenastrum capricornutum*)	13[1]	EC_{50} (96 hr)[3,4]	Freshwater alga (*Selenastrum capricornutum*)
Acetic Acid	62.8[b]	NOEC (21 day)[2,5]	(*Daphnia magna*)	301[d]	LC_{50} (48 hr)[5,6]	Freshwater crustacean
Phosphoric Acid	20[c]	LC_{50} (72hr)[7] algae	Freshwater algae	200[d]	LC_{50} (72 hr)[7] algae	Freshwater algae
Sodium Polyacrylate	11.2[8b]	NOEC (21 days)	Freshwater crustacean (*Daphnia magna*)	180[8d]	LC_{50} (96 hr)'	Freshwater algae (*Scenedesmus subspicatus*)
Acrylic Acid	0.34[9b]	NOEC (72h)	Freshwater alga (*Selenastrum capricornutum*)	1.7[9a]	EC_{50} (96hr)	Freshwater alga (*Selenastrum capricornutum*)

Table Notes:[a] application factor 100; [b] application factor 500; [c] application factor 10000; [d] application factor 1000; [1]this value is set at same level as the chronic value as a lower acute value would result otherwise [2]NOEC = No Observable Effect Concentration.[3]Jaworska et al (2002);[4]EC_{50} = Effect concentration for 50% of the study individuals. [5]ECHA dossier Acetic acid; [6]LC_{50} = Lethal concentration for 50% of the study individuals; [7]ECHA dossier phosphoric acid;[8]SDA, 1996 [9]Sverdup et al.,2001

2.7 Application of background mean concentrations

Several chemicals present within the expected marine discharges during the commissioning and operational phases of the site have no assigned saltwater EQS values that are at present accepted and are naturally present in marine waters (e.g. manganese, aluminium, lithium hydroxide, sulphate, sodium, chloride, suspended solids, phosphorus, chemical oxygen demand (COD) and biochemical oxygen demand (BOD)). Review of other screening assessments concerning marine discharges indicates that it is appropriate to use an ambient mean baseline concentration as a substitute benchmark value against which the significance of a chemical can be assessed. The mean baseline concentrations adopted as substitute benchmark water quality standards are based on the overall average values determined from the water quality monitoring undertaken during 2010 (BEEMS TR189) and in some cases from the supplementary studies during 2014/15 (BEEMS TR314).

3 Marine water quality baseline

The status of marine waters adjacent to Sizewell has been measured to determine whether the chemical composition of any planned discharges from the SZC development site will result in deterioration of marine water quality. The Suffolk waterbody which is adjacent to Sizewell is a heavily modified waterbody because of the presence of coastal protection and flood protection. As of 2015 the waterbody is considered of Moderate Ecological Potential because the dissolved inorganic nitrogen concentration; a supporting element is judged to be Moderate (Environment Agency, Catchment data explorer, 2019).

3.1 Data sources

Supporting data used in this assessment were derived from four main sources. Historic data relating to marine water quality were sourced from the scientific literature. Most of the data from this source focus on the quality of estuaries discharging into the Suffolk Waterbody. Water quality data were also obtained from the Environment Agency. Thirdly data on coastal sea surface temperatures were collated into time-series over 48 years based on data provided on behalf of Cefas, by councils, companies and other organisations. Finally, new data were obtained from a BEEMS monitoring programme focussed on current and planned cooling water discharge locations off Sizewell. The temperature and historic monitoring data are reported in detail in BEEMS Technical Report TR131. As the data extracted from the scientific literature do not specifically focus on the Suffolk waterbody or relevant ZoI for the site, most reliance in the following sections is placed on the other data sources.

3.2 Historic data

This section describes Environment Agency monitoring surveys for compliance and therefore the sites chosen, type of analysis and detection limits are set in this context. The data for dissolved metals covers the period 1989 to 2006 and include data for sites from off Felixstowe to just off the river Yare (Figure 3). However only four of the nine locations sampled in the original survey are within the Suffolk waterbody or ZoI and these are referred to below. Nutrients and inorganics data include samples collected between 1983 and the early part of 2014. The EQS are derived from Directive 2013/39/EU about priority substances, cadmium, lead, nickel, and mercury.

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 concentrations measured and values below detection are interspersed with high values. For other determinands, for sample points outside the waterbody, cadmium exceeds its EQS value Off the River Deben, chromium VI at the Mouth of the Orwell, off Aldeburgh, off Dunwich and off the Yare. In the case of chromium VI there were only one or two measured values between 1991 -1994 and these led to EQS exceedance with subsequent values below detection up to 1999 (the last monitoring date). The lower revised EQS for cadmium, chromium VI and zinc relative to the high detection limits at the time of the original analysis means that it is not possible to determine the number of sites that might have breached the standard. Copper is also close to its EQS at the mouth of the Orwell but dissolved organic carbon values were not available and need to be taken account of in assessing compliance with the EQS.

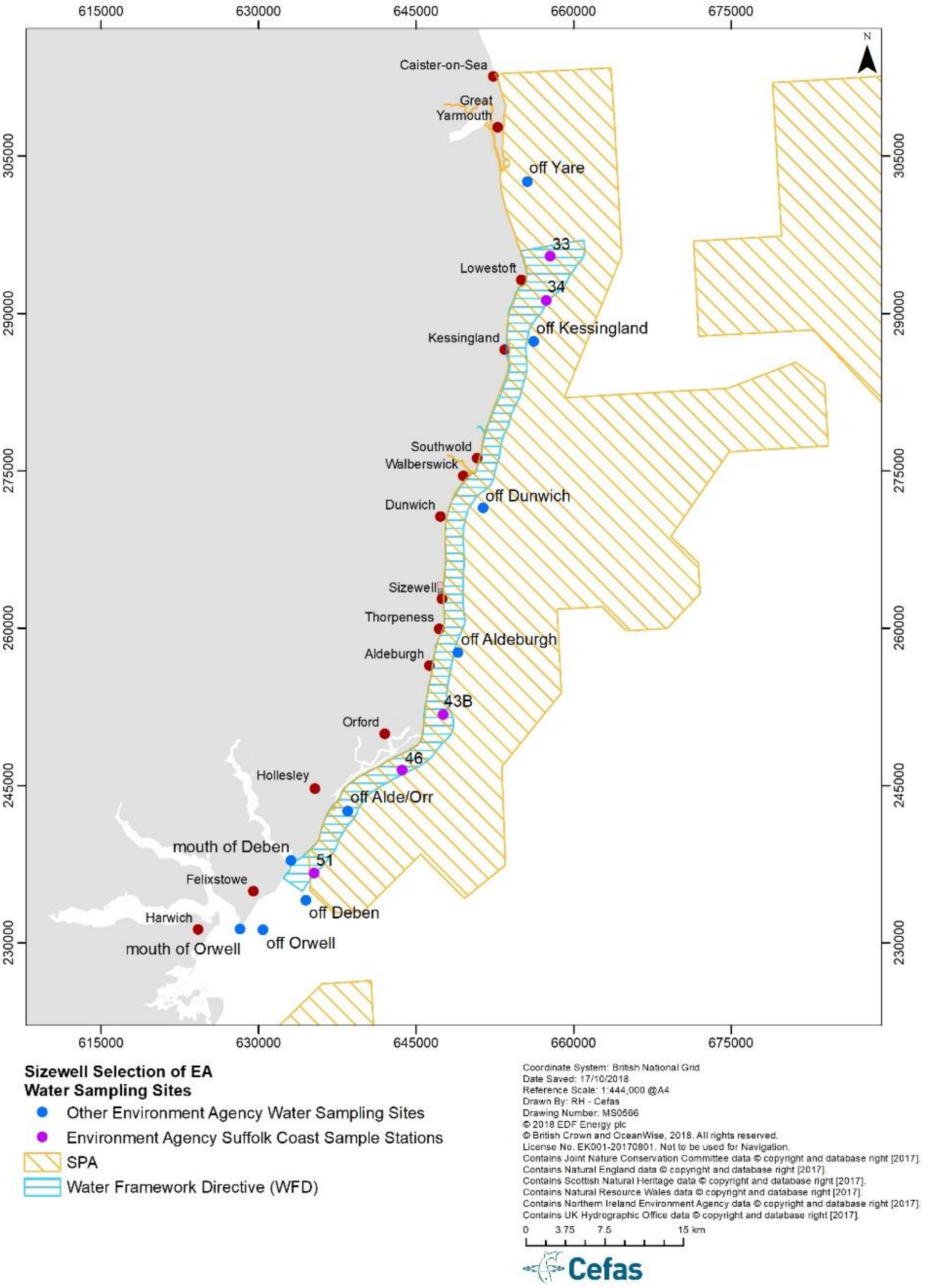

Figure 3 The Environment Agency (EA) sampling stations for which water quality data were available are shown in relation to Sizewell Power Station and major towns on the Suffolk coast. The numbered sample locations are the Suffolk Waterbody sampling points and the Suffolk Waterbody is delimited by the green hatched area near to shore. The brown hatched area extending further offshore shows the upper part of the Outer Thames Estuary SPA. Additional EA sampling points are shown as blue circles.

3.3 BEEMS monitoring data

A marine water quality monitoring programme was established off the Suffolk coast near Sizewell B power station to assess the concentrations of many elements and compounds and their variation over a range of time scales. The programme ran from February 2010 to February 2011, and the programme's results are presented in BEEMS Technical Report TR189. A spatial survey was conducted at twelve sampling stations (Figure 4). The sampling was centred upon the existing cooling water outfall for Sizewell B, at station 5 (Figure 4). A tidal-cycle survey was carried out during which water samples were acquired at hourly intervals at station 5 over an ebb/flood tidal cycle during spring tide conditions. A seasonal survey was also carried out by acquiring water samples near slack water at stations 5 and 11 on 21 occasions throughout the programme.

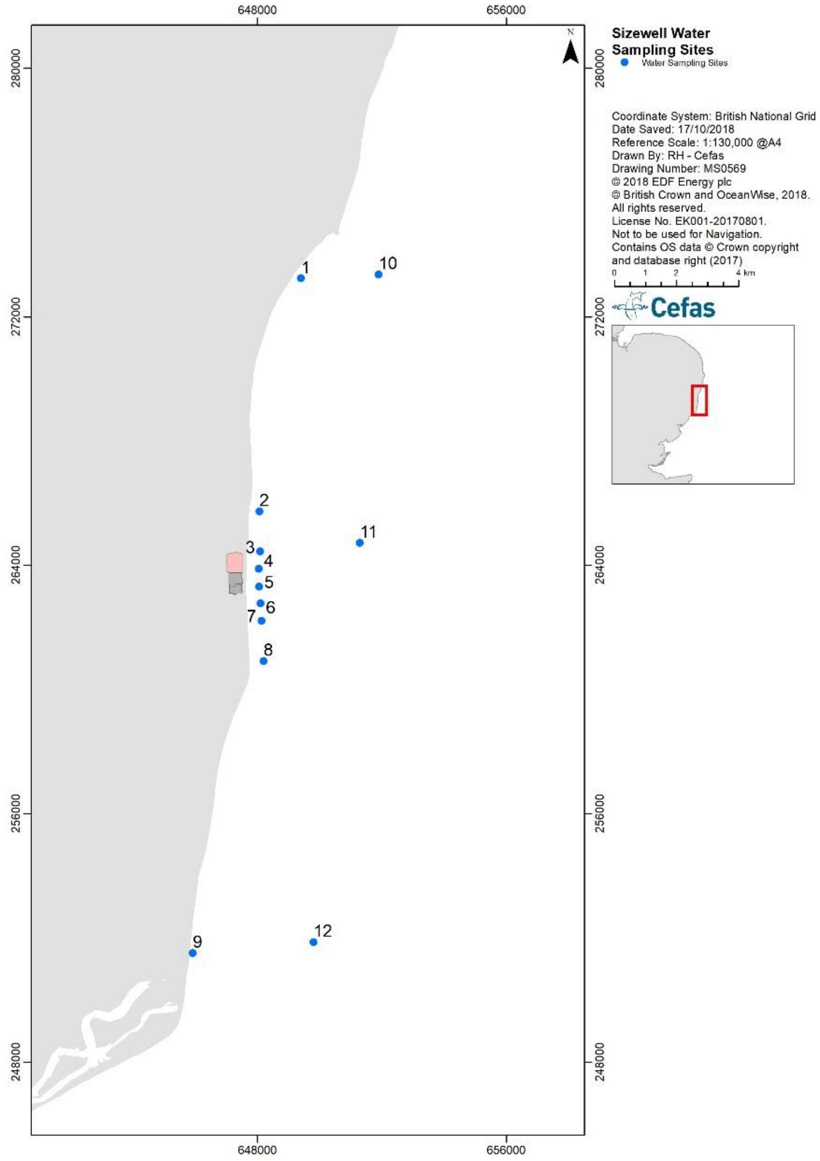

Figure 4 Location of the BEEMS sampling sites in the 2010 Sizewell monitoring survey

Conductivity, temperature, and depth sensor (CTD) profiles showed that the waters sampled are well mixed for salinity. The temperature profiles indicate the presence of a thermally buoyant plume of water at the sea surface. Many of the chemical analyses give 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 (stations 1 to 9) and offshore (stations 10 to 12) were noted, with the exceptions of suspended solids and turbidity. The higher measurements of suspended solids and turbidity inshore of Sizewell Bank are likely to be related to the shallower water depth and local sediment resuspension.

Concentrations of dissolved copper, arsenic, zinc, mercury, and cadmium exceed EQS levels on occasions. Some exceedance of the Environmental Quality Standard (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 more than their EQS was recorded for some polycyclic aromatic hydrocarbons (PAHs), biphenyl and bis (2-ethylhexyl) phthalate (DEHP), though most of the analyses for these compounds are negative. Exceedance of EQS concentrations for these organic compounds were detected at stations 1, 5, 9 and 12. These exceedances of organic EQSs were observed in samples acquired on three sampling dates: 7th and 8th April and the 19th May 2010.

Measured total residual oxidant (TRO) concentrations varied between 10 and 160µgl^{-1}. The EQS for TRO is 10µgl^{-1} (0.01mgl^{-1}) but the limit of detection of the analytical method is of the order of 20µgl^{-1} with the limit of quantification even higher therefore some caution must be applied to interpretation of measured results. The mean of all the TRO measurements (n = 725) was 40µgl^{-1}. Slight localised elevation of TRO was observed near the cooling water outfall and was below the level of detection within 2.4 km to the north and 500 m to the south. Elevated TRO was observed at the southern extremity of the survey area (at stations 9 and 12) but there was no spatial pattern to indicate that this elevation was connected to the power station outfall.

Hydrazine (N_2H_4), an ammonia-derived compound and a strong reducing agent, is a chemical that is used in the secondary circuits of boilers and steam generators in power stations (including nuclear) because of its anti-oxidant properties and for this reason initial surveys included sampling and analysis for hydrazine. A wide range of hydrazine concentrations were apparently measured in the first 9 months of monitoring. Doubts about the validity of the ultraviolet-visible spectrophotometry results, based on the limits of quantification of the technique and potential interference, led to the use of an alternative analytical method. For the final three months of the programme a gas chromatography mass spectrometry (GC-MS) technique was used on water samples to measure hydrazine concentrations in addition to the spectrophotometric technique. The GC-MS technique was far more sensitive and indicated that hydrazine concentrations were generally below the limit of detection (0.01µgl^{-1}or 10ngl^{-1}). Prior hydrazine results are therefore considered unreliable. Three positive results were obtained from morpholine analyses conducted on water samples from stations 5 and 11. Morpholine is not used by Sizewell B power station therefore the origin and validity of these values is uncertain.

No concentrations of environmental concern were measured in the analyses carried out on sediment samples acquired at stations 5 and 11. All radionuclide concentrations measured in seawater samples were very low and were consistent with routine local radionuclide monitoring by the Environment Agency.

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 indicate that EQSs may occasionally be exceeded, but there is no indication that the Sizewell B power station causes these.

During 2014 and extending into the beginning of February 2015 additional water samples were collected monthly from up to four locations offshore of Sizewell B (Figure 5). The sample locations were the Sizewell B intake and outfall, the SZC planned combined intake/outfall and a BEEMS designated position just offshore of Dunwich labelled as SZ3 BEEMS reference station. The primary data referenced in this assessment are the measured nutrient concentrations which are discussed in more detail in the Sizewell supplementary monitoring data report, BEEMS Technical Report TR314.

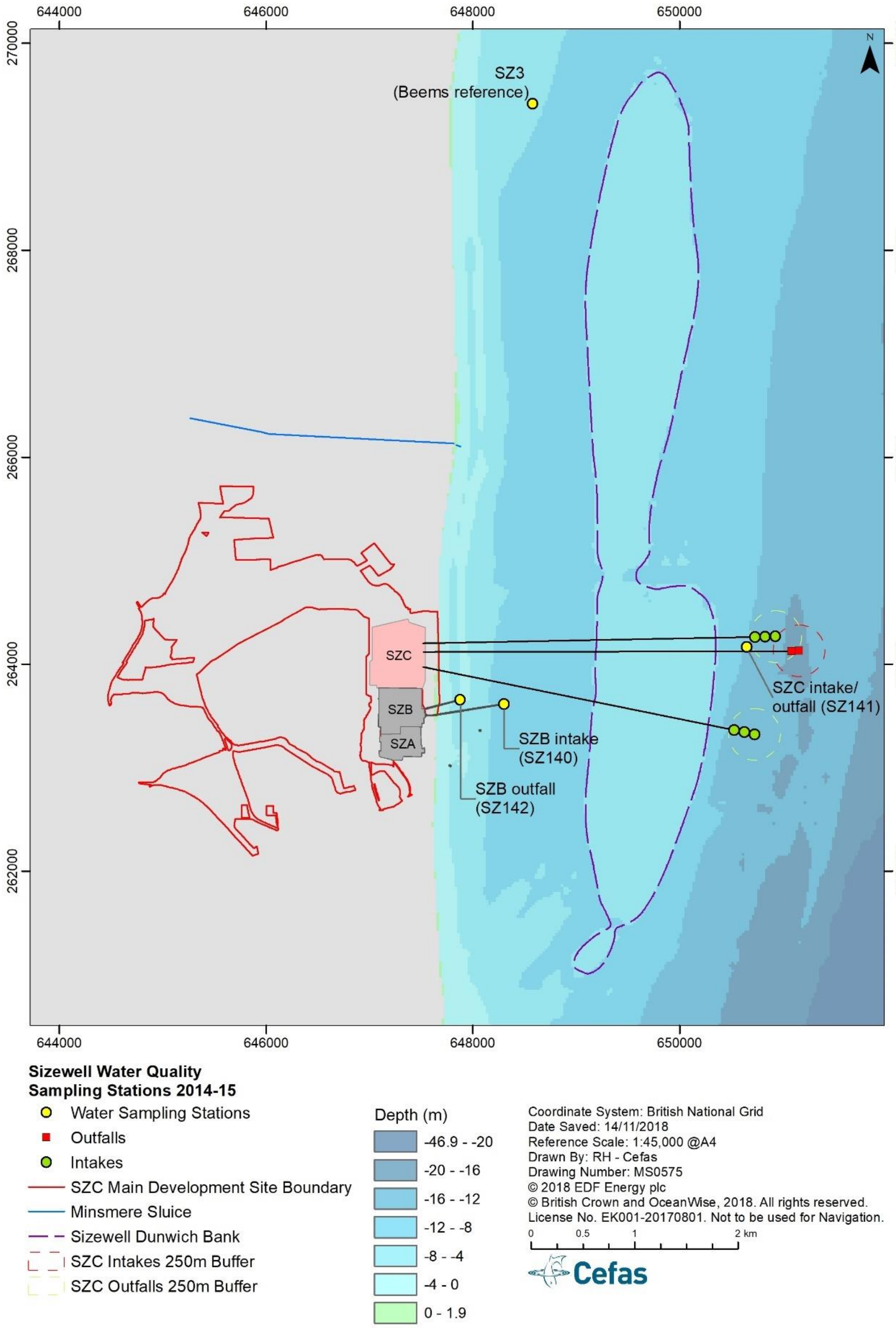

Figure 5 Map showing the marine water quality sampling locations during 2014/15 (BEEMS TR314) at Sizewell B intake and outfall, the SZC planned intake/outfall and a BEEMS reference station SZ3.

4 Construction discharges

4.1 Background

The detailed information relating to expected chemical discharges during construction, commissioning, and operation of SZC was provided primarily in documents supplied by EDF and references with supporting information and approaches adopted for the Hinkley C development. It should be noted that some of the references quoted below are not specific to the Sizewell site and are based on the information provided in (publicly available) PCER documentation (PCER, 2009) and therefore are applicable to a generic UKEPR site. Regardless of information source appropriate adjustments are made where more specific details are known in this report to consider the proposal to construct two EPR units at SZC.

4.2 Drainage and wastewater

Wastes produced in the early phase of construction when no route for marine discharge is available will be tankered off site for appropriate disposal. Construction of the CDO and potentially the Fish Recovery and Return tunnels is likely to contribute much smaller quantities of groundwater and for a shorter period than those described and assessed in the following sections.

The CDO will be constructed by TBM and will be the primary discharge point for construction phase discharges of tertiary treated sewage, main site dewatering, TBM effluents and commissioning phase hydrazine releases (Figure 6). Discharges will be treated with a silt-buster or similar technology to minimise suspended solids being discharged into the receiving waters.

During construction of the CDO, the TBM is likely to be used to drag a pre-welded pipe into position. Pre-welding allows quality control prior to burial. The design of the CDO head has not yet been undertaken but is assumed to be the same as the FRR and comprise a concrete block with dimensions subject to final engineering design.

It is not planned for the CDO to function during the operational phase, however, the exact nature of all discharges that might occur during operation is not fully resolved. It is assumed that outages, every 12-18 months, will occur for each EPR separately and outage discharges, including hydrazine will be via the cooling water stream of the operational EPR. This is to say that both EPRs will not be offline simultaneously requiring outage discharges of hydrazine to be made via the CDO.

Construction phase drainage that may be discharged to the marine environment includes:

- Surface water drainage
- Effluent from the treatment of sewage plant and potable water by the on-site treatment works;
- Water pumped from both groundwater and excavations during construction dewatering activities.
- Wash water from cleaning concrete production equipment.
- Waste water from horizontal cooling water system tunnelling operations.

The main contaminants expected in the surface drainage from the construction area are suspended solids and hydrocarbons. Surface drainage water generation during the construction phase is likely to be highly variable over the course of the build period according to site activity and weather conditions.

The background concentration of metals measured in various groundwater sources at the SZC development site and the potential implications of their discharge are discussed below.

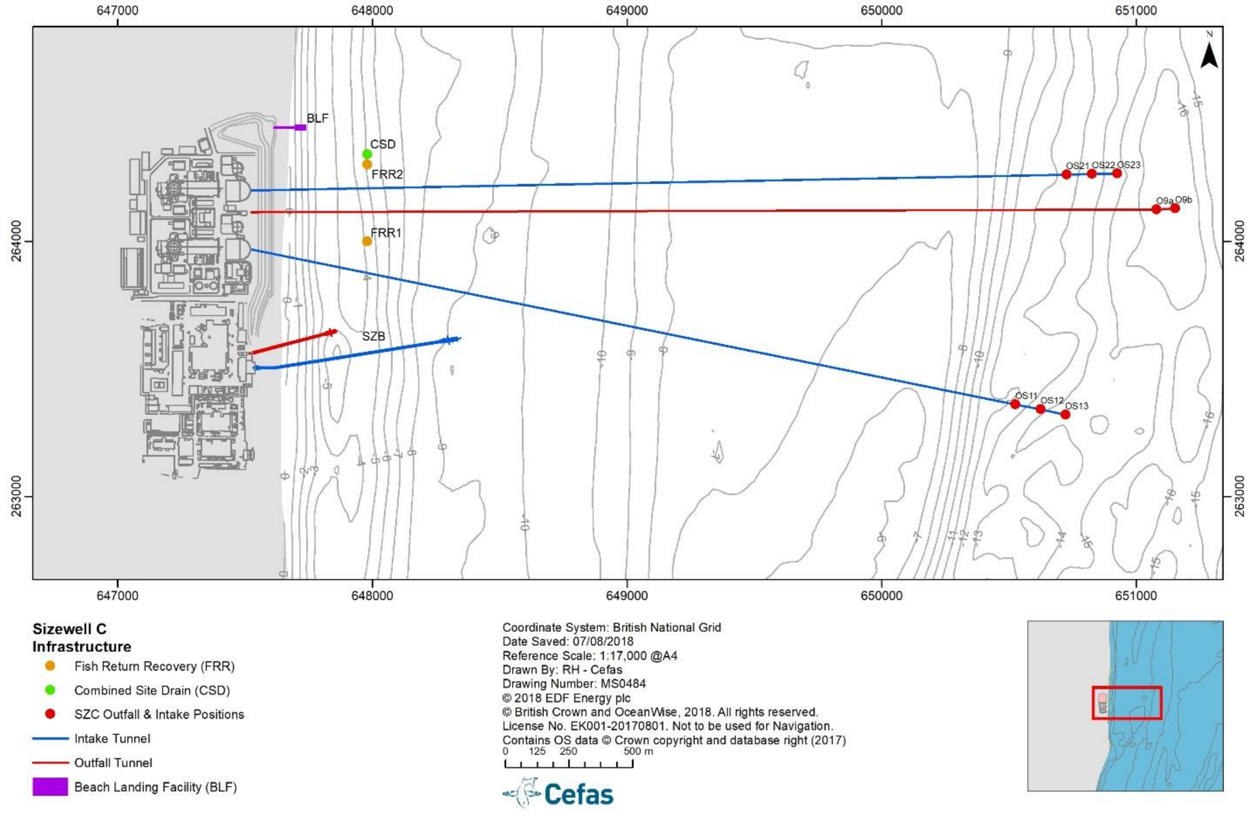

Figure 6 Schematic of development locations in the marine environment overlaid on bathymetry, blue indicates intake tunnels, red indicates outfall tunnels.

4.3 Construction discharge schedule

The CDO will be the primary discharge point for construction phase discharges of tertiary treated sewage, main site dewatering, TBM effluents and commissioning phase hydrazine releases.

As different site discharges may be present at the same time the timing, duration and magnitude of the likely discharges are important to determine. Table 6 shows an indicative set of construction discharge scenarios based on the example of phasing used for HPC but where known including specific information for SZC such as expected groundwater discharge rates and timing.

A cut-off wall will be constructed around the main construction site and over a 28-day period, groundwater will be lowered within this at an estimated discharge rate of 124ls^{-1} or 446m^{3}hr^{-1} (over this initial period the total waste water volume including the groundwater will be 0.155m^{3}sec^{-1}). For the remainder of the construction period groundwater dewatering is estimated to occur at a rate of 15ls^{-1} or 54m^{3}hr^{-1}.

Package units for treatment of sewage and wastewater from welfare facilities would be established during the construction period with an estimated average discharge rate of 13.3ls^{-1} and potential maximum of 30ls^{-1} based on current plans at Hinkley Point.

Small amounts of concrete wash water are also likely to be discharged this is expected to contribute relatively small daily volumes up to 10m^3 a day (0.1ls^{-1}).

During tunnelling a combination of small quantities of groundwater and potentially residual concentrations of ground conditioning chemicals used in tunnelling may also be discharged.

A schedule of potential combined discharges during construction has been adapted based on that expected at Hinkley Point C and is shown in Table 6.

Table 6 Construction discharge scenarios during different phases (Case A-E) of construction at Sizewell C

Date and activity change	Main site Groundwater (l s^{-1})	Sewage (l s^{-1})	Tunnelling wastes (and associated) discharges (l s^{-1})	Case	Total Discharge (l s^{-1})	Comments
WK 1 discharge available						
	124	0	0	A	124	Worst Case Metals
WK 17 tunnelling start						
	15		7	B	22	
WK 26 permanent STP			SCL ramp up			
	15	13.3	22	C	50.3	
WK 49			GW + soil conditioning 1 TBM			
	15	13.3	26.7	D	55	
WK 49		Occasional Max sewage	GW + soil conditioning 1 TBM			
	15	30	26.7	D1	71.7	Worst Case Sewage
WK 81			2 TBMs			
	15	13.3	6	E	~34	Worst Case TBM

- **Case A** is associated with the highest groundwater element and is the worst case for metals and will be screened at 124ls^{-1}
- **Case D** is the most usual case for sewage and faecal coliforms and includes groundwater from the main site and tunneling. Additional contributions to N from hydrazine use during commissioning will also be considered with this scenario.
- **Case D1** is worst case for sewage of 30ls^{-1} at 20,000µgl^{-1}combined with inputs from groundwater.
- **Case E** is the worst case for the TBM machines with the potential for 2 lots of ground conditioning chemicals to be discharged although recovery systems mean this is likely to be a negligible input.

The following information is included to enable the plausible worst-case volume and contaminant concentrations to be considered for permitting. The schedule will inevitably change, but the summary of the worst-case conditions should provide conservative values representative of the likely changes. No seasonal dependence of the schedule has been considered therefore changes to the start or end times do not affect conclusions in the assessment: the assessment of impact is not dependent on the seasonality of the operations. The main seasonal factors affecting the discharge are wind variations and wave mixing. The modelling undertaken does not include wave mixing and so is conservative. Seasonal increases in wave height will increase mixing and reduce the areas of intersection (if any exist) between features and discharged waters above EQS concentrations.

Groundwater comprises the main dewatering flow (which after the initial dewatering phase remains constant at 15ls^{--1} through the period considered) plus the contributions of groundwater resulting from the tunnelling and associated operations. Figure 7 shows that the groundwater discharge starts at 124ls^{--1} from dewatering (Case A) which is the maximum groundwater contribution.

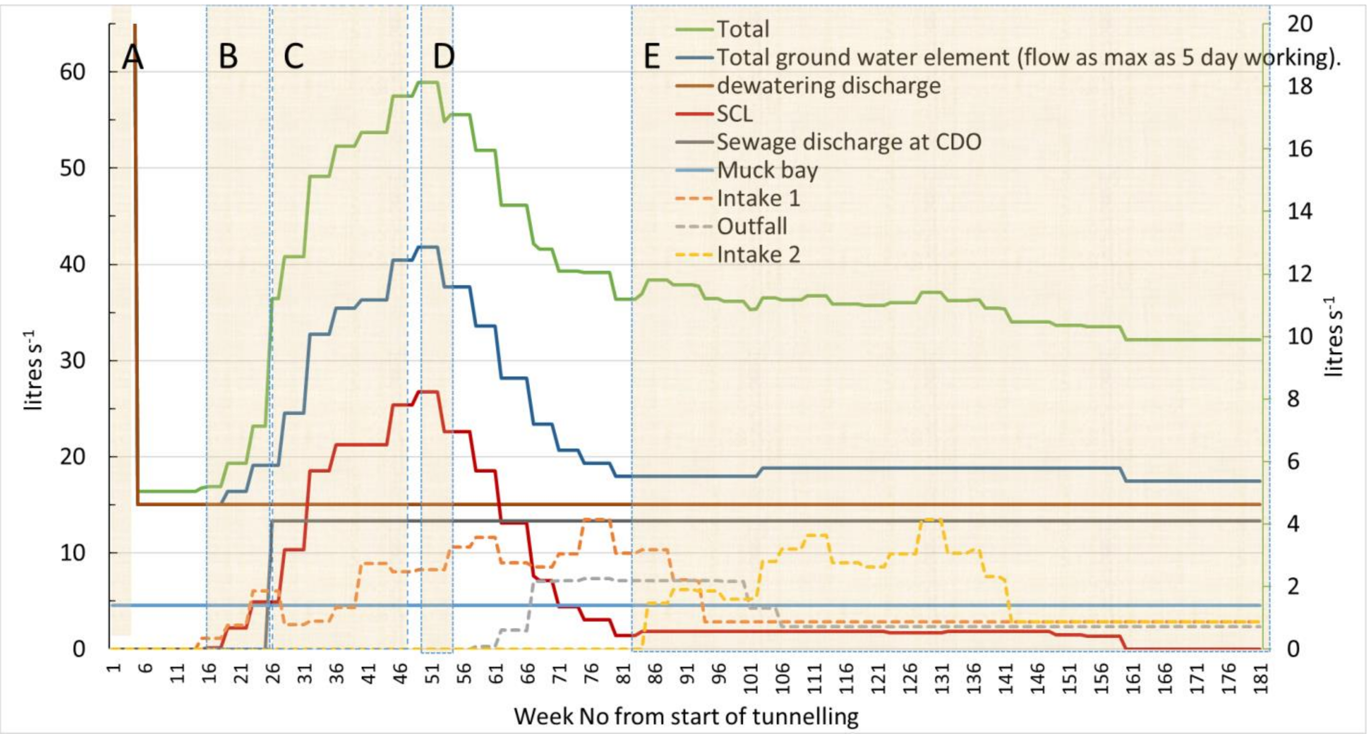

Figure 7 Likely flow volumes discharged at the CDO location from the start of tunnelling. Discharge volumes from 'Muck Bay' and TBM tunnelling for SZC intake 1, outfall and intake 2 are shown on the right hand axis. Timing is based on Hinkley C development and subject to change.

Groundwater reduces to 15ls^{-1} after the first month and then, at around week 17, is added to by the discharge from the SCL (spray concrete-lined) works for approximately 50 weeks. Additional groundwater contributions during tunnelling increase groundwater input to around 42ls^{-1} (Case D). Thereafter, the groundwater element of the discharge reverts to levels of around 15ls^{-1} (Case E). Except for DIN and ammoniacal nitrogen the EVF calculation of groundwater derived substances uses only the groundwater volume with no assumption of additional dilution/contribution from the sewage discharge.

Figure 7 shows that the maximum discharges of flows that contain metals will occur during Case A. The maximum DIN input will be during Case D (between weeks 45 and 53 when the groundwater element reaches 42ls^{-1}). Case D is relatively transitory. Case D1, which includes an extreme case of sewage discharge, is also likely to be highly transitory. Once the SCL works are complete (Case E) the total groundwater discharge falls to 15ls^{-1}. The waste from the TBM soil conditioning chemicals if present is likely to make the largest contribution during Case E. The total discharge volume during Case E is approximately 34ls^{-1}.

Wastewater will be generated if mud assisted drilling is adopted for construction of the horizontal cooling water tunnels. The initial estimated volume of wastewater generated during this process is based on that derived from the construction discharge schedule developed for Hinkley Point C

For assessment, maximum loads are to be addressed within modelling scenarios. The issues of concern being, maximum loads of; heavy metals, Un-ionised ammonia, Dissolved Inorganic Nitrogen (DIN), Biochemical oxygen demand, faecal coliforms from treated sewage effluent, metals and DIN from groundwater and any tunnel boring additives that are not recovered for reuse.

4.4 Total loads of cadmium and mercury

There are specific requirements for the minimisation of the annual loads of selected hazardous substances and cadmium and mercury are included and require assessment. Figure 8 shows the discharge rate for groundwater left axis and blue line. Groundwater discharge is very high (above left axis maximum shown) in the first 28 days (124ls^{-1}) during the main dewatering on site and then decreases rapidly to around 15ls^{-1}.

From around week 16 to 76 groundwater varies due to overlapping contributions from tunnelling of intake 1, the outfall and intake 2. Over this whole period the cumulative load of cadmium and of mercury derived from the groundwater is shown by the brown and red lines and the scale on the right-hand axis. Over this 3.5 year period the cumulative load for cadmium is 0.45kg and for mercury is 0.05kg. Both these load figures meet the requirement to not exceed a significant annual load of 1kg for mercury or 5kg for cadmium. Trace contamination of raw materials used in demineralisation of water used during cold commissioning may contribute additional loadings of mercury and cadmium but based on maximum annual loadings during normal operation when the systems are in full use the additional annual loadings, cadmium 0.37kg and mercury 0.099kg (Table 29) would not result in exceedance of the significant loads.

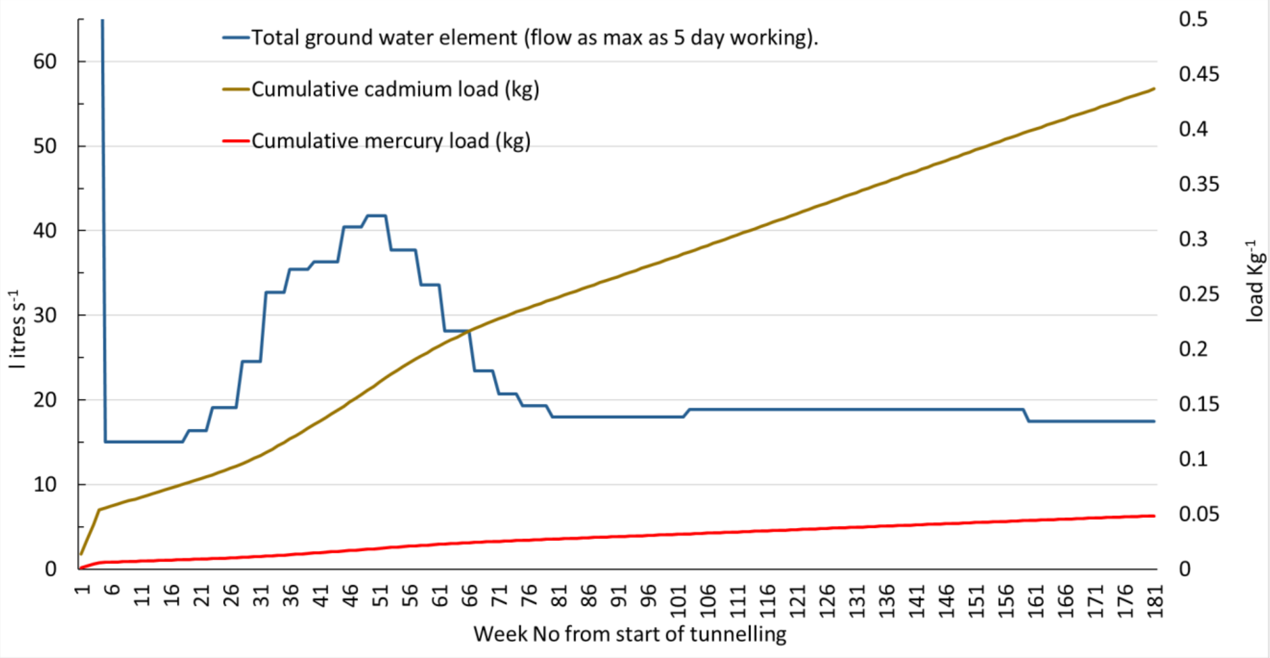

Figure 8. Just over 3.5 year timeline of groundwater discharge (ls^{-1} left axis) and resulting cumulative metal load for Mercury and Cadmium (kg right axis).

4.5 Discharges screened out of assessment

Other temporary and more variable discharges to marine water may form part of the surface drainage strategy during the construction phase together with the range of expected discharges detailed above. The main expected contaminants in these discharges are suspended solids, Biochemical Oxygen Demand (BOD) and hydrocarbons. Assessment using the Environment Agency/Defra screening of contaminant contributions from surface drainage sources (Defra and Environment Agency Guidance, 2016) is not appropriate due to their highly variable nature over the construction period. Hydrocarbons can be removed from effluent prior to discharge by the incorporation of suitable oil separators within temporary drainage systems and any potential for chemical and oil spills during construction activities, whilst recognised, would be covered under the Government waste management guidelines. Therefore, no chemical release effects to the water and sediment quality of the local area are expected from these variable sources and they are therefore screened out of further assessment. Siltbuster or similar technology would be used to manage suspended sediments in drainage.

5 Screening assessment of construction discharge

5.1 Background

As part of a surface water risk assessment (Environment Agency and Department for Environment Food and Rural Affairs, 2016) the concentration of substances present in the discharge must be assessed against a list of specific pollutants and their Environmental Quality Standards (EQS). Initial screening tests (historically referred to as H1 tests) were conducted to determine if the concentrations of priority substances and specific pollutants in the discharge exceeded their respective EQS. For any substances that breach the EQS in the initial screening tests (Test 1) a further screening test is applied that takes account of initial dilution upon discharge (Test 5).

The EA Test 5 screening applies to the discharge from the CDO because the discharge is to the subtidal environment and beyond 50m from mean low water spring (MLWS) tidal level. Separate guidance is provided for assessment of large cooling water discharges that would occur during operation see section 9.

5.2 Handling of substance data

When calculating summary statistics for all substances, any values below the method detection limit were adjusted to a value equal to the detection limit. For metals, modelling tests use both total and dissolved concentrations to assess potential deterioration of surface water quality (Environment Agency, 2014). The total concentration of substances is used in the initial screen and in subsequent modelling to take account of uncertainty regarding the partitioning of substances into the dissolved phase as the groundwater mixes with the seawater. For several neutral hydrophobic chemicals and some metals, however, solubility would be expected to decrease under saline conditions (Turner, 2003). In this assessment only, dissolved substance data were available for the groundwater. The assessment includes the screening of the source terms against the saltwater EQS values presented in the Water Framework Directive (Standards and Classification) Directions (England and Wales) (WFD, 2015). EDF has reviewed the data from the boreholes that will form the longer-term network (those along the northern, western and eastern sides of the deep excavation) as well as wider data sets that are reflective of current arrangements, including temporary boreholes installed to enhance the efficacy of local dewatering. In each case, the 95th percentile for each of the substances of concern has been considered as this excludes anomalously high values while still providing a robust assessment. To enable a robust assessment of the potential impacts of the proposed discharge on the water environment and on the interest features to be made, the worst-case values have been selected from these datasets. Summary statistics for the concentrations of substances measured in the site groundwater carried forward to the screening assessment are shown in Table 7, 8 and 9.

The updated guidance for surface water pollution (Environment Agency, 2016) recommends the application of an initial test (Test 1) for discharges to Transitional and Coastal (TraC) waters in which the discharge concentration is compared to the relevant quality standard or equivalent for that substance. Where the discharge concentration exceeds the standard concentration, further assessment is required. When the discharge concentration is divided by the EQS in Test 1 any values of 0.5 and above are taken forward to the next stage of screening. As this construction discharge will be subtidal and is over 50 metres offshore, a further test (“Test 5”) is recommended. Test 5 divides the concentration of a substance and volume discharged (the discharge specific Effective Volume Flux, EVF) by its EQS minus background concentration (the location specific Allowable Effective Volume Flux, AEVF). If the EVF is not greater than the AEVF, then the discharge is insignificant and is screened out. The AEVF references the discharge depth and this value can be up to a maximum of 3.5 metres. For Sizewell the discharge depth for construction relative to chart datum is greater than 3.5 metres therefore 3.5 this is the AEVF used for comparison as shown in Table 8 and 9.

The discharge concentrations in grey shading in Table 7 are those used in the EVF calculation. Theoretically, the mean values could be used in the EVF calculation with the annual average EQS, however, this assumes that the mean discharge is an annual average. As the discharge concentration is determined by the dewatering process it is not appropriate to assume a random process contributing to the discharge concentration, and the discharge is intended to occur over several years. There could, for instance, be many months when values above the mean are present in the chemical discharge. As a precautionary approach, the 95th percentile discharge concentrations have been used for calculating the EVF values.

As the suspended sediment concentration at a given location directly affects light penetration and the potential for increased phytoplankton growth, the reference concentration of dissolved inorganic nitrogen (DIN) for TraC waters for the Good/Moderate boundary also references the suspended sediment concentration. Several monitoring studies have measured the suspended sediment regime off Sizewell (BEEMS TR189). Suspended Particulate matter (SPM) data was also gathered from MODIS satellite database (Dolphin, Silva and Rees, 2011) for a project evaluating natural sediment variability in Regional Environmental Assessment areas in the North Sea and English Channel. Satellite data for suspended particulate matter showed average mean SPM value at Sizewell during April to August of 31mgl^{-1}(and average maximum 80mgl^{-1}) and during September to March 73mgl^{-1}(and average maximum 180mgl^{-1}). An annual mean SPM for these data was 55.3mgl^{-1}. With reference to the suspended sediment levels associated with WFD nitrogen standards (Appendix C) and based on the satellite data and previous monitoring surveys Sizewell is classed as of intermediate turbidity (Water Framework Directive Standards and Classification Directions, 2015).

The volume of water that would need to be disposed of during the initial dewatering phase is in the order of 300,000 m^3 based on the hydraulic properties of the materials within the cut-off wall around the main construction site. It is estimated that to lower groundwater within the cut-off wall to the design level will take 28 days at a rate of 124ls^{-1}. Following the initial lowering of water levels there will be some nominal ongoing discharge throughout the construction phase to deal with nuisance water (rainfall, seepage through the cut-off wall) but the volumes will be very small at estimated values of 15ls^{-1}. Groundwater samples were analysed during 2014-16 (ATKINS, 2016). A survey of exploratory boreholes across the site analysed for a suite of chemicals and polycyclic aromatic hydrocarbons, PCBs, various organic chemicals commonly present as contaminants in groundwater were below respective detection limits (details Appendix A). Ammonium, nitrite, and nitrate and eight metals analysed for were above detection and the results are summarised Table 7.

Table 7 Metal concentration range measured in SZC construction site groundwater and relevant EQS values and marine background concentrations.

Substance	Mean dissolved concentration µg l^{-1}	95% dissolved concentration µg l^{-1}	Saltwater EQS AA µg l^{-1}	Saltwater EQS MAC µg l^{-1}	Marine Background concentration µg l^{-1}
Arsenic	3.55	11.5	25	-	1.07
Cadmium	0.10	0.18	0.2	1.5	0.05
Chromium	6.39	18.45	0.6	32	0.57
Copper	1.87	4.25	3.76	-	2.15
Lead	1.07	1.07[1]	1.3	14	-
Zinc	7.34	17.5	6.8[2]		15.12
Mercury	0.013	0.023	-	0.07	0.02
Iron	395	1500	1000	-	50

1 The limited number of values above detection limits leads to a mean value higher than the 95 percentile which represents a value below detection limit therefore the higher mean value is used here 2: The EQS for zinc may be adjusted to take account of local background

Two assessments are made for groundwater substance inputs, one for the initial 28 days of construction period during which the groundwater contribution to site discharges is at a rate of 124ls^{-1} (Table 8) and for the remainder of the construction period at 15ls^{-1}(Table 9).

Table 8 Determination of whether after discharge and initial mixing the calculated contribution to dissolved metals from the site groundwater (124ls^{-1}, Case A) during the first 28 days of the construction period is likely to exceed the acceptable threshold above which significant impacts may occur

Parameter value	**95 percentile Dissolved metal concentration** **µg l^{-1}**	**TraC Water test 1 <100%EQS**	**Pass/Fail**	**TraC Water test 5 EVF<AEVF**	**Pass/Fail**
Arsenic	11.5 (n=82,151) [i]	**0.46** (11.5/25[ii])	≤1.0 (Pass)	0.06 (11.5x0.124[iii])/(25-1.07[iv])	0.06<3.5[v] (Pass)
Cadmium	0.18 (n=17,151) [i]	**0.9** (0.18/0.2[ii])	≤1.0 (Pass)	0.149 (0.18x0.124[iii])/(0.2-0.05[iv])	0.149<3.5 [v] (Pass)
Chromium (mean)	18.45 (n=111,152) [i]	**30.75** (18.45/0.6[ii])	≥1.0 (Fail)	**76.3** (18.45x0.124[iii])/(0.6-0.57[iv])	76.3>3.5 [v] **(Fail)**
Chromium (95 Percentile)	18.45 (n=111,152) [i]	0.58 (18.45/32[ii])	≤1.0 (Pass)	0.07 (18.45x0.124[iii])/(0.6-0.57[iv])	0.07<3.5 [v] (Pass)
Copper	4.25 (n=57,151) [i]	**1.13** (4.25/3.76[ii])	≥1.0 (Fail)	0.33 (4.25x0.124[iii])/(3.76-2.15[iv])	0.33<3.5 [v] (Pass)
Zinc	17.5 (n=134,151) [i]	**2.6** (17.5/6.8[ii])	≥1.0 (Fail)	N/A (17.5x0.124[iii])/(6.8-15.12[iv])	N/A
Mercury (95 percentile)	0.023 (n=31,151) [i]	**0.33** (0.023/0.02[ii])	≤1.0 (Pass)	0.057 (0.023x0.124[iii])/(0.07-0.02[iv])	0.057<3.5 [v] (Pass)
Iron	+1500 (n=37,151) [i]	**1.5** (1500/1000[ii])	≥1.0 (Fail)	0.196 (1500x0.124[iii])/(1000-50[iv])	0.196<3.5 [v] (Pass)
Lead	1.07 (n=3,151) [i]	(0.82) (1.07/1.3[ii])	≤1.0 (Pass)	0.44 (1.07x0.124[iii])/(1.3-1.0 [vi])	0.44<3.5 [v] (Pass)
Lead (95th percentile)	0.58 (n=3,151) [i]	0.04 (0.58/14[ii])	≤1.0 (Pass)	0.005 (0.58x0.124[iii])/(1.3-1.0)	0.005<3.5 [v] (Pass)

[i] Number of values measured above detection and total number of values; [ii] Annual average EQS value (also includes 95 percentile for chromium and lead) [iii] total construction effluent discharge m^3/sec [iv] mean background concentration Sizewell TR314 2014/15 and Appendix E; [v] Allowable effective volume flux is taken as the maximum value of 3.5

Table 9 Determination of whether after discharge and initial mixing the calculated contribution to dissolved metalsfrom the site groundwater (uses maximum groundwater value, Case D) during the main construction period is likely to exceed the acceptable threshold above which significant impacts may occur

Parameter value	**Calculated dissolved metal discharge concentration** $\mu g\ l^{-1}$	**TraC Water test 1 <100%EQS**	**Pass/Fail**	**TraC Water test 5 EVF<AEVF**	**Pass/Fail**
Arsenic	11.5 (n=82,151) [i]	**0.46** (11.5/25[ii])	≤1.0 (Pass)	0.02 (11.5x0.042[iii])/(25-1.07[iv])	0.02<3.5[v] (Pass)
Cadmium	0.18 (n=17,151) [i]	**0.9** (0.18/0.2[ii])	≤1.0 (Pass)	0.05 (0.18x0.042[iii])/(0.2-0.05[iv])	0.05<3.5 [v] (Pass)
Chromium (mean)	18.45 (n=111,152) [i]	**30.75** (18.45/0.6[ii])	≥1.0 (Fail)	**25.64** (18.45x0.042[iii])/(0.6-0.57[iv])	**25.64>3.5 [v]** **(Fail)**
Chromium (95 Percentile)	18.45 (n=111,152) [i]	0.58 (18.45/32[ii])	≤1.0 (Pass)	0.024 (18.45x0.042[iii])/(0.6-0.57[iv])	0.024<3.5 [v] (Pass)
Copper	4.25 (n=57,151) [i]	**1.13** (4.25/3.76[ii])	≥1.0 (Fail)	0.11 (4.25x0.042[iii])/(3.76-2.15[iv])	0.11<3.5 [v] (Pass)
Zinc	17.5 (n=134,151) [i]	**2.6** (17.5/6.8[ii])	≥1.0 (Fail)	N/A	N/A
Mercury	0.023 (n=31,151) [i]	**0.33** (0.023/0.02[ii])	≤1.0 (Pass)	0.01 (0.023x0.042[iii])/(0.07-0.02[iv])	0.01<3.5 [v] (Pass)
Iron	1500 (n=37,151) [i]	**1.5** (1500/1000[ii])	≥1.0 (Fail)	0.07 (1500x0.042[iii])/(1000-50[iv])	0.07<3.5 [v] (Pass)
Lead	0.58 (n=3,151) [i]	(0.45) (1.07/1.3[ii])	≤1.0 (Pass)	0.15 (1.07x0.042[iii])/(1.3-1[vi])	0.15<3.5 [v] (Pass)
Lead (95th percentile)	0.58 (n=3,151) [i]	0.04 (0.58/14[ii])	≤1.0 (Pass)	0.002 (0.58x0.042[iii])/(1.3-1[vi])	0.002<3.5 [v] (Pass)

[i] Number of values measured above detection and total number of values; [ii] Annual average EQS value (also includes 95 percentile for chromium and lead) [iii] maximum groundwater construction effluent discharge (Case D) m^3/sec [iv] mean background concentration Sizewell TR314 2014/15 and Appendix E; [v] Allowable effective volume flux is taken as the maximum value of 3.5, [vi] lead background detection limit in BEEMS TR189

The Effective Volume Flux of the discharge (EVF) is defined as:

$EVF = (EFR \times RC) / (EQS - BC)\ m^3\ s^{-1}$

Where:

EFR = the effluent discharge rate (m^3 s^{-1})
RC = release concentration of the priority substance of concern (μgl^{-1})
EQS = EQS (AA) of the substance of concern (μgl^{-1})
BC = mean background concentration at the discharge location (μgl^{-1})

The metals contamination in boreholes can vary and the data provide dissolved concentrations only so the 95 percentile concentrations have been used to provide a more conservative assessment.

Dewatering discharges do not pass initial screening tests for chromium during the first 28 days of the construction period. Although zinc concentrations are relatively low at just over twice the EQS because the site background concentrations for zinc are above the EQS, Test 5 cannot be conducted. Both zinc and chromium are therefore taken forward for more detailed modelling.

5.3 Screening assessment of un-ionised ammonia resulting from construction discharge to the marine environment

Ammonia enters freshwater and marine water bodies from sewage effluent inputs, from industrial and agricultural activities and from the breakdown of organic matter. In the marine environment the toxicity of ionised ammonia (NH_4) 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 NH_4 can also be toxicologically significant. Total ammonia values of 1100 (annual average) and 8000µg/l NH_4-N (WQTAG086, 2005) are therefore set as guide values for habitats andthese are considered. In general, the un-ionised form of ammonia is more toxic than the ionised form. At higher pH values, un-ionised ammonia represents a greater proportion of the total ammonia concentration. Temperature increase also raises the relative proportion of un-ionised ammonia, but this effect is much less marked than for pH change, e.g. a temperature increase of 10°C (from 10 to 20°C) may double the proportion of un-ionised ammonia, but a pH change from a pH 7 to pH 8 produces an approximately tenfold increase (Eddy, 2005). A greater percentage of ammonia will also be in the un-ionised form when the salinity is lower.
The concentration of un-ionised ammonia can therefore be derived from knowledge of the total ammoniacal nitrogen concentration (i.e. NH_4 as N), the salinity, the pH and temperature using the EA calculator (Clegg and Whitfield, 1995). pH is the most important with an approximate doubling in un-ionised ammonia concentration between pH 7.5 and 8.

The EQS for un-ionised ammonia is 21μgl^{-1} expressed as an annual average, however being consistent with the previous screening, this value is compared with the 95th percentile source contributions. The 95th percentile values used for the source terms were a groundwater ammonium concentration of 5557.2μgl^{-1} as N and a treated sewage effluent maximum concentration of 20,000μgl^{-1} as N. 20,000μgl^{-1} as N represents the design standard of the sewage treatment plant.

Table 10 shows the un-ionised ammonia concentration in construction effluents based on initial physiochemical conditions and the hypothetical un-ionised concentration based on seawater conditions if the total ammonia (NH_4) concentration was undiluted. Cases A, D1, D and sewage only are considered. In each example case the un-ionised ammonia concentration in the source effluent under initial physicochemical conditions exceeds the EQS and so would fail Test 1 of the H1 assessment. Under seawater conditions concentrations of un-ionised ammonia would exceed the EQS by a higher margin. Because the effluent discharges represent relatively small discharge volumes and the un-ionised ammonia concentrations are not many times above the EQS the test 5 dilution assessment results in all discharges passing the assessment.

At this stage further assessment would normally not be required but further work has been conducted to assess the potential extent of the mixing zone that is predicted to be in exceedance of the EQS.

Table 10. Starting concentrations before mixing with seawater for un-ionised ammonia concentrations for groundwater (Case A), treated sewage and combined discharge (D and D1) derived using the EA calculator as a source term before mixing. (un-ionised ammonia levels are also shown for seawater conditions assuming no dilution of the source effluent)

Discharge	**Groundwater ls^{-1}**	**Sewage ls^{-1}**	**Ammoniacal nitrogen (N) (µgl^{-1})**	**Salinity**	**Temp °C**	**pH**	**Un-ionised ammonia (µgl^{-1})**	**Test 5 Result**
Case A	124	-	5,557	1	11.43	7.3	22.8	0.14
Case D	41.7(15+26.7)[1]	13.3	9,049	1	11.43	7.3	37.2	0.10
Case D1	41.7(15+26.7)	30	11,600	1	11.43	7.3	47.6	0.16
Sewage discharge only	-	13.3	20,000	1	11.43	7.3	82.1	0.05
Case A	124	-	5,557	33.3	11.43	8.05	22.8	0.61
Case D	41.7(15+26.7)[1]	13.3	9,049	33.3	11.43	8.05	37.2	0.44
Case D1	41.7(15+26.7)	30	11,600	33.3	11.43	8.05	47.6	0.73
Sewage discharge only	-	13.3	20,000	33.3	11.43	8.05	82.1	0.23

[1] groundwater from main site and from tunnelling

For some Cases small sources which would dilute the concentration, but which may not be present all the time have not been considered (e.g. in case D there could be 4 litres per second of additional water not containing DIN).

1) Case A total discharge is 124ls^{-1} with a 95th percentile concentration of 5,557µgl^{-1} ammoniacal Nitrogen as N.
2) Case D total discharge is 55ls^{-1} with a 95th percentile concentration of 9,049µgl^{-1} ammoniacal Nitrogen as N.
3) Case D1 total discharge is 71.7ls^{-1} with a 95th percentile concentration of 11,600µgl^{-1} ammoniacal Nitrogen as N.
4) Sewage only discharge is13.3ls^{-1} at a planned maximum of 20,000µgl^{-1} ammoniacal Nitrogen as N.

Mixing of the different sources contributing ammoniacal nitrogen and the ratio of un-ionised to ionised ammonia upon mixing with seawater is evaluated with dilution rates using CORMIX and these data are presented and discussed in section 6.

5.4 Dissolved inorganic nitrogen (DIN) contribution to nutrient status

Background winter DIN concentrations in Greater Sizewell Bay, are mean 25.5µmol (minimum 21, maximum 31) or, as N, 357µgl^{-1} (minimum 0.30, maximum 0.43) (source: BEEMS Technical Report TR314 **Error! Reference source not found.**).

The discharge of DIN at the CDO is made up of the following sources:

1. The total dewatering discharge (with a maximum flow during Case D of approximately 41.7ls^{-1}) with a mean concentration of 1021µgl^{-1} as N;

2. The sewage treatment from the main plant construction with a flow of 1150m^3 day^{-1} or 13.3ls^{-1}. With secondary treatment, this implies 5000µgl^{-1} of ammoniacal nitrogen as N. This value is used conservatively as a mean but is most likely to represent the 95th percentile concentration.

In addition to these sources a further small volume of discharge ~3ls^{-1} of discharge may be contributed from sources not containing DIN from the use of tunnelling chemicals. Combining the flow sources gives a maximum flow (during Case D) of 55ls^{-1} with a concentration 1980µgl^{-1}(as N) if conservatively ignoring the dilution of 3ls^{-1} which may not always be present.

5.4.1 Maximum concentration and flow

Considering additional contributions besides ammoniacal nitrogen to nitrogen in sewage the maximum concentration of DIN in the sewage discharge could be up to 23,000µgl^{-1} of nitrogen as N (Table 11). The mean flow rate is 13.3ls^{-1} but flow may peak intermittently up to 30ls^{-1}. It should be stressed that the 95th percentile concentration of the sewage treatment plant is still 5000µgl^{-1}. This value has been used as previously and is still a conservative estimate of the total loading discharged. Maximum discharge flow occurs during the first month at 124ls^{-1} but consists only of groundwater contributions to DIN. It is possible that maximum discharge flow could occur during the Case D period. Using mean conditions for concentration and total maximum combined flow, regime D1$_{mean}$, becomes 71.7ls^{-1} at 2,680µgl^{-1} (as N). In a very unlikely case the maximum sewage flow (30ls^{-1}) and maximum concentrations for sewage (23000µgl^{-1}) and 95th percentile for ground water (5,636µgl^{-1}), would be 71.7ls^{-1} at 12900µgl^{-1} (as N) which is the D1 Case. The latter stages of the construction/commissioning period are E$_{mean}$ and E with flow rates of approximately 28.3ls^{-1} (there would be further volume contributions from tunnelling wastewater, but these would not contribute DIN) and concentrations of 2,890µgl^{-1} and 5,340µgl^{-1} respectively.

The discharges during construction that may contain DIN are likely to be of variable duration and concentration. Table 11 illustrates some potential cases. For inorganic nitrogen the Water Framework Directive standard for Good status is based on the winter dissolved inorganic nitrogen 99th percentile for TraC waters of intermediate turbidity (suspended solids levels of 10 to <100mgl^{-1}) 99th percentile winter concentration that varies according to turbidity. For the H1 assessment a value of 980µgl^{-1} as a 99th percentile for Good status has been adopted as a benchmark standard. In each case considered the background benchmark value exceeds the benchmark nitrogen value in the discharges (Table11).

Table 11. DIN concentrations for groundwater (GW), treated sewage (STW) and combined discharge.

Case	Groundwater flow ls^{-1}	DIN concentration µgl^{-1}	Sewage Flow ls^{-1}	DIN concentration µgl^{-1}	DIN Discharge concentration µgl^{-1}	Test 5 Result
A	124	5636 (95%)	0	0	5636	1.26[1]
D1 mean	41.7	1021 (mean)	30	5000	2686	0.35
D1	41.7	5636 (95%)	30	23000	12901	1.67
E mean	15	1021 (mean)	13.3	5000	2891	0.15
E	15	5636 (95%)	13.3	5000	5337	0.27

[1] Test 5 is (m^3/sec x discharge concentration)/(EQS-background) for this example this is (0.124 x 5636)/(980-426) =1.26 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 Environment Agency guidance unpublished 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.

Applying Test 5 of the H1 assessment to the discharges of DIN from example cases during the construction period (Table 11) all values passed the assessment following initial dilution i.e. none of the values exceeds a value of 3.5. Although the DIN assessment indicates that the discharge concentration and volume are likely to have a limited extent of effect the natural background for DIN varies during the year and inputs during summer periods when nitrogen is more limited may have a greater effect on phytoplankton growth therefore further modelling assessment of the loadings is made to determine this.

The highest most continuous daily loadings will be contributed during Case $D1_{mean}$, which includes a maximum sewage discharge rate and highest groundwater discharge rate (except for the initial dewatering period in the first month of construction). The total flow rate during $D1_{mean}$ is 71.7$ls^{-1}$and a concentration (represented by the 95th percentile for sewage) of 2680µgl^{-1} would lead to a discharge of 16.6kgd^{-1}.

During commissioning, un-ionised ammonia is used (approximately 0.66kgd^{-1} average daily discharge) in the steam generator of the EPR and as this precedes construction/operation of the cooling water system the discharge will also occur through the CDO. Nitrogen input from commissioning is added to the groundwater and sewage loading derived for Case $D1_{mean}$ to provide a representative worst-case daily loading of 17.3kgd^{-1} DIN. This loading is therefore used for assessment of the potential impact on phytoplankton growth for the construction/commissioning period.

5.5 Phosphorus influence on nutrient status

Phosphorus load discharged during construction is contributed from groundwater, from treated sewage effluent and from use of phosphate during commissioning. A concentration 10mg l^{-1} as P was derived for treated sewage from package units based on Natural England, 2016. For groundwater a 50th percentile value of 0.04mg l^{-1} as TP was derived for Thames groundwater by Stuart and Lapworth, 2016 and is used here as a substitute prior to site data becoming available. For the cold commissioning input reference was made to HPC-EDECME-AU-000-RET-000063, 2017 and a maximum discharge of phosphate per day based on a period of hydraulic testing and preservation of closed cooling circuits, chilled water and electrically produced hot water systems). A value of 594kg PO_4 use over 85 days (covering various phases of EPR commissioning) was used as a reference to derive a daily value of 2.28kg as P. Adding the commissioning load to that of treated sewage (~26kg) and groundwater gives a total load of 28.2kg for assessment of combined nutrient inputs during construction and cold commissioning using a phytoplankton growth model.

5.6 BOD influence on dissolved oxygen

The Water Framework Directive applies to 1 nm from the coast (approx. 1850m) and from 2016 the Marine Strategy Framework Directive applies to the UK boundary. These 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 background BOD near to the Sizewell B cooling water discharge based on monitoring done in 2010 (BEEMS Technical Report TR189) has a mean value of 2mgl^{-1}. Any area not exceeding 1.5mgl^{-1} deviation from background is expected to generate less than 0.5mgl^{-1} impact on dissolved oxygen (OSPAR Comprehensive studies report, 1997). Based on Hinkley Point information, during construction of SZC the sewage treatment works is expected to achieve a maximum concentration of BOD of 40mgl^{-1} (i.e. over 5 days).

Based on the expected number of staff on site during the construction phase and waste water production of 100 litres/per head/per day a more typical sewage discharge of 13.3ls^{-1} (Case D) is expected through most of the construction phase but a maximum of 30ls^{-1} is also included as Case D1. Groundwater contribution is not yet confirmed so a value of 5mgl^{-1} BOD (representing Good status classification of surface waters of specific types) and this together with relevant groundwater flow rates is taken account of for Case A, D and D1 to allow assessment.

5.7 Coliforms, enterococci – bathing water standards and shellfish

This assessment is based on bathing water regulations (2013. No. 1675) for coastal and transitional waters for which Good status requires that at the bathing water monitoring points 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 therefore necessary to confirm that treatment and dilution of the sewage effluents produced during the construction period meets the required standard. An assessment of effluent treatment levels was considered to derive initial loadings of sewage microorganisms and then the CORMIX model was used to assess dilution of the discharge and this is described in section 6.

5.8 Tunnelling wastewater and chemicals

The offshore cooling water infrastructure consists of two subterranean intake tunnels and one outfall tunnel. Tunnels would be excavated by tunnel boring machines (TBMs) from land. Spoil from the cutting face of the TBMs would be removed by a screw conveyor, then transported by conveyor belt to the landward muck bay for licenced disposal.

Groundwater would be generated from digging the galleries allowing access to the tunnels. During the transport of spoil material, groundwater and TBM chemicals can leach from the conveyor belts and fall to the tunnel floor. Wastewater on the tunnel floor would be discharged via the CDO. Discharges would be treated with a silt-buster or similar technology to minimise sediment inputs.

The waste from the TBM soil conditioning chemicals if present is likely to make the largest contribution during Case E as two tunnel boring machines would be in operation and two volumes of makeup water containing conditioning chemicals would be discharged. This assumption is based on the work conducted at HPC. The total discharge volume during Case E is approximately $34ls^{-1}$ of which ~$6ls^{-1}$ is contributed by soil conditioning water and chemicals. It is uncertain whether similar chemical use to that planned for HPC will occur during tunnelling for Sizewell C but representative worst case use and discharge scenarios are modelled based on HPC to allow assessment of the potential influence of discharges upon water quality at Sizewell.

Various chemicals may be required during the tunnelling process:

- fuelling and lubrication of the TBM;
- sealing the tunnel walls against water/soil ingress, and;
- ground conditioning.

Fuel and lubricants would be subject to management protocols and oil/chemical spills will be contained by appropriate treatment and disposal. Sealants and greases are impervious to water and will remain associated with the tunnel walls or be removed with the spoil.

The underlying geology at Sizewell differs from Hinkley Point and a bentonite slurry tunnelling method is anticipated at Sizewell. Bentonite is a rock formed of highly colloidal and plastic clays composed mainly of montmorillonite, a clay mineral and is regularly used in construction and offshore drilling operations. Bentonite is included on the OSPAR list of PLONOR substances (pose little or no risk to the environment). These substances do not normally need to be strongly regulated as, from assessment of their intrinsic properties, the OSPAR Commission considers that they pose little or no risk to the environment. Although during operation of TBMs bentonite recovery systems are used (as bentonite is a valuable resource in the tunnelling process) the potential release into the receiving waters is assessed. The World Health Organisation (WHO, 2005) reviewed information on environmental properties of bentonite and describe several short-term studies (24 hours) on marine fish, crustacea and molluscs for which no mortality was observed at an exposure concentration of $7500mgl^{-1}$ sodium bentonite (Daugherty, 1951). A value of $19000mgl^{-1}$ was also recorded as a 96hour LC_{50} for the rainbow trout a freshwater fish species (Sprague and Logan, 1979).

A bentonite concentration in the $6l^{-1}$ volume per second of tunnelling wastewater of $50mgl^{-1}$ is estimated (EDF, 2010). The total volume of wastewater including groundwater generated during tunnelling is estimated as 34.3 l^{-1} per second and the resulting bentonite concentration would therefore be $8.8mgl^{-1}$. There is no EQS established for bentonite so the 95th percentile and mean plume area is derived to determine extent of any potential influence on water quality based on the limited effects dataset.

In some TBM soil conditioning applications several different surfactant chemicals may be required. The use and discharge of two surfactant chemicals the anti- clogging agent BASF Rheosoil 143 and the soil conditioning additive CLB F5 M that are planned for use with the HPC tunnelling operation and that present higher risk quotients in terms of chemical properties are modelled for Sizewell. This approach has been taken to provide a representative upper bounding assessment of potential effects of discharges from this process. The active substances in the TBM chemical products were identified from respective material safety datasheets. The substances identified are surfactants from chemical groups commonly found in household detergent products for which there are a range of toxicity studies available. Based upon common elements of their chemical composition, Predicted No Effect Concentrations (PNEC) have been established for representative surfactants and these are applied. PNEC values shown in Table 12 for each active substance are either taken directly from relevant risk assessment reports i.e. for 2-methyl-2-4 pentanediol (SIDS initial assessment report, 2001), or use the lowest PNEC from a substance group assessment i.e. PNEC values calculated for other alcohol ethoxylate sulphates are derived for representative carbon chain length substance or worst case if not known (Table 15 in HERA, 2004,) and for mono-C10-16-alkyl sodium sulphate (Table 13 HERA 2002). The Effective Flux Volume (EVF) is calculated for all the active substances and the discharge assessment is based on the component within the greatest EVF equating to the product that is present in the highest quantities and/or the lowest PNEC. In the case of the anti- clogging agent BASF Rheosoil 143, the active substance is sodium lauryl ether sulphate and for soil conditioning-additive, CLB F5 M the active substances with the lowest PNEC is from the mono-C10-16-alkyl sodium sulphate group (Table 12).

Table 12 ‘H1’ assessment of example ground conditioning chemicals and their active substances. The initial screening result for subtidal discharges in Transitional and Coastal waters (TraC)Test 5 is provided. Chemicals failing the TraC Test are assessed in greater detail.

Conditioning Product	**Estimated discharge concentration of active substance (mg/l)**	**Saltwater AA EQS (μgl^{-1}) [1]**	**Background concentration (μgl-1)**	**Effective volume flux (Case E) Total flow 34.3 l/s**	**TraC Water test 5 EVF < 3.0 (Pass/Fail)**
BASF Rheosoil 143	23.13	40	0	19.89	Fail
CLB F5 M Ethoxylated sulphates	7.71	35	0	7.58	Fail
CLB F5 M Mono- alkyl sodium sulphate	7.71	4.5	0	58.94	Fail

[1] These EQS values were derived from HERA (2004) for BASF Rheosoil 143 (sodium lauryl ether sulphate) and CLB F5 M (Ethoxylated, sulphates). [2] A group of compounds known as alkyl sulphates (AS) are found in CLB F5 M. Toxicity of AS compounds increases with increasing alkyl chain length (C12-C18), whilst solubility is inversely related to chain length. As such, C14 has the lowest reported NOEC values of the AS group. PNEC values for each AS chain-length have been established by applying a factor of 10 to the lowest chronic NOEC; the PNEC for C14 is 4.5 µg/l (HERA, 2002). The C14 PNEC is over 4-fold lower than the next most toxic chain-length AS, however, it has been applied as the EQS value as a precautionary measure. The PNEC values are conservative and values derived from micro- and mesocosm studies have identified PNECs in the range of 7.5 – 224 µg/l, and 110 µg/l, respectively (HERA, 2002; and references therein).

The estimated discharge concentration for each of the two conditioning products (three component surfactants) screened using the H1 methodology exceeded their respective EQS values in Test 1 and taking account of initial dilution are also predicted to exceed the maximum EVF value of 3.5 in Test 5. As these TBM values exceed the discharge test they are assessed in more detail using CORMIX modelling and this assessment is provided in the following section.

6 Review and assessment of potentially significant construction discharges

6.1 Background

Potential discharges to the marine environment have been assessed for each phase of the planned SZC development these are during construction, commissioning and operation. The H1 annex D1 2014 guidance (Environment Agency, 2014) is not considered to be entirely appropriate for the highly variable discharge volumes that occur during construction or to the large volume discharges associated with cooling water but is used here to provide an initial screening approach to identify chemicals that require more detailed assessment.

The main expected contaminants in construction discharges are suspended solids, BOD and hydrocarbons and are associated with the preparatory works and the main building erection and the presence of construction staff on site. The level of suspended solids and hydrocarbons in site drainage will be monitored and controlled within acceptable limits.

Measurement of groundwater contamination showed that total petroleum hydrocarbons, polycyclic aromatic hydrocarbons, volatile organic compounds, polychlorinated biphenyls and several physical factors were below reasonable levels of detection (Appendix A).

6.2 Discharge assessment methodology

The release and mixing of metals in the construction discharge was modelled using CORMIX US EPA supported mixing zone model (CORMIX Version 10.0GT HYDRO1 Version 10.0.1.0 April 2017) and the validated Sizewell curvilinear GETM model. CORMIX is used to predict the rate of chemical plume dilution and plume geometry from the Combined Discharge Outfall (CDO). The GETM model is a 3D hydrodynamic model with an inbuilt passive tracer to represent zinc and chromium. As a worst case, it was assumed that there was no loss of dissolved metals due to sediment absorption or biological uptake. Using these assumptions, concentrations can be scaled, as the modelled concentration was simply a function of dilution. The GETM model setup, calibration and validation are described in British Energy Estuarine & Marine Studies (BEEMS) Technical Report TR229. The surface is forced with re-analysed data from a meteorological model (ERA40 interim from ECMWF). The boundary conditions were forced by the Danish Maritime Safety Administration (DaMSA) operational forecasting models, as described in BEEMS Technical Report TR229. The proposed discharge is a low volume of groundwater, treated sewage effluent and tunnelling waste with concentrations of some contaminants exceeding EQS levels. The location and basic properties of the proposed discharge are shown in Table 13.

Table 13 CDO discharge scenarios during different phases (Case A-E) of construction at Sizewell C

Discharge Characteristics	Value
Location OSBG	647980 E 264340 N
Charted water depth (surface to bed) at discharge location	At least 4.0 m
Discharge flow	Varies with Case.
Discharge salinity	1 PSU

6.2.1 Modelling buoyant plume

In this study, the GETM model domain used a discrete grid with dimensions of 25m by 25m (at its finest resolution) and 21 vertical layers in a sigma co-ordinate system in which the layer thickness changed with water depth. The discharge flow for Case A (124ls^{-1}) was small compared with the total volume in the model grid cell, so to avoid excessive initial dilution, the discharge was made into the model surface layer, which is consistent with the results of the near field CORMIX modelling of a buoyant plume (see Figure 18, Appendix D).

It should be noted that in a buoyant plume with a discharge in an offshore location, unless mixing occurs, there will be no impact on seabed features. Consideration of the tidal cycle is useful in understanding the likely modes of impact. When the flood tide is at its strongest (with flow to the south), the discharge plume will initially be buoyant, and will then be advected in a narrow surface streak and mixed down. As mixing occurs the concentration within the streak will rapidly drop. At high water, near slack tide, a pool of the discharged water will form at the surface which will be advected northwards as the ebb tide increases.

6.3 Modelling metals discharges

Several metals were present, and these were assessed using tests 1 and 5. Initial checks using 95 percentile discharge concentrations measured in groundwater samples (ATKINS, 2014/16 data) showed that chromium exceeded its annual EQS and failed test 5 which assessed exceedance of the EQS following initial dilution. The zinc 95 percentile concentration in the discharge exceeded the mean EQS for zinc. It was not possible however to evaluate the zinc discharge using the initial dilution test 5 as the background concentration data for zinc indicate that it exceeds the EQS. Chromium and zinc were therefore taken forward for modelling assessment.
The mean background concentration of zinc in the environment is 15.12µgl^{-1} whilst the EQS is 6.8µgl^{-1}. Since the background levels are in exceedance of the EQS level, the EQS cannot be used as the threshold value for the CORMIX modelling. The detection limit for zinc in seawater samples (BEEMS TR314) is 0.4µgl^{-1}. Therefore, the threshold value for Zinc is set at 15.12+0.4 = 15.52µgl^{-1}, which represents the limit at which zinc would no longer be detected above the background concentration.

The mean background concentration of chromium in the environment is 0.57µgl^{-1} (BEEMS TR314) whilst the EQS is 0.6µgl^{-1}.

Both zinc and chromium were modelled for Case A (124ls^{-1}) with a source concentration of 17.5µgl^{-1}and 18.45µgl^{-1}, respectively. CORMIX shows that for zinc the outfall plume would no longer be detectable within 3m. For chromium the outfall plume would fall below the EQS within 25m.

CORMIX output data suggest an initial dilution, for both zinc and chromium, was 47-fold at 25m from the discharge (i.e. the same size as a single grid cell in GETM). GETM slightly under-predicts the initial dilution with the discharge volume of 124ls^{-1} entering the model surface layer. The total volume in the upper grid cell is approximately 120m^3. GETM shows a 40-fold dilution in the first 25m, meaning the plume extends slightly further. For chromium the plume concentrations are low, when evaluated against a chromium background of 0.58µgl^{-1} there was no exceedance at the bed but a mean surface area of 5.49ha exceeded the mean EQS 0.6µgl^{-1}.There was no exceedance at the bed for zinc and the total surface area for which the influence of the discharge plume would be detectable above background is 0.11ha, or 2 grid cells (BEEMS TR488).

Both CORMIX and GETM are conservative estimates as they do not include additional mixing and dilution due to waves.

6.4 Modelling un-ionised ammonia discharges

Ammoniacal nitrogen exists in both ionised and un-ionised form in the combined groundwater and sewage discharges from the construction site with the ratio of each determined by pH, temperature and salinity. Un-ionised ammonia is generally considered more toxic and has an annual average EQS of 21µgl^{-1}.
When a primarily freshwater effluent (groundwater + treated sewage) is discharged and mixes with seawater the total ammonia concentration is diluted eventually to background levels, the effluent becomes more

saline, pH increases and starting temperature eventually becomes the same as the background seawater. At each stage of dilution, the proportion of un-ionised ammonia is determined by the total ammonia concentration, the pH, temperature and salinity. By deriving the un-ionised ammonia concentration at successive stages of increasing effluent dilution the point at which the effluent is mixed enough to be below the EQS of 21µgl^{-1} (considering natural background) can be determined.

Discharge modelling can then be applied to derive the distance at which this required level of mixing is achieved such that the proportion of un-ionised ammonia plus background is below the EQS.
The initial total ammonia (NH_4-N) concentration derived by combining the groundwater and sewage sources was presented in (Table 11) and this value is applied in the EA un-ionised ammonia calculator along with the starting conditions of groundwater + sewage, pH, temperature and salinity. The output from this assessment provides the initial un-ionised ammonia concentration in the groundwater and sewage mix.

The physicochemical parameters required for the effluent/seawater mixing plot are provided in the start and finish components of the mixing relationship:

a. freshwater, of average pH (7.3) and 95th percentile of ammoniacal nitrogen (Atkins, 2014, 2016 and permit), and an average temperature of 11.43ºC (BEEMS TR131 Edition 2).

b. seawater, with a mean temperature of 11.43ºC, 50th percentile salinity (33.3) (BEEMS TR189) and the 50th percentile seawater pH (8.05) (BEMS TR189). The mean ammoniacal nitrogen in the sea water background was 11.38µgl^{-1} as N (BEEMS TR314).

A mixing figure (Figure 9) was used to take account of changing physicochemical conditions as the mainly freshwater discharge from the CDO mixes with seawater and becomes fully saline.

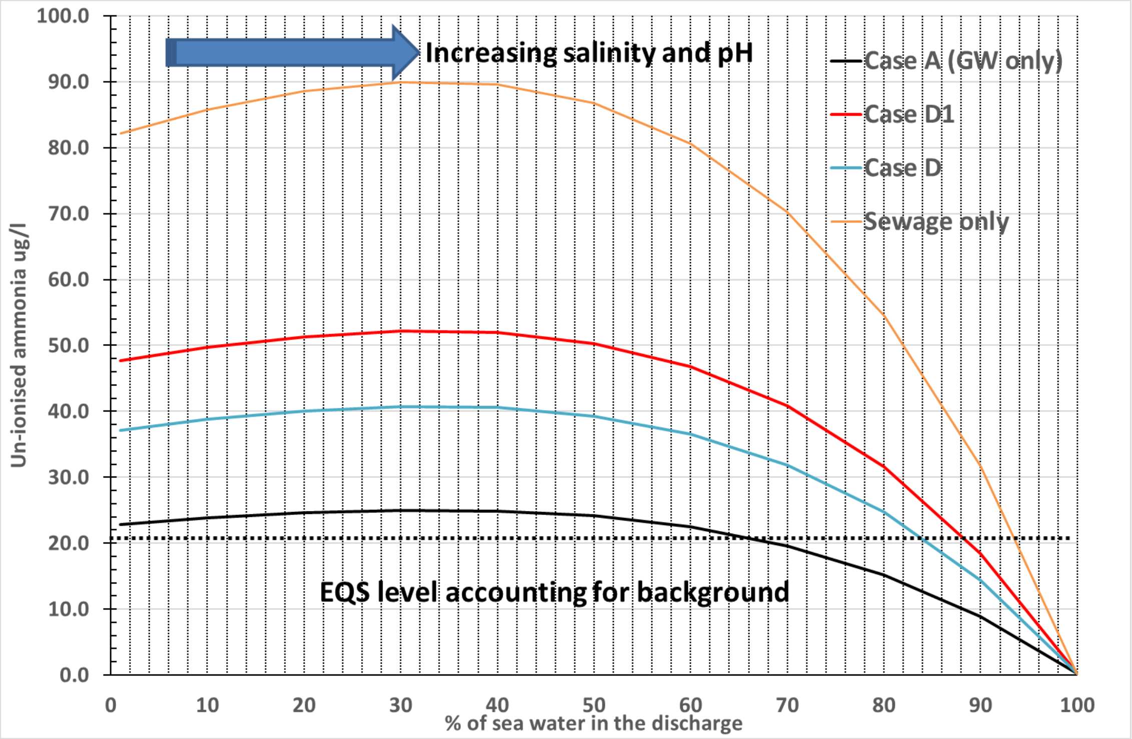

Figure 9. The change in proportion of un-ionised ammonia (µgl^{-1}) as the discharge, is mixed with seawater for sewage only, and cases Amax, D and D1

The associated change in the un-ionised ammonia concentration in the construction discharge relative to its annual average EQS was also assessed against the level of mixing. The calculations shown in Figure 9 are independent of the volume of the discharge, this graph therefore must be considered in combination with the estimated dilution rates derived from the CORMIX modelling. Case A, Case D1 and Sewage only discharges have been modelled with CORMIX. As Case D is a lower flowrate and source input, its impact will be lower, and was not modelled.

It is evident from **Error! Reference source not found.** that there is exceedance of the EQS (21µgl^{-1}) when less than 68% mixing has occurred for Case A, 84% mixing for Cases D, 88% for D1 and 94% for the sewage only case. In relation to Case A, it can be seen from Figure 19 (Appendix D) that a dilution factor of 2.13, (68% mixing) occurs after 3.67m for a discharge of 124ls^{-1}. Figure 20 (Appendix D) is relevant to case D1, showing that a dilution factor of 7.33 (88% mixing) occurs after approximately 3.89m. The sewage only case (Figure 21, Appendix D), which is unlikely to occur, would be compliant with a dilution factor of 15.67 (94% mixing). This dilution is likely to have occurred within 6.3m of the discharge.

In the marine environment the toxicity of ionised ammonia (NH_4) 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 NH_4 can also be toxicologically significant. Total ammonia values of 1100 (annual average) and 8000µg/l NH_4-N are therefore set as guide values for habitats (WQTAG086, 2005). The total ammonium concentration at the point of mixing described above is at background 11.38µg/l NH_4-N and well below levels of concern at mixing distance.

6.5 Assessment of total contributions to dissolved inorganic nitrogen (DIN) and phosphorus using a phytoplankton box model

The effect of chlorination at Sizewell B (SZB) and the proposed Sizewell C (SZC) on phytoplankton that pass through the power station was simulated with an emphasis on the spring bloom and summertime production using a phytoplankton box model. The combined loadings of nitrogen and phosphorus as previously described (section 5.4 and 5.5) from the construction and cold commissioning inputs together with relevant inputs from SZB resulting from the use of conditioning chemicals and the discharge of treated sewage were assessed. 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 construction, so that no change in phytoplankton growth beyond natural variability would be observed.

A model run over an annual cycle predicts a 0.13% difference in annual gross production (BEEMS TR385) of carbon and this level of change would not be discriminated above natural background variation.

6.6 Assessment of phosphorus loading

A total daily maximum phosphorus load of 28.2kg (daily maximum for sewage and groundwater added to maximum input from commissioning) was used as an input parameter combined with the DIN loads described in section 5.6 to run a phytoplankton growth model (Combined Phytoplankton and Macroalgae (CPM) model) (BEEMS TR385). A model run over an annual cycle showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.13%.

6.7 Biochemical oxygen demand influence on dissolved oxygen

The background BOD near to the Sizewell B cooling water discharge based on monitoring done in 2010 (BEEMS Technical Report TR189) has a mean value of 2mg l^{-1}. Dissolved oxygen levels at the site are ‘high’ with a mean DO concentration of 7.5mgl^{-1} (BEEMS Technical Report TR303) adjusted to an equivalent salinity of 35 this represents 6.27mgl^{-1} (Water Framework Directive Standards and Classification Directions, 2015). The waters off Sizewell are well mixed vertically. Reduction of oxygen concentration will only occur if the rate of consumption due to BOD is greater than that which can be replenished by the daily exchange for the Greater Sizewell Bay and the oxygen transfer across the water surface.

Using 13.3ls^{-1} and BOD of 40mgl^{-1} and taking account of groundwater contributions a daily BOD of 121kg was estimated for Case D1 scenario, 64kg for Case D and 53kg forCase A. Every 1.5mgl^{-1} BOD is estimated to result in 0.5mgl^{-1} oxygen use (OSPAR Comprehensive studies report, 1997). Therefore, oxygen required to meet these BOD loadings would be D1 40.6kg/day, D 21.3kg/day and Case A 17.7kg/day. Daily water exchange for GSB is ca., 36 million m^3 so in relative terms the demand is very small. Typical values of oxygen flux are 100mmol m^{-2}d^{-1} (Hull, 2016) or 3.2gm^{-2}d^{-1}. At a mean salinity adjusted background oxygen concentration of 6.27mgl^{-1} a total of 40.6kg of oxygen would be transferred across 1.2ha in a day. Therefore, DO is likely to remain at high status. The discharges of BOD during construction are therefore considered to be of negligible significance for dissolved oxygen modification.

6.8 Modelling assessment of coliforms and intestinal enterococci

Based on data in support of the Hinkley Point C development (pers. Comm., EDF), estimates were provided for maximum levels of faecal indicator organisms for the raw sewage input to the treatment plant (240 x 10^6 E.coli and 13.6 x 10^6 intestinal enterococci, Table 14). Secondary treatment implies a 100 factor (2 log) reduction in faecal indicator microorganisms, coliforms and enterococci. If UV treatment is also applied a 5.4 log reduction is assumed.

Following either sewage treatment at a secondary or tertiary (UV) level the distance from the CDO discharge point at which enough dilution occurs to be below relevant microbiological standard levels, has been estimated using CORMIX for Case D (30ls^{-1}) sewage discharge and Case D1 (72ls^{-1}) (Table 14).

The discharge plume from the CDO is buoyant and will be on the surface (Figure 18, Appendix D), but it should be noted that the Cormix modelling does not include mixing due to waves and that mixing rates are most likely a significant under estimate as surface wave mixing will increase the mixing rate. Following either sewage treatment at a secondary or tertiary (UV) level the distance from the discharge point, at which enough dilution occurs to be below relevant microbiological standard levels, has been estimated using CORMIX for Case D (30ls^{-1}) sewage discharge and Case D1 (72ls^{-1}). These are shown in Figure 22 and Figure 23, in Appendix D. The discharge plume is buoyant and will be on the surface (Figure 18 Appendix D). CORMIX estimates show that the concentration of intestinal Enterococci cells are likely to exceed the bathing water standard only within 66m of the discharge for the 30ls^{-1} case, without UV treatment. For the larger discharge volume (72ls^{-1}) the bathing water standards are exceeded for 460m. With UV treatment, even at the higher discharge volume, exceedance is limited to less than 1 metre of the discharge. Typically, the sewage discharge may not be discharged on its own, but as part of other discharges, these other discharges will add direct dilution which compensates for the inhibition of mixing. The discharge has been modelled using the total volume although the sewage component is only a percentage of this therefore the assessment is conservative. The discharge point is not in designated bathing waters. Treatment from the plant is sufficient to ensure that *E.coli* concentrations in discharged waters comply with bathing water standards within a maximum of 3.1km from the discharge point (without UV treatment) and <1m (with UV treatment) (Table 14). 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. This assessment is based on bathing water regulations (2013. No. 1675) 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.

Table 14 Estimate of minimum distance from point of discharge at which microbiological standards for bathing waters are met following different levels of sewage treatment

Species	**Standard cells/ 100ml**	**Discharge concentration cells / 100ml**	**2^{ndry} treatment 2 log reduction**	**Dilution required to meet bathing water standard**	**Maximum potential distance from the discharge at which meets bathing water standard**		**UV treatment reduction[1]**	**Dilution factor required for discharge to meet bathing water standard**	**Maximum distance from the discharge at which it meets bathing water standard**
					30ls^{-1}	**72ls^{-1}**			
E.coli	500	240,000,000	2400000	4800	~1.7 km	~3.1 km	955.5	1.9	<1 m pass immediately on discharge, for both cases.
Entero-cocci	200	13,600,000	136000	680	~66 m	~460 m	54.1	0.3	<1 m pass immediately on discharge, for both cases.

[1] a log 5.4 reduction is achieved by UV treatment for *E. Coli* and a log 4.4 reduction for enterococci, assuming background concentrations are zero.

6.9 Modelling use and potential discharge of chemicals during tunnelling

As with the groundwater metals, the release and mixing of TBM chemicals in the construction discharge was modelled by considering them as passive tracers (no decay rate). As such, a single model run was carried out with single tracer at a release rate of 34.3 ls^{-1} with an initial concentration of 100 μgl^{-1}. The results were then scaled to the appropriate concentrations for each chemical, as the modelled concentration was simply a function of dilution. The discharge was modelled as a freshwater input with no thermal uplift. Table 15 shows the model parameters used for TBM chemical modelling.

Table 15 GETM TBM modelling run parameters.

Run ID	**Description**	**Intake location**	**Discharge location**	**Metals discharge at the outfall (μg/l)**	**Discharge flow and Delta T (m^3/s @ °C)**	**Time period**
Sewage_construction-100ug	Discharge from SZB, with TBM discharge from SZC CDO	IB	OB	0	51.5 @ 11.0	/5/2009-1/6/2009
		None	CDO	100	0.034@0	

A tunnelling discharge of bentonite at a concentration of 8.8mgl^{-1} was modelled using GETM and the results are shown in Table 16. The concentration of bentonite in suspension is orders of magnitude lower than baseline suspended sediments concentrations predicted during construction (BEEMS TR480), with 95th percentile concentrations of 10μgl^{-1} restricted to sea surface areas of 10.8ha and at mean concentration 1.35ha at the surface. No areas of the bed were affected at this concentration. Limited data on survival of organisms exposed to bentonite suspensions indicate that the small areas affected, and the low discharge concentrations are likely to have negligible effects on water quality.

Table 16: Area of the plume at different concentration levels of bentonite, with an 8.8mgl^{-1} release concentration.

Release Concentration	µg/l	Mean surface (ha)	Mean seabed (ha)	95th percentile surface (ha)	95th percentile seabed (ha)
8.8 mgl^{-1}	2	19.06	0.90	235.7	170.0
	4	5.16	0	36.8	1.01
	6	2.47	0	19.7	0
	8	1.91	0	13.6	0
	10	1.35	0	10.8	0

For the soil conditioning chemical discharges, the total Rheosoil plume areas at the EQS (40 µgl^{-1} as a mean and 95th percentile) were calculated and are shown in Table 17. There is a small area of exceedance at the surface 1.01ha and no exceedance at the bed for a mean assessment. There was no exceedance of the EQS for CLB F5 M at the seabed and the area at the surface exceeding the EQS were small (Table 18) with 3.14ha for a mean assessment.

Table 17: Area of the plume at different concentration levels of Rheosoil, with a 23.13 mgl^{-1} release concentration. Values in bold exceed the EQS concentration.

Release Concentration	EQS	µg/l	Mean surface (ha)	Mean seabed (ha)	95th percentile surface (ha)	95th percentile seabed (ha)
23.13 mgl^{-1}	40 µgl^{-1}	5	22.20	1.91	321.73	224.61
		10	5.49	0	39.25	1.68
		20	1.91	0	14.24	0
		30	1.35	0	8.63	0
		40	**1.01**	**0**	**5.83**	**0**

Table 18: Area of the plume at different concentration levels of CLB F5 M, with a 7.71 mgl^{-1} release concentration. Valued in bold exceed the EQS concentration.

Release Concentration	EQS	µg/l	Mean surface (ha)	Mean seabed (ha)	95th percentile surface (ha)	95th percentile seabed (ha)
7.71 mgl^{-1}	4.5 µgl^{-1}	1	119.98	58.54	1605.04	1386.37
		2	13.91	0	132.88	80.20
		3	6.17	0	45.08	5.27
		4	3.81	0	30.39	0
		4.5	**3.14**	**0**	**25.01**	**0**

The most toxic of the active ingredients for BASF Rheosoil 143 Sodium lauryl ether sulfate was modelled for the tunnelling discharge and is an example of an alcohol ethoxysulphate. Although tunnelling would occur over several years only very small areas at the surface are predicted to exceed the EQS for Rheosoil and this group of surfactants are shown to be readily degradable with no indication for the formation of persistent or markedly toxic metabolites (HERA, 2004). The most toxic active component of CLB F5 M, mono- alkyl sodium sulphate is an example of an alkyl sulphate and experimental and field data also indicate this group to be readily degradable (HERA, 2002).

7 Screening assessment of commissioning discharges

7.1 Background

When the cooling water system is commissioned a range of tests will be conducted and conditioning of the entire plant will be undertaken with demineralised water and various chemical additives. During cold commissioning this process will generate wastewater containing several chemicals that will be discharged through the CDO.

During the commissioning phase the range of expected wastewater sources are:

- Surface drainage from across the site (assuming these discharges are made to local marine waters as part of the drainage strategy);
- Drainage from on-site purification plants (assuming these discharges are made to the marine environment as part of the site drainage strategy);
- Effluent from the demineralisation plant;
- Chemicals used for the conditioning of a range of circuits within the EPR units;

7.2 Screening assessment of Cold Flush Testing (CFT) of SZC Unit 1

No operational cooling system will be available for the disposal and dilution of commissioning phase effluents during the cold flush testing for construction of the first EPR. Therefore, the only available discharge route for this wastewater stream will be through the CDO.

Testing of the primary and secondary circuits requires them to be filled and flushed several times each with demineralised water and treatment chemicals. The maximum daily discharge volume is 1500m^3d^{-1}, equivalent to the contents of the two 750m^3 tanks that serve this waste stream. NNB GenCo proposes to empty each tank once a day, although not at the same time. No operational cooling system will be available for the disposal and dilution of commissioning phase effluents during the cold flush testing (CFT) stage for the first unit to be constructed during the phased development of the SZC site. Therefore, the only available discharge route for this wastewater stream will be through the CDO. If there is overlap in the period when each EPR is being commissioned this would increase discharge duration and load, but discharge concentration may be similar.

Cold flush testing involves cleansing and flushing the various plant systems with demineralised water to remove surface deposits and residual debris from the installation. NNB GenCo's intention would be for CFT effluent to be discharged to the Sizewell Bay via the CDO serving the SZC construction site. The discharges resulting from CFT will be subject to a separate, later water discharge activity permit application.

7.3 Screening assessment of Cold Flush Testing (CFT) of SZC Unit 1

One of the chemicals that could potentially be included in the commissioning tests is hydrazine. Hydrazine is an oxygen scavenger and is used in power plants to inhibit corrosion in steam generation circuits. There is evidence that hydrazine is harmful to aquatic organisms at low concentrations with the lowest acute six-day EC_{50} of 0.4ngl^{-1} for growth inhibition of a marine alga, *Dunaliella tertiolecta* (see Appendix B for PNEC evaluation for hydrazine). Hydrazine persistence in the marine environment is low to moderate dependent upon its concentration and the water quality. There is no established EQS for hydrazine and so a chronic PNEC (Predicted No-Effect Concentration) of 0.4ngl^{-1} has been calculated for long term discharges (expressed as a mean concentration value) and an acute PNEC of 4 ngl^{-1} for short term discharges (expressed as a 95th percentile value). More recent assessments used in support of Canadian Federal Water Quality Guidelines for hydrazine indicate concentrations below 0.2µgl^{-1} have a low probability of adverse effects for marine life, whilst a freshwater threshold of 2.6µgl^{-1} is applied based on a greater availability of data in the freshwater environment (Environment Canada, 2013). Based on derivation of the more recent Canadian guidelines the lower chronic and acute PNEC derivations (0.4 and 4ngl^{-1}) are considered as precautionary triggers for further ecological investigation.

Prior to the release of hydrazine from the holding tanks, hydrazine would be treated to reduce the discharge concentration. Various treatment options are under investigation and it is anticipated that a discharge concentration of 15µgl^{-1} is achievable as a representative upper bounding concentration equivalent to a 95th percentile. As a discharge concentration of 15µgl^{-1} exceeds the EQS and fails the Test 5 dilution test this discharge concentration is modelled using GETM.

During commissioning two other chemical discharges for which use is anticipated are the circuit conditioning chemicals ethanolamine (at 4000µgl^{-1}) and ammonia principally in the un-ionised form (at 12000µgl^{-1}) due to the higher pH (ca.,10) maintained in the circuits. The same commissioning discharge volume and rate of discharge as that used for hydrazine are assumed. The expected concentrations used during commissioning were assessed using H1 test 1 and 5 (Table 19). Only the un-ionised ammonia fails Test 5 and requires further modelling assessment.

Table 19: H1 Test 1 and 5 for discharges of ethanolamine and un-ionised ammonia during commissioning.

Substance	**Estimated discharge concentration µgl^{-1}**	**Saltwater AA EQS µgl^{-1}**	**Background concentration µgl^{-1}**	Effective volume flux Total flow 83.3 l/s	TraC Water test 5 EVF < 3.0 (Pass/Fail)
Ethanolamine	4000	160	-	2.08	Pass
Un-ionised ammonia	12000	21	0.2	47.6	Fail

7.4 Hot functional testing

Hot functional testing begins following completion of CFT and when all the required systems are available. It takes place before fuelling the reactor and only once the cooling water infrastructure is in place and operational. The objective of HFT is to test the reactor and associated systems under pressure, temperature, flow and chemical conditioning as close to normal operating conditions as practicable without putting nuclear fuel at risk. The effluent produced during HFT would be diluted within the cooling water system before being discharged via the outfall tunnel to the adjacent marine environment.

Due to the current stage of the project and the long lead time until commissioning takes place, detailed information on the nature of the discharges during HFT is limited, but it is assumed that HFT can be considered as running the systems under normal operating conditions. It would therefore be expected that the assessment for operational discharges would also apply to that during HFT.

7.5 Chlorination system testing

Testing of the chlorination system will be undertaken during the commissioning phase, but it is assumed that this would only occur once the full cooling water system was in place and operational.

8 Impact assessment of commissioning discharges

8.1 Background

Modelling of the discharges from the commissioning of the EPRs when the cooling water system is unavailable assumes a maximum discharge rate of 83.3l^{-1} per second from a total holding volume of 1500m^3 (two tanks of 750m^3).
The modelling has been undertaken using the validated GETM model of Sizewell that was used for thermal plume and chemical plume studies previously described in BEEMS Technical Report TR302 and TR303. The model was chosen to support the chemical runs because it is better able to reproduce the natural variability due to meteorological and tidal conditions.

The commissioning discharge is from the CDO, the salinity of the discharge is modelled as freshwater with no thermal uplift and discharge location parameters are as described for the construction discharge (further detail is provided in BEEMS TR494).

For the commissioning release of hydrazine, a release concentration of 15μgl^{-1} released in daily pulses of 5.0 h starting at 12:00. This discharge period is enough to empty the total volume of both treatment tanks 1,500 m^3. The simulation was carried out for a period of 1 month (1st of May 2009-31st of May 2009), to encompass a full spring neap cycle. This is the same hydrodynamic GETM results that were used to investigate the effect of chlorination of the cooling water system to deter biofouling, as reported in BEEMS Technical Report TR303. The month of May was chosen due to having the highest phytoplankton growth which drives the whole marine ecosystem. Due to the pulse-like discharge, the interpretation of the short-term results (daily) is biased to the moment of the tidal cycle when hydrazine has been released. In order to evaluate this effect, an additional simulation was carried out with the release pulses starting at 18:00.

8.2 Hydrazine commissioning assessment

The initial assessment to determine the potential for an effect on water quality considers total areas of exceedance with results shown in Table 20.

To investigate the potential interaction of the hydrazine discharge concentration with relevant environmental sensitivities the results for assessment against the acute and chronic PNEC are compared against three criteria:

The likelihood that hydrazine could enter the Minsmere Sluice; Levels of hydrazine at the seabed over the Coralline Crag; The area of intersection of the acute hydrazine plume with Little Tern foraging areas

The Minsmere sluice controls the seawater that can flow into various drainage channels including those used to periodically supply a saline input to the Minsmere salt marshes. The sluice only opens for half an hour at high tide. Due to the proximity of the Minsmere sluice to the SZC construction discharge location an investigation was undertaken to determine whether the hydrazine plume could intersect with the sluice at concentrations above the chronic or acute PNECs and, if so, when. This is relevant, because if high hydrazine concentrations occur at times when the sluice is open, then it could enter channels that are used periodically to introduce saline water into the RSPB Minsmere reserve. The potential to influence movement of Eels into or out of the saltmarshes is also considered.

The Coralline Crag is a geological formation of special ecological interest in the area of Aldeburgh and Orford (Suffolk). Coralline Crag is a rock formation formed of bryozoan and mollusc microfossil debris that protrudes from the seabed. *Sabellaria spinulosa* has been found on the Coralline Crag and work is ongoing to determine whether the Sabellaria has formed reefs as defined under Annex I of The Habitats Directive (European Commission Council Directive EEC/92/43 on the Conservation of Natural Habitats and of Wild

Fauna and Flora) (BEEMS Technical Report TR473). Sabellaria reefs are listed as a marine habitat to be protected for their role in harbouring diversity. The proximity of the Coralline Crag to the SZC construction discharge site makes it susceptible to being exposed to hydrazine discharges.

Within 20 km of SZC are several nationally and internationally designated protected areas for flora and fauna, one of which is the Minsmere to Walberwick Special Area of Protection (SPA). Minsmere SPA is designated for the protection of several breeding, wintering and passage bird populations of European importance, including little tern (*Sterna albifrons*). Little terns feed by fishing in the top few centimetres of water column (del Hoyo *et al*., 1996) and have a limited foraging range of 2.4km offshore and 3.9km north and south (Parsons *et al*., 2015). Little terns are therefore potentially vulnerable to the impact of hydrazine if the hydrazine plume acts to deter fish from entering the little tern foraging area.

To assess the spatial extent of the hydrazine plume and compare the resulting concentrations with the PNEC values (chronic and acute), the mean and 95th percentile of the hydrazine concentrations was extracted from the 31-day model run. For hydrazine the chronic PNEC value is 0.4ngl^{-1} for long term discharges (mean of the concentration values) and the acute PNEC value is 4ngl^{-1} for shorter term discharges (represented by the 95th percentile).

The 95th percentile results show that the plume at the surface is shorter and thinner than the mean plume. The plume at the seabed shows a similar elongated narrow plume (BEEMS TR494). Table 20 provides a summary of the area of the plume that exceeds both concentration thresholds. For completeness, not only the chronic and acute PNEC values were included, but also other values between 0.1 and 0.5ngl^{-1} for the chronic concentrations and between 1 and 5ngl^{-1} for the acute concentrations. In addition to the two PNEC value considered in this report, the area exceeding 200ngl^{-1} as a 95th percentile, as set by the Canadian Federal Water Quality Guidelines for hydrazine, have been included in Table 20.

The area exceeding the derived acute and chronic PNECs is less at the bed than the surface. At the surface ~27 and ~54ha exceed the acute and chronic PNEC respectively. At the surface the exceedance for the 200ngl^{-1} Canadian standard is 0.34ha, which represents three model grid cells (25 x 25 m) around and including the hydrazine discharge from the CDO.

Table 20: Area of the plume at different concentration levels of hydrazine, with a 15 µgl^{-1} release concentration. Valued in bold exceed the respective PNEC concentrations.

Release Concentration		**ng/l**	**95th percentile surface (ha)**	**95th percentile seabed (ha)**	**Mean surface (ha)**	**Mean seabed (ha)**
5:00h release 15µgl^{-1} **at 83.3l/sec**	Chronic PNEC	0.1			93.19	22.32
		0.2			53.60	11.33
		0.3			39.47	5.83
		0.4			**30.50**	**2.92**
		0.5			25.57	1.79
	Acute PNEC	1	52.03	21.53		
		2	27.36	10.99		
		3	18.17	6.17		
		4	**12.90**	**2.92**		
		5	10.54	1.57		
	Canadian Standard	**200**	**0.34**	**0.00**		

As the hydrazine chemical plume lies completely inside the Outer Thames Estuary SPA and the Suffolk Coastal waterbody, the areas of exceedance for the chronic and acute PNECs are the same as for the whole plume.

The hydrazine concentration at the surface, over the 31 days was modelled at the node closest to the location of the Minsmere sluice for the 15µgl^{-1} release concentration in pulses of 5.0 h starting at 12:00, and the other starting at 18:00. Table 21 provides a summary of the peak concentrations. At no time are the concentrations above the chronic PNEC present. Concentrations of 0.07ngl^{-1} can be found at the location of the Minsmere Sluice at the surface when hydrazine is released at 12:00 with a release concentration of 15µgl^{-1}. In all the cases, the plume does not stay in the vicinity of the sluice from after one high tide to the next (approximately 12h later). Since the Minsmere sluice only opens for half an hour after high tide, this means that the hydrazine plume does not coincide in time with the sluice opening. The hydrazine plume is transported northward towards Minsmere during the falling tide, meaning that the sluice water supply that is periodically used to add additional saltwater to the Minsmere salt marshes is unlikely to be exposed to hydrazine. The likelihood of any hydrazine exposure in the sluice water would also be made considerably less likely due to rapid degradation of hydrazine with a half-life of ca., 30 minutes.

Table 21: Summary of peak hydrazine concentrations at Minsmere sluice, time of occurrence and duration of the plume.

Hydrazine Simulation results			**Peak concentration (ng/l)**	**Time after high water (hours)**	**Duration above Chronic PNEC (hours)**	**Duration above Acute PNEC (hours)**
15µgl^{-1}	Release at 12h	Surface	0.07	0.0	0.0	0.07
		Bottom	0.07	0.0	0.0	0.07
	Release at 18h	Surface	0.12	0.0	0.0	0.12
		Bottom	0.11	0.0	0.0	0.11

The potential for hydrazine concentrations in proximity to the Minsmere sluice to deter passage of Eels (which are a prey item for several bird species) into or out from the sluice is also considered. The European eel is catadromous, breeding in a specific region of the North Atlantic (thought to be the Sargasso Sea) (Wheeler, 1969; Arnold, J. D. and McCleave, 2002; van Ginneken and Maes, 2005). After hatching the young larvae (known as leptocephali) are transported back to European coasts by ocean currents (Wheeler, 1969; van Ginneken and Maes, 2005). As they approach the continental shelf, the leptocephali become glass eels, then transition into elvers. In the North Sea, elvers ascend rivers in March and April after metamorphosis, although some may remain in estuaries or coastal waters (Tzeng et al., 1997). Little is known about the residence times of glass eels in the southern North Sea. The eels reach the coast and seek a salinity cue to transition from oceanic waters to coastal ones, so the time spent in the open North Sea is dependent on when they sense this cue. Once in freshwater, the eels spend many years growing and feeding and after reaching a specific size range begin migrating out to sea.

There is limited data on the toxicity of hydrazine to marine fish, however, freshwater examples indicate the most sensitive species have a 96h LC50 value of 610µg/l (Environment Canada, 2013). This acute toxicity threshold is orders of magnitude higher than the source concentration from the proposed CDO commissioning discharge. There is the potential concern for sublethal effects particularly in relation to migratory eels. In the UK glass eels enter river systems from the sea in March and April whilst yellow eels migrate from the rivers back to sea in September to December. Commissioning discharges could coincide with the period of eel migration, as such the concentration of hydrazine at the Minsmere sluice (the closest entry point to freshwater from the CDO) was investigated. There is a paucity of data on sublethal effects of hydrazine on fish. One study identified evidence of behavioural responses including an increase in aggressive behaviours in laboratory trials with freshwater bluegill (Lepomis macrochirus), which the authors attributed to the irritant effects of hydrazine (Fisher *et al.* 1980). However, behavioural responses occurred at concentrations of 0.1mg/l and above, still considerably higher than the instantaneous maximum concentration at the sluice (0.12ng/l). Furthermore, hydrazine plumes would only intersect the sluice during an ebbing tide when water levels would be falling. As such, glass eels entering the sluice at high water are unlikely to be exposed. The predicted peak concentrations of hydrazine in proximity to the sluice in any case are many times below levels shown to cause sublethal effects in fish so Eels moving to or from the saltmarshes in the vicinity of the sluice would also not be exposed to significant concentrations of hydrazine. The hydrazine discharge plume has a low likelihood of affecting Eel migration along the coast since at the point of discharge the maximum concentration is 15µg/l (many times below known sublethal levels) and also degrades rapidly. It is therefore considered unlikely that commissioning discharges of hydrazine would affect eel migration given the low peak concentration relative to known effects levels and limited potential for exposure.

A similar assessment was conducted for the coralline crag. The model results show that at a 15µgl^{-1} release concentration the chronic PNEC is not exceeded at the seabed and only for 0.25 h at the surface. But Sabellaria (as a benthic feature) would not be exposed to acute concentrations. Table 22 provides a summary of the peak concentration of hydrazine and the duration of the plume above the chronic PNEC. The peak concentration of hydrazine at the seabed, with a 15 µgl^{-1} release concentration, is (0.05ngl^{-1}) and is below the acute and chronic PNEC.

Table 22: Summary of peak hydrazine concentrations at the Coralline Crag, time of occurrence and duration of the plume.

Hydrazine Simulation results			Peak concentration (ng/l)	Duration above Chronic PNEC (hours)	Duration above Acute PNEC (hours)
15µg/l	Release at 12h	Surface	0.06	0.0	0.0
		Bottom	0.05	0.0	0.0
	Release at 18h	Surface	0.46	0.25	0.0
		Bottom	0.04	0.0	0.0

In the Greater Sizewell Bay, there are three breeding colonies of little terns at Dingle, Minsmere and Slaughden (BEEMS Technical Report TR431). Little Terns have a foraging range of 2.4km offshore and 3.9 km north and south (Parsons *et al*., 2015). Results show that only the Minsmere colony is potentially affected by the hydrazine plume. The hydrazine plume never intersects with the Dingle colony to the north and the Slaughden colony to the south. At a release concentration of 15µgl^{-1}, the instantaneous area of intersection between the hydrazine plume and the foraging area of the Minsmere colony represents a peak of ca., 2.6% of the colony foraging area for the 12:00 and 18:00 releases (this assessment is based on the more precautionary PNECs not those derived under the Canadian standards).

Table 23 provides a summary of the peak area intersection with Minsmere little tern colony and the duration of the plume. Whilst the plume intersection with 15µgl^{-1} release concentration regularly exceeds 1% of the foraging area, the duration of the plume is short, with concentrations exceeding the acute PNEC for no longer than ca., 4 hours.

It is possible during EPR commissioning that one EPR is operational and discharging via the cooling water system whilst the second is commissioned and so this is given further consideration in the operation assessment.

Table 23: Summary of peak hydrazine intersections with Minsmere little tern colony and the duration of the plume greater than the acute PNEC 4ng/l.

Release concentration	Hydrazine release	Mean area intersection (%)	Peak area intersection (%)	Duration above 1% threshold (hours)	Duration above 1% threshold (% of day)	Number of acute exceedances per month

15µg/l	Release 12:00h	0.12	2.56	0.25 – 3.5	1.0 – 14.6	12
	Release 18:00h	0.12	2.02	0.25 – 2.0	1.0 – 8.3	16

8.3 Un-ionised ammonia commissioning assessment

The discharge of un-ionised ammonia during the commissioning phase of the EPR construction was modelled using the validated GETM model of Sizewell. The maximum ammoniacal nitrogen (N) concentration discharged during commissioning the turbine hall equipment and steam generator is expressed as 12000µgl^{-1} with a system ca., pH 10 within a commissioning discharge of 83.3 l^{-1} sec^{-1}. At this pH a total ammonium concentration will partition as 17,806µgl^{-1} NH_4-N and 12000µgl^{-1} NH_3-N. This ammonia concentration and the physicochemical conditions of the EPR commissioning demineralised water provide the initial point for construction of a dilution plot as the effluent mixes with seawater. Successive stages of NH_4-N dilution and decreasing pH from 10 to a seawater background of 8.05, and increasing salinity to that of seawater (33.3) are used to derive equivalent un-ionised ammonia NH_3-N at each stage of dilution using the Environment Agency provided calculator (Clegg and Whitfield,1995). Based on this dilution 94.4 mixing of the commissioning discharge is required to achieve an NH_3-N concentration less than the EQS of 21µgl^{-1}. (also accounting for a NH_3-N background of 0.2µgl^{-1}).

For the GETM model, an initial concentration of 12,000µgl^{-1} assumed as NH_3-N was discharged at 83.3 l^{-1} sec^{-1} from the CDO location with a freshwater salinity. To avoid excessive initial dilution, the discharge is released in the surface layer of the model, as was done with other assessed chemical discharges (BEEMS Technical Report TR303). A mixing level of 94.4% is enough together with the changing pH, and salinity that occurs as the wastewater mixes with seawater to reduce the un-ionised ammonia below its EQS and is equivalent to a 16.8-fold dilution.

The modelling results from GETM show there is no plume in exceedance of the EQS for the un-ionised ammonia. In the direct vicinity of the outfall (<5m) the un-ionised ammonia of the discharge will exceed the EQS. But this behaviour is smaller than the model grid cell size (25m). By the time the discharge has got to the boundary of the initial grid cell, mixing would have reduced the plume such that the EQS is not exceeded. Comparisons against previous nearfield modelling using CORMIX suggest a 16.8-fold dilution is achieved within approximately 10m. Therefore, the GETM model was unlikely to produce a plume. The maximum concentration at the surface and seabed is 50µgl^{-1} and 1.39µgl^{-1} NH_3-N, respectively. This represents the minimum value of the grid cell of discharge, an area of 25 m x 25 m. While this can be considered as a potential underestimate of the concentrations at the immediate point of discharge (i.e. <5 m), however, it demonstrates that exceedance of EQS would be highly spatially restricted to the area close to the immediate point of discharge. As for the construction discharge assessment the ammonia concentration at the point of mixing described above is at background 11.38µg/l NH_4-N and well below levels of concern (WQTAG086, 2005) at mixing distance.

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9 Assessment of the source input data for operational discharges

9.1 Background

Expected discharges to local marine waters from SZC during the operational phase may be broadly characterised as:

- Surface drainage from across the developed site;
- Sanitary wastewater from on-site purification plants;
- Effluent from demineralisation plant;
- Chemicals discharged during the operation of the units; and
- Discharges associated with chlorination.

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.

9.2 Ammoniacal nitrogen load derivation

For the operational phase, SZCs nitrogen discharges several sources and waste streams are considered. The un-ionised ammonia figures in Table 24 were calculated using the Environment Agency calculator (Clegg and Whitfield, 1995) which requires input data for temperature, salinity, pH and total ammonia and takes account of typical (annual average) and worst-case (24 hour) temperature uplift. All these source physicochemical data were specific to the Sizewell site. The data recorded during the 2010 monitoring survey at Sizewell (BEEMS TR189) were the reference source for the relevant physicochemical data used to derive un-ionised ammonia values for screening. For the annual assessment a 98th percentile temperature value (19.4˚C) a 50th percentile pH (8.02) 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 SZC (BEEMS TR302) 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 (BEEMS TR303). Hence a value of 23.2˚C with the 98th percentile temperature (19.4˚C), 95th percentile pH (8.2) and 5th percentile salinity (31.7) was used to derive the maximum 24h loading for un-ionised ammonia. Very similar summary statistics for physicochemical parameters were derived from a more recent monitoring survey reported in TR314 but as the differences in the datasets were not large and modelling was developed around the earlier dataset and the scenarios provide a precautionary assessment it was not considered necessary to re-run this modelling using slightly updated values

Table 24 Operational phase chemical discharges of nitrogen from sum of waste streams for 2 EPR units (based on EDECME120678 PREL A, 2011 and adapted using input data from TR131 ED 2, TR314 and TR303)

Substance	Maximum annual loading (kg yr^{-1})	Maximum 24-hour loading (kg d^{-1})
Nitrogen (as N) (excluding hydrazine, morpholine and ethanolamine)	10130[1]	332
Nitrogen (in terms of ammonia ions NH_4 excluding hydrazine, morpholine and ethanolamine)	13009	77[1]
Nitrogen (in terms of Un-ionised ammonia NH_3	958[2]	27

1 nitrogen is potentially contributed by hydrazine, ethanolamine and morpholine and consideration is given to this in section 11.6 2 figures are back calculated from the un-ionised ammonia concentration derived from the un-ionised ammonia calculator using the NH_4 concentration that results from the combined sanitary and conditioning inputs and site background physicochemical data (see Table 26)

9.3 Hydrazine load derivation

The main operational waste streams that potentially contribute to discharges of hydrazine are shown in Table 25. Waste 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).

The D stream hydrazine loads only which are derived from the secondary circuit daily are therefore used in the following calculations.

Table 25 Operational phase chemical discharges of hydrazine from sum of waste streams for 2 EPR units (based on EDECME120678 PREL A, 2011)

	Waste stream discharge B+C	Waste stream discharge D (kg yr^{-1})
Hydrazine (daily) (kg d^{-1})	1	3
Hydrazine (annual) (kg y^{-1})	3	24.3

9.4 Sanitary waste discharges and calculation of un-ionised ammonia combined inputs

Information on sanitary waste discharges during the operational phase are based on plans used for Hinkley point. For estimation of loadings from the treatment works into the cooling water for the H1 Assessment the following are assumed:

- Maximum number of operational staff present during 24 hours (under outage conditions) based on Hinkely Point C – 1900 personnel;

- Waste water production per person – 100 l d^{-1}; and
- Discharge concentrations – BOD 20 mg l^{-1}, Total Ammonia 20 mg $l^{-1}$and Total Suspended solids 30mgl^{-1}. Based on these criteria the calculated discharge loadings are presented in Table 26. Further details relating to the calculation of these loadings are presented in EDF, 2011.

To obtain a total discharge loading value for the 2 EPRs during operation the values for total ammonia and suspended solids have been combined with other sources for each for the screening assessment,

For the EA screening assessment total ammonia concentrations from operational inputs (sanitary plus other inputs i.e. circuit conditioning) and the existing site background values are combined. Both a maximum 24 hour loading, and an average annual loading are considered. For the maximum loading assessment extreme values for temperature, pH and salinity are used in the EA un-ionised ammonia calculator with the 24 hour loading and site background ammonia to derive the maximum un-ionised ammonia value. 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 data in the EA calculator to derive the annual un-ionised ammonia concentration. The ammonia background concentration in the seawater is based on monitoring data from BEEMS Technical Report TR314. The physicochemical data for the site are derived from BEEMS report TR189 (see Table 26)

Table 26 Calculated discharge concentration of un-ionised ammonia (as N) for treated sanitary effluent and combined inputs

Parameter	**Derivation of value**	**24-hour value**	**Annual value**
BOD	Sanitary loading	3.8 (kg d^{-1})	1387 (kg yr^{-1})
Suspended solids	Sanitary loading	5.3 (kg d^{-1})	1916 (kg yr^{-1})
Total Ammonia	Sanitary loading	3.8 (kg d^{-1})	1,387 (kg yr^{-1})
Total Ammonia (Circuit conditioning)	Circuit conditioning loading	77.1 (kg d^{-1})	13009 (kg yr^{-1})
Maximum ammonia concentration in discharge NH_4-N	Based on a 66[1] (24 h) and 116 cumec flow	10.49 µg l^{-1}	3.06 µg l^{-1}
Temperature data used in calculator	Based on maximum site background 19.5+ either thermal uplift of 23.2 or 11.6 °C[1]	42.6	31.1
pH data used in calculator	Based on 95 percentile and 50th percentile	8.23	8.05
Salinity data used in calculator	Based on 95 percentile and 50th percentile	31.7	33.27
Site background ammonia NH_4-N	Based on 95th percentile and mean	26.3 µg l^{-1}	11.38 µg l^{-1}
Total ammonia in discharge including background NH_4-N	95th percentile and mean background added to respective mean and 95th percentile discharge	36.78 µg l^{-1}	14.44 µg l^{-1}
Un-ionised ammonia concentration NH_3-N	Calculated with EA un-ionised calculator (Clegg and Whitfield, 1995) using combined discharge concentration plus background ammonia	7.32 µg l^{-1}	0.96 µg l^{-1}

[1] see TR302 'worst case scenario when 2 out of 4 pumps were under maintenance the flow of cooling water would be halved

9.5 Sanitary waste discharges and microbiological parameters

Based on the Hinkley Point C estimates are made of maximum discharge concentrations of inputs into the sewage treatment plant. Secondary treatment implies a 100 factor (2 log) reduction in Coliforms and enterococci. If UV treatment is applied a 5.4 log reduction is assumed. The dilution factor required to reduce the coliforms to levels that would comply with bathing water standards has been derived.

9.6 Chlorinated discharges

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 SZC cooling water (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 Total Residual Oxidant (TRO) dose of 200μgl^{-1} in critical sections of the CW plant and at the inlet to the condensers (BEEMS Technical Report TR316).

The expected discharges from the chlorination process include:

- Residual oxidants in the form of free chlorine and chlorinated compounds. The range and proportions of chlorinated compounds are variable and relate to the presence of organic material and bromine or bromide concentrations in the sea water being treated.
- Trihalomethanes which are present as bromoform at Sizewell.

A precautionary discharge source term of 150μgl^{-1} was derived for the planned cooling water discharge based on the expected decay of TRO between the inlet to the condensers and the point of discharge from the cooling water outlet (BEEMS TR316). In laboratory studies six specific chlorination byproducts (CBPs) were analysed for in chlorinated seawater from Sizewell these were: bromoform; dibromochloromethane (DBCM); bromodichloromethane (BDCM) and dibromoacetonitrile (DBAN); dibromoaceitic acid (DBAA);) and 2,4,6 tribromophenol. Of the six CBPs analysed, DBCM was measured at close to its detection limit and the other CBPs except for bromoform were below detection (BEEMS TR217). Following additions of chlorine to Sizewell seawater of 250 -500μgl^{-1} bromoform was detected at concentrations of 5 – 29μgl^{-1}. Based on interpolation of the chlorine dose required to achieve a target value of 200μgl^{-1} TRO the equivalent bromoform concentration that results was 190μgl^{-1} and so this value is used as the representative discharge concentration for the planned Sizewell C (BEEMS TR303).

9.7 Demineralisation plant discharges

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 SZC 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 27. 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. Sequestering agents are used in the desalination plant to prevent mineral deposits forming on the reverse osmosis membranes. For the SZC demineralisation plant one of two sequestering agents will be used i.e. either ATMP or a sodium polymer sequestering agent.

a) ATMP based sequestering agent

Amino tri-methylene phosphonic acid (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 27.

For assessing the sodium component of the ATMP the loading values have been added to those from other sources in Table 28.

Table 27 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

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 28.

Table 28 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

9.8 Trace metals in 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. As part of the H1 assessment there are specific requirements for the minimisation of the annual loads of the priority hazardous substances cadmium and mercury. An H1 assessment of discharge concentrations of cadmium and mercury was carried out to demonstrate that the levels discharge during normal operations will be small with a negligible environmental impact. This was based on operational experience and feedback from EDF’s French fleet of nuclear power stations. Table 29 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 29 Estimated annual contributions of cadmium and mercury from the raw material chemical use in water treatment systems

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

The loadings for the non-radioactive contaminants associated with radioactive discharges for two EPR units are detailed in Table 30. For the assessment of discharges, it has been assumed that all metals within the effluent are present 100% in the dissolved state and therefore biologically available. This provides a worst-case scenario in terms of the modelling assessment.

Table 30 Operational phase chemical loadings for 2 EPR units based on EDF, 2014 and subsequent modifications incorporated in HPC-EDECME-XX-000-RET-000061)

Substance	Circuit conditioning (kg yr^{-1})	Sanitary waste discharge (kg yr^{-1})	Producing demineralised water (kg yr^{-1})[1]	Maximum annual loading (kg yr^{-1})	Maximum 24-hour loading (kg d^{-1})
Boric acid (H_3BO_3)	14000	-	-	14000	5625
Boron	2448	-	-	2448	984
Lithium hydroxide	8.8	-	-	8.73	4.4
Hydrazine	24.3			24.3	3
Morpholine	1680	-	-	1674	92.3
Ethanolamine	920	-	-	919	24.75
Nitrogen as N	10130	1595	-	11725	332
Un-ionised Ammonia (NH_3)	-	-	-	958[2]	27[2]
Phosphates (PO_4^3)	800	-	-	790	352.5
Detergents		-	624	624	-
Suspended solids	2800	2080	88000	92879	870
BOD	-	1387	-	1387	3.8
COD	5050	-	-	5050	330
Aluminium	5.26	-	-	5.26	1.1
Copper	0.42	-	-	0.42	0.08
Chromium	8.37	-	-	8.37	1.7
Iron	34.97		46000	46035	257
Manganese	3.33			3.33	0.67
Nickel	0.44			0.44	0.09
Lead	0.3			0.3	0.07
Zinc	5.6			6.0	1.2
Chloride			87100[3]	87100	450
Sulphates			98400[3]	98400	2000
Sodium			52400[3]	52400	855
ATMP			9100	9100	45
HEDP			890	890	4.5
Acetic Acid			14	14	0.1
Phosphoric acid			12	12	0.1
Sodium polyacrylate			8030	8030	40
Acrylic acid			165	165	1
Chlorine (TRO) and bromoform[3]					(150µgl^{-1}), 190µgl^{-1}

[1]discharges from demineralisation of mains water not yet determined figures represent combined demineralisation and desalination and therefore bounding;[2]These figures are back calculated from the un-ionised ammonia concentration derived from the un-ionised ammonia calculator using the NH_4 concentration that results from the combined sanitary and conditioning inputs;[3]Based on the expected chlorine dose required to achieve a target concentration of 200µg l^{-1} at the condensers of the power station and taking account of subsequent decay of TRO a precautionary discharge source term of 150µgl^{-1} is proposed in TR316 and for bromoform 180µgl^{-1} (BEEMS TR303).

10 Operational assessment and modeling methodology

10.1 Background

Potential discharges to the marine environment have been assessed for the operational phase of the planned SZC. For large cooling water discharges that are discharged to estuaries or coastal waters a specific screening assessment recommended by Defra and Environment Agency, (Clearing the Waters for All, 2016) is applied.

10.2 Screening operational discharges

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”).

Substances are assessed in two stages: screening and modelling. For the modelling assessments the Cooling Water discharge locations are shown in Table 31.

Table 31 Preferred location and depth of SZC cooling water outfall heads.

	Latitude WGS84 (degrees N)	Longitude WGS84 (degrees E)	Easting BNG (m)	Northing BNG (m)	Depth ODN (m)
O9a Same location as O9 in TR301	52.21807	1.67435	651080	264125	16.9
O9b	52.21803	1.67544	651155	264125	16.8
WGS84: World Geodetic system 1984, BNG: British National Grid, ODN: Ordnance Datum Newlyn					

10.3 Assumptions and limitations

Several assumptions were made to conduct the calculations for EQS AA and EQS MAC assessment for large cooling water discharges:

1) The discharge loadings used are those shown in Table 30.

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.

3) 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 (see section 2).

4) 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. (EU Technical Guidance, 2003).

5) For annual discharge assessments where two long term test 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 (EU Technical Guidance, 2003).

6) 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 116m^3sec^{-1} as a worst case under normal operational flow.

7) For 24 hour discharges the assessment has been made for a discharge flow of 66m^3s^{-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).

8) 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.

9) The chemical discharge values consider any initial dilution or degradation of chemicals within holding tanks.

10) 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 TR189 and in Sizewell 2014/15 supplementary monitoring report TR314.

    Discharge loadings have been used for both desalination and demineralisation processes. For SZC it is proposed that only a demineralisation plant will be used and therefore loadings from these sources represent a worst-case scenario.

10.4 Screening results for Operational discharges

Table 32 shows the assessment for large cooling water discharges that are discharged to TraC waters for 24h operational discharges and Table 33 shows respective results for the annual operational discharges. Table 32discharge concentrations are compared to the Water Framework Directive annual average environmental quality standards (WFD AA-EQS = Annual Average EQS), and in Table 33 the WFD EQS MAC = Maximum Acceptable Concentration EQS where these are available or AA values if not. In some cases, alternative or surrogate values have had to referenced i.e Pre-WFD EQS values have been adopted for assessment of boron; Coastal and Transitional Water WFD EQS for chromium is for chromium VI; and in some cases, toxicity data values are compared. Where no toxicity data are available background concentrations measured at the site are compared. For nitrogen reference is made to the winter dissolved inorganic nitrogen 99th percentile for TraC waters of intermediate turbidity (suspended solids levels of 10 to <100mgl^{-1}, Appendix C)[1]. Calculations for the maximum 24h loadings are based on a discharge volume of 66m^{3}sec^{-1} under maintenance conditions with a single operational EPR. The maximum annual discharge of 116m^{3}sec^{-1} is based on a single EPR unit having a minimal operational cooling water flow of 58m^{3}sec^{-1} under low tide conditions (worst-case scenario within ‘standard operation’).

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[1] 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 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. Howeverthe screening assessment here would only slightly change and modelling using a combined macro algal and phytoplankton model is used to provide a definitive assessment of annual inputs.

Table 32 Screening MAC for large cooling water discharges for the maximum 24 hour loadings predicted for operational phase chemical discharges – bold underlined values indicate failure of the relevant test.

Substance	EQS or surrogate value $\mu g l^{-1}$	Derivation of surrogate	Discharge + background ($\mu g l^{-1}$)	Max discharge /EQS <1
Boron[1]	7000	Pre WFD EQS	4656	0.67
Lithium hydroxide	65[2]	Mean background	90.2[2]	**1.39**[3]
Hydrazine	0.004	Acute PNEC	0.53[4,5]	**131.5**
Morpholine	28	Acute PNEC	16.18	0.58
Ethanolamine	160	Acute PNEC	4.34[5]	0.03
Nitrogen as N	980[6]	WFD 99th percentile	484.3[7]	0.49
Un-ionised Ammonia (NH_3.N)	21	WFD AA-EQS	7.34[8]	0.35
Phosphates (PO_4-P)	33.5	Mean background	127	**3.79**
Suspended solids	74000[3]	Mean background	154[5]	0.002
BOD	2000	Mean background	0.675[5,9]	0.0003
COD	239000	Mean background	57.87[5]	0.00024
Aluminium	12	Mean background	20.19	**1.68**
Copper	3.76	WFD AA-EQS	4.76	**1.27**
Cadmium	1.5	WFD MAC-EQS	0.13	0.09
Chromium	32	WFD MAC-EQS	2.48	0.08
Iron	1000	WFD AA-EQS	302	0.3
Manganese	2	Mean background	-	-
Mercury	0.07	WFD MAC-EQS	0.02[10]	0.29
Nickel	34	WFD MAC-EQS	1.17	0.03
Lead	14	WFD MAC-EQS	3.94	0.28
Zinc	6.8	WFD AA-EQS	46	**6.77**
Chloride	14128000	Mean background	78.9[5]	0.00
Sulphates	2778000	Mean background	350.7[5]	0.00
Sodium	10400000	Mean background	150[5]	0.00
ATMP	74	NOEC (96h fw[11] algae)	7.89[5]	0.11
HEDP	13	EC_{50} (96 h fw algae)	0.79[5]	0.06
Acetic Acid	301	LC_{50} 48h fw crust	0.02[5]	0.00006
Phosphoric acid	200	LC_{50} 72h fw algae	0.02[5]	0.0001
Sodium polyacrylate	180	LC_{50} 96h fw algae;	7.01[5]	0.04
Acrylic acid	1.7	EC_{50} (96 h fw algae)	0.18[5]	0.1
Chlorine (TRO) bromoform	(10) 5	MAC-EQS	(150), 190	**(15)38**

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 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 NH4 concentration that results from the combined sanitary and conditioning inputs [69] 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.10 The mean is used in place of the 95th percentile as values below detection result in lower 11 fw represents freshwater species toxicity test data which determines PNEC

Reference to Table 32 shows that for the 24 hour discharge assessment, hydrazine, chlorine produced residual oxidants (TRO) 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 95th 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 and as phosphate can contribute to nutrient status it will be given further consideration in section 11.

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, and un-ionised ammonia.

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 it is the background concentration that has the most influence on the scale of the cooling water discharge concentration relative to the EQS. As 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 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 (see Appendix B) 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 11

The 24 hour discharge concentration of dissolved inorganic nitrogen was 49% of the site 99th percentile winter standard for water bodies of intermediate turbidity. As the loading of DIN may influence algal growth this is further assessed using a combined marcoalgal and phytoplankton model.

For annual loadings in the operational cooling water discharge hydrazine, chlorine and bromoform again exceed relevant PNEC or EQS values in the screening assessment and so more detailed modelling will also consider this discharge scenario. Discharges during the operational phase would also just exceed or equal the annual average PNEC for lithium hydroxide, phosphates, aluminium, and zinc (Table 33).

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 11.

Zinc fails the annual loading discharge 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.

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 further consideration in section 11. Un-ionised ammonia concentration was low at 0.05% of its EQS but is also given further consideration in section 11 in relation to the influence of temperature elevation on the percentage of un-ionised ammonia.

Table 33 Screening Test for large cooling water discharges for average annual loadings predicted for operational phase discharges for 2 EPR units at SZC – bold underlined values indicate failure of test.

Substance	EQS/surrogate value $\mu g\ l^{-1}$	Derivation of surrogate	Discharge concentration including background ($\mu g\ l^{-1}$)	Annual Discharge/EQS <1
Boron[1]	7000	Pre WFD EQS	4145.67	0.59
Lithium hydroxide	65[2]	Mean background	65[2]	**1.00**[3]
Hydrazine	0.0004	Chronic PNEC	0.01[4]	**16.6**
Morpholine	17	Chronic PNEC	0.46[5]	0.03
Ethanolamine	160	Acute PNEC	0.25[5]	0.001
Nitrogen as N	980[6]	WFD 99th percentile	360.12[7]	0.37
Un-ionised Ammonia (NH_3-N)	21	WFD AA-EQS	0.96[8]	0.05
Phosphates	33	Mean background	33.57	**1.00**
Detergents	-	-	0.17[5,9]	0.2
Suspended solids	74000[3]	Mean background	25.4[5]	0.0003
BOD	2000	Mean background	0.38[5,10]	0.0002
COD	239000	Mean background	1.38[5]	0.00001
Aluminium	12	Mean background	12	**1.00**
Cadmium	0.2	WFD AA-EQS	0.05	0.25
Copper	3.76	WFD AA-EQS	2.15	0.57
Chromium	0.6	WFD AA-EQS	0.57	0.95
Iron	1000	WFD AA-EQS	132.58	0.13
Manganese	2	Mean background	-	0.00
Mercury	0.07	WFD MAC-EQS	0.02	0.29
Nickel	8.6	WFD AA-EQS	0.79	0.09
Lead	1.3	WFD AA-EQS	1.0	**0.76**
Zinc	6.8	WFD AA-EQS	14.7	**2.16**
Chloride	14128000	Mean background	23.81[5,6]	-
Sulphates	2778000	Mean background	26.90[5]	-
Sodium	10400000	Mean background	14.32[5]	-
ATMP	74	NOEC 96h fw[11] algae	2.49[5]	0.03
HEDP	13	NOEC 96h algae	0.24[5]	0.02
Acetic Acid	62.8	NOEC 21d fw crust	0.004[5]	0.0001
Phosphoric acid	20	LC_{50} 72h algae	0.003[5]	0.0002
Sodium polyacrylate	11.2	NOEC 72h fw crust	2.20[5]	0.20
Acrylic acid	0.34	NOEC 72 h fw algae	0.05[5]	**0.13**

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 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 1595kg/y 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 NH4 concentration that results from the combined sanitary and conditioning inputs 9 Detergents are assumed to be non-ionic for cleaning reverse osmosis membranes (Beyer et al, 2017) and the PNEC is derived from Belanger et al 2006 cited in Table 4.37 Hera, 2009 for most toxic alcohol ethoxylates with chain length C18 and added application factor of 10 is applied to this value as it is based on freshwater data 10 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 (0.38µgl-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 11 fw represents freshwater species toxicity test data which determines PNEC

11 Review and assessment of potentially significant operational discharges

11.1 Background

During operation, discharges from site are expected to be primarily via the main seawater cooling system (CFT). Various potential chemical discharges may occur at different times or continuously dependent on different operational processes. The main approach for modelling these discharges is to apply the GETM Sizewell model with input data related to the specific chemical decay and kinetics. More detail on the modelling is provided in BEEM TR303. The outputs from each modelling run enable an assessment of the area influenced by the relevant discharge plume that exceeds or is below a threshold value specific to the chemical of interest. This report supports an assessment of the overall influence of any discharges from SZC on water and sediment quality so total areas over which a given threshold value is exceeded are considered. Other BEEMS reports consider areas of exceedance relative to other receptors and therefore express areas of exceedance with reference to the location or distribution of the receptor of interest.

11.2 Cooling water chlorination modelling

Chlorine is commonly applied to the seawater to prevent biofouling of cooling water systems of coastal power stations. In seawater which typically has a high bromide concentration (68mgl^{-1}) chlorination results in displacement of chlorine atoms by bromine atoms with the formation of hypobromous acid, hypobromite ion and bromamines. The primary biocidal effects of seawater chlorination therefore result from oxidants associated with the bromine chemistry and these are measured and expressed as the total residual oxidant concentration or TRO.

Based upon the known risk of biofouling at Sizewell, EDF Energy would need to chlorinate the SZC cooling water (CRF) 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 is to continuously dose during the growing season of the principal biofouling species (e.g. the mussel) to achieve a minimum TRO dose of 0.2mgl^{-1} in critical sections of the CW plant and at the inlet to the condensers. Chlorination of the cooling water has the potential to directly affect any entrained organisms and indirectly to affect organisms in the discharge footprint. To provide enough protection to the marine environment chlorine has an EQS of 10µg l^{-1} for seawater set as a maximum allowable concentration and expressed as a 95 percentile (UKTAG, 2013, Defra 2014).

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 Total Residual Oxidant (TRO) dose of 0.2mgl^{-1} in critical sections of the CW plant and at the inlet to the condensers. The TRO discharge concentration from the CW systems at outfall heads would be 0.15mgl^{-1}. The FRR system would have its own discharge point but would not be chlorinated – currently assumed at location FRR1 Discharge Easting 647980 and Northing 264000 and FRR2 discharge Easting 647980 and Northing 264300, 4m depth ODN, 475m tunnel length).

Sizewell B has a permit to discharge cooling water with a maximum TRO concentration of 0.3mgl^{-1} all year round and this source term has been used for the modelling studies to assess in combination effects in BEEMS Technical Report TR303.

The total residual oxidants (TRO) resulting from the combination of chorine and organic material in the water are modelled in TR303 using an empirical demand/decay formulation derived from experiments with Sizewell seawater and coupled into the GETM Sizewell model.

Two scenarios were considered: chlorination of SZB plus SZC operating in combination, and chlorination of SZB only. A discharge of 132m^{3}s^{-1} has been modelled for TRO for SZC. For each model run a month-long simulation was analysed and the mean and 95th percentile of the TRO concentrations was extracted. Table 34. Figures 10 and 11 present the area of the plume that exceeds a concentration threshold of 10µgl^{-1}. For SZC only, there is an area of 2.13ha exceeding the EQS at the seabed and 337.65ha at the sea surface. Figure 10 shows that the SZC plume does not mix with the SZB plume.

Table 34 Total areas exceeding the TRO EQS (These values are based on 132m^{3}s^{-1} discharge from SZC).

Model		TRO =10µgl^{-1} as a 95th percentile surface	seabed
SZB+SZC	ha	726.21	167.08
SZB only	ha	388.56	164.95
SZC only	ha	337.65	2.13

Table 35 presents the area of the TRO plume that exceeds the EQS concentration threshold. For completeness, not only the EQS value was included but also other values between 1 and 20µgl^{-1}. Analysis of the TRO modelling runs shows that the EQS will be exceeded in the mixing zone at the surface and seabed for SZC and SZB. An important observation from this modelling is the separation of the TRO plumes from SZB and SZC discharges with no interaction between them down to the level of 1µgl^{-1} of TRO (Figure 12). This is important because it implies that, within reason, the chlorination regimes of the two developments can be managed independently.

Table 35: Area of the plume at different levels of TRO concentration (from BEEMS Technical report TR303 Edition 4).

Model run	**µg l^{-1}**	**95th percentile surface (ha)**	**95th percentile seabed (ha)**	**mean surface (ha)**	**mean seabed (ha)**
TRO_2outf_May - Chlorination of SZB + SZC	1	5450.62	3662.9	1704.96	579.31
	2	3302.04	1415.19	869.52	234.26
	4	1710.23	428.1	412.22	129.41
	6	1214.69	251.52	238.07	64.03
	8	928.17	200.28	157.89	27.13
	EQS 10	**726.21**	**167.08**	112.81	16.82
	15	436.55	101.93	64.82	8.63
	20	289.87	52.03	44.07	4.93
TRO_2outf_MayTROB - Chlorination of SZB only	1	1652.14	1136.86	756.49	363.32
	2	1206.05	559.79	460.55	226.40
	4	821.86	332.71	257.02	126.72
	6	617.99	244.23	168.21	63.02
	8	483.09	197.14	122.90	27.03
	EQS 10	**388.56**	**164.95**	94.98	16.59
	15	264.98	101.26	60.11	8.41
	20	192.32	51.69	42.50	5.15
SZC only	1	3798.48	2526.04	948.47	215.99
	2	2095.99	855.4	408.97	7.86
	4	888.37	95.39	155.2	2.69
	6	596.7	7.29	69.86	1.01
	8	445.08	3.14	34.99	0.1
	EQS 10	**337.65**	**2.13**	17.83	0.23
	15	171.57	0.67	4.71	0.22
	20	97.55	0.34	1.57	-

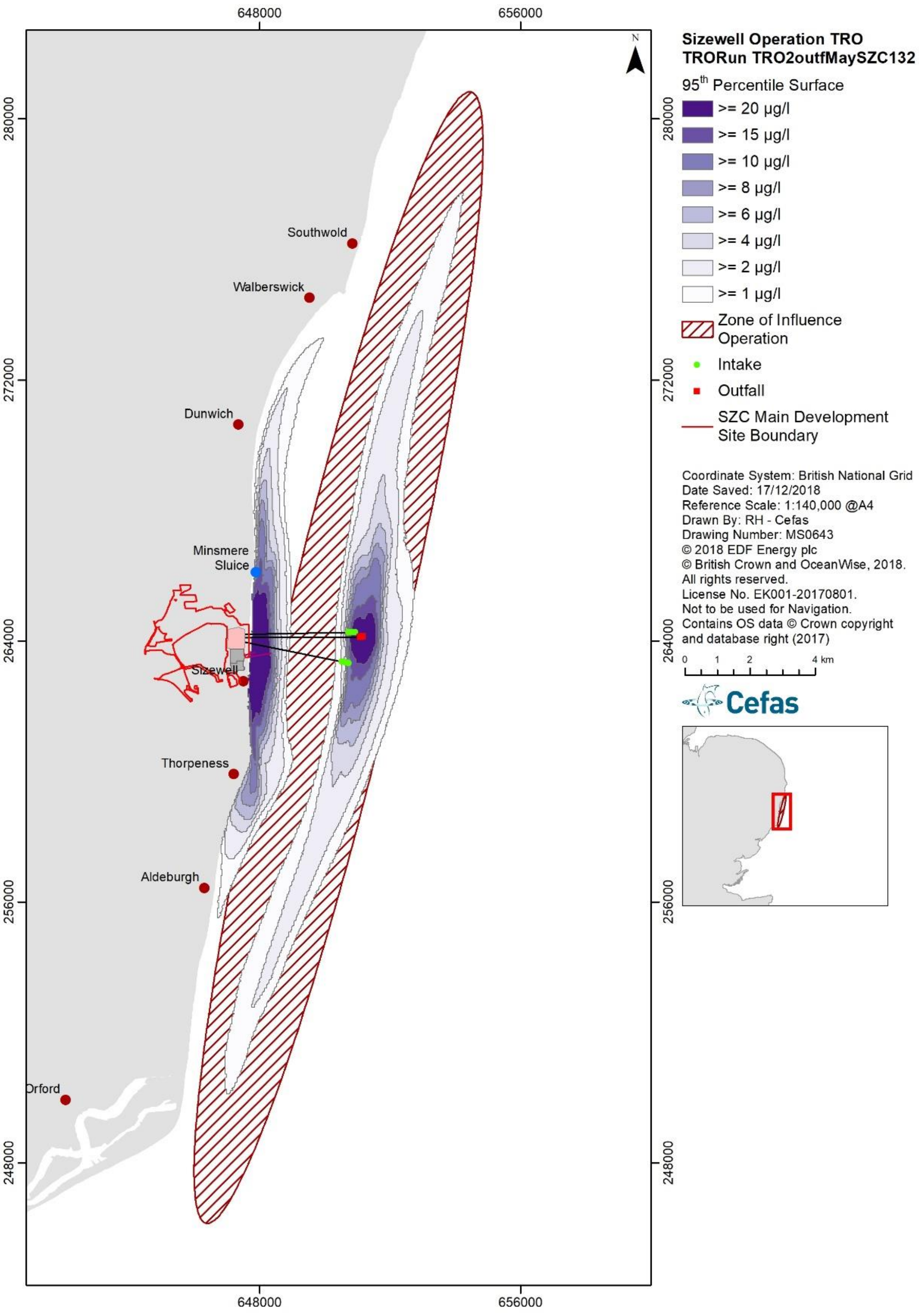

Figure 10: SZB + SZC modelling: 95th percentile of the TRO concentration at the surface (µgl^{-1}). The hatched area shows the outer tidal excursion.

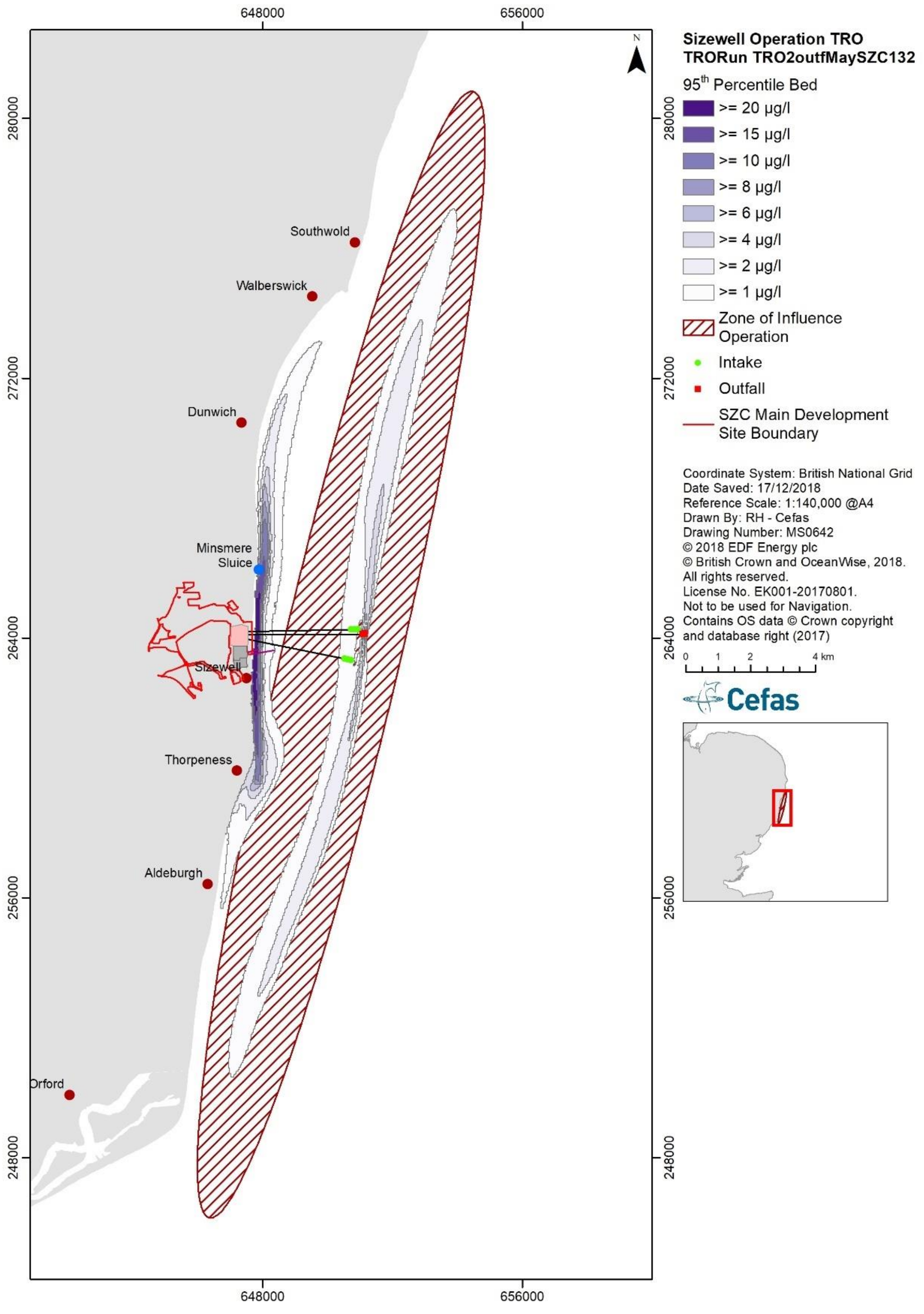

Figure 11 95th percentile of the TRO concentration at the seabed for chlorination from SZB and SZC (run TRO_2outf_May, from TR 303).

11.3 Cooling water chlorination by-products discharge modelling

Another consequence of the chlorination of the power station is the formation of chlorination by-products (CBP's) 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 (BEEMS Technical Report TR217). Bromoform is lost through volatilization to the atmosphere, with the loss rate a function of the thermal stratification and values obtained from the literature (Mackay and Leinonen, 1975) and coupled into the GETM Sizewell model.

Since bromoform is a product of chlorination, the same scenarios as for TRO were considered: chlorination of SZB plus SZC operating in combination and chlorination of SZB 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 5µgl^{-1} as a 95%ile has been used (Taylor 2006). 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 HPC WDA permit application). Figure 12 and 13 and Table 36 show the area of the plume that exceeds the relevant concentration threshold.

Table 36: Total areas exceeding the Bromoform PNEC.

Model		PNEC = 5µgl^{-1} as a 95th percentile Surface ha	 Seabed ha
SZB+SZC	ha	357.94	130.19
SZB only	ha	305.80	129.52
SZC only	ha	52.14	0.67

Like the TRO plume, the bromoform plume is a long, narrow feature parallel to the coast. Also, the SZB plume is always within the channel inshore of the Sizewell-Dunwich Bank and does not overlap with the SZC plume that is outside the Bank (Figure 12). Both plumes are strongly stratified with larger areas at the surface than at the seabed. The SZC plume is generally smaller and narrower than that due to SZB; the exception is at the 1µgl^{-1} contour for the 95th percentile where the SZC plume has a longer extent but at higher concentrations the SZC plume is always smaller. This is due to the lower initial discharge concentration and greater water depth at the SZC outfall location (16m vs. 5m for SZB outfall).

The Bromoform plume areas that exceed the PNEC (5µgl^{-1} as a 95th percentile) have been calculated and are shown in Table 36. For SZC only, the area exceeding the applied EQS at the seabed is 0.67ha and 52.14ha at the sea surface.

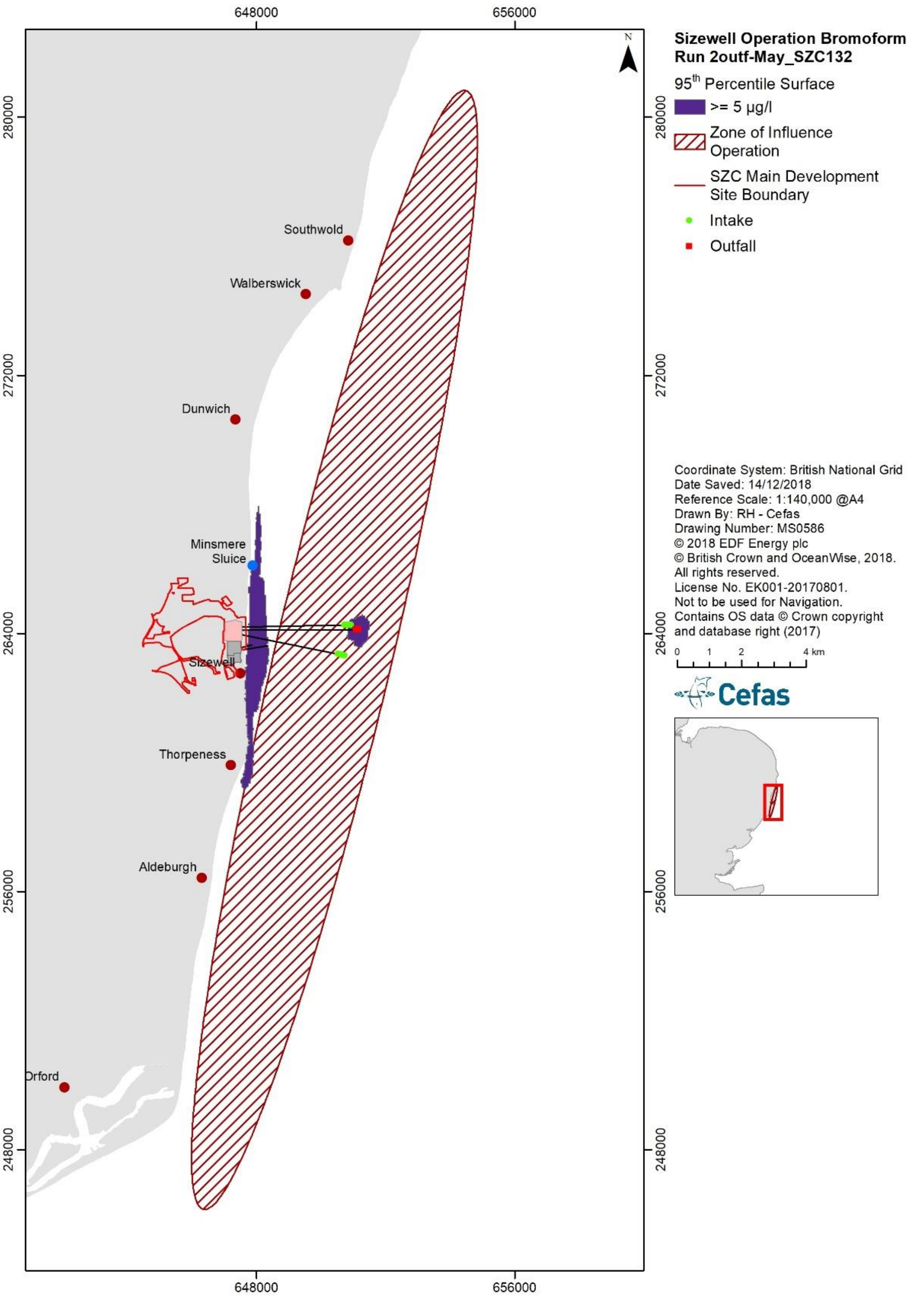

Figure 12: 95th percentile of the Bromoform concentration at the surface for chlorination from SZB and SZC (run Brom_2outf_May). Black line delineates the PNEC of 5µgl^{-1}. The hatched area shows the outer tidal excursion.

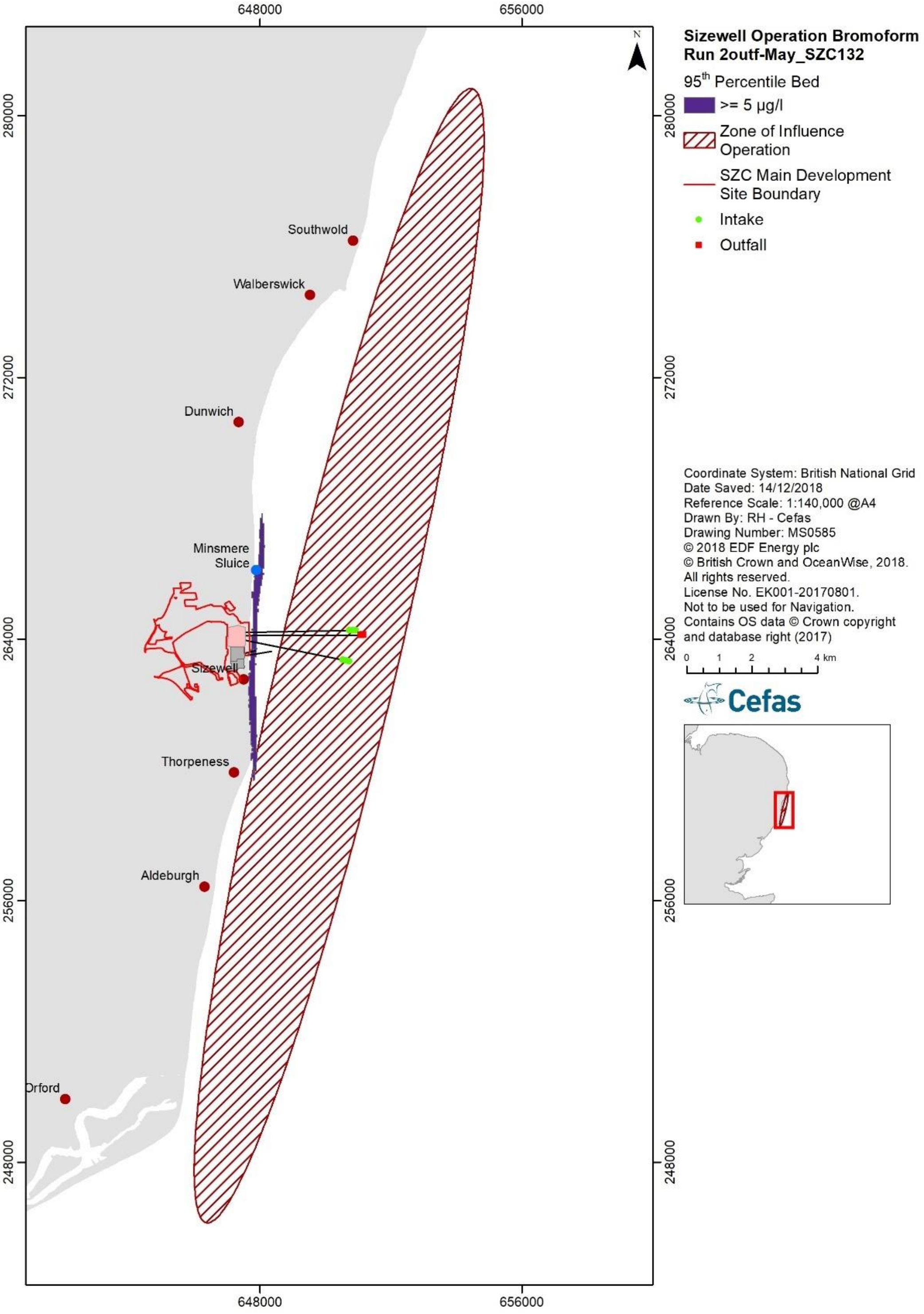

Figure 13. 95th percentile of the Bromoform concentration at the bottom for chlorination from SZB (run Brom_SZB_May-29).

11.4 Hydrazine assessment

There is evidence that hydrazine is harmful to aquatic organisms at low concentrations with the lowest acute six-day EC50 of 0.4µgl^{-1} for growth inhibition of a marine alga, *Dunaliella tertiolecta*. Hydrazine persistence in the marine environment is low to moderate dependent upon its concentration and the water quality. There is no established EQS for hydrazine and so a chronic PNEC (Predicted No-Effect Concentration) of 0.4ngl^{-1} has been calculated for long term discharges (calculated as the mean of the concentration values) and an acute PNEC of 4ngl^{-1} for short term discharges (represented by the 95th percentile).

In this report the daily discharges from the Sizewell C secondary circuit have been modelled corresponding to an annual hydrazine discharge of 24kg per annum into the cooling water flow. For more detailed modelling it is assumed that the proposed Stream D annual discharge of hydrazine 24.3 kgy^{-1} is discharged over 365 d i.e. no outages and a daily mean hydrazine discharge of 66.6 g into a 116 cumecs CW flow (concentration in treatment tank of 0.089 or 0.044mgl^{-1} depending on whether one or two holding tanks are used and assumes worst case daily discharge volume). To understand the impact of different discharge rates from the treatment tanks and assuming no treatment, two discharge scenarios were studied for SZC: the first one considering a hydrazine discharge of 69ngl^{-1} in daily pulses of 2.32h starting at 12pm, and the second one of 34.5ngl^{-1} of hydrazine discharged in daily pulses of 4.63h duration starting at 12pm. The amount of mass that is released in each of these scenarios is the same. Due to the pulse-like discharge, the interpretation of the short-term results (daily) is biased to the moment of the tidal cycle when hydrazine has been released. In order to minimize this aliasing with the tidal signal, the simulation period has been fixed to 28 days (from the 1st of May to the 29th of May), which corresponds to two complete tidal cycles.

Hydrazine is modelled by using an empirical decay formulation derived in the laboratory and coupled into the GETM Sizewell model (BEEMS Technical Report TR145 and updated in TR352). The derivation of this decay constant has proved problematic in the past because of limitations in the stability and sensitivity of analytical methods for the measurement of hydrazine in seawater. The experiments described in TR145 used an analytical method with a limit of detection of approximately 10µgl^{-1} and therefore had to perform decay experiments using initial hydrazine concentrations of 50 – 300µgl^{-1} which are considerably greater than the estimated concentration of the daily discharges from Sizewell C. These experiments produced an estimated hydrazine half-life of 12-35 hrs which in agreement with previous reported work and was used in the modelling reported in Technical Report TR303. Previous work by Cefas and others has obtained indications that the half-life of hydrazine in seawater is concentration dependent however it has previously not been possible to confirm that the half-life continues to fall at concentrations of less than 100ngl^{-1}. More recent work has been conducted using a proven method developed by Cefas that has a Limit of Detection of 5ngl^{-1}. A more extensive set of studies has now shown that for concentrations of hydrazine between 30-3000 ng l^{-1}, the decay rate of hydrazine in Sizewell sea water follows first-order kinetics and has a half-life of 38 minutes. This work is reported in TR352.

In BEEMS Technical Report TR303 each hydrazine model run was for 28 days (two tidal cycles) and the mean and 95th percentile of the hydrazine concentrations was extracted. Table 37 presents the area of the plume that exceeds both concentration thresholds. For completeness, not only the chronic and acute PNEC values were included, but also other values between 0.1 and 0.5ngl^{-1} for the chronic concentrations and between 1 and 5ngl^{-1} for the acute concentrations.

Table 37: Total area of the plume at different levels of Hydrazine concentration.

Model run		**ngl^{-1}**	**95th percentile surface (ha)**	**95th percentile seabed (ha)**	**Mean surface (ha)**	**Mean seabed (ha)**
Hydrazine_SZC_34ng_May – release of hydrazine in pulses of 4.63h a day starting at 12pm. SZC only	Chronic PNEC	0.1			3914.09	3364.50
		0.2			1269.19	795.85
		0.3			389.46	1.46
		0.4			**156.88**	**0.34**
		0.5			66.16	0.11
	Acute PNEC	1	446.42	15.14		
		2	132.54	0.78		
		3	54.72	0.00		
		4	**17.38**	**0.00**		
		5	1.23	0.00		
Hydrazine_SZC_69ng_May- release of hydrazine in pulses of 2.32h a day starting at 12pm. SZC only	Chronic PNEC	0.1			4399.32	3788.72
		0.2			1477.99	942.53
		0.3			441.04	2.24
		0.4			**158.12**	**0.56**
		0.5			60.55	0.11
	Acute PNEC	1	329.35	2.8		
		2	49.11	0.67		
		3	22.5	0.22		
		4	**13.79**	**0.22**		
		5	3.58	0.11		

The hydrazine plume areas at the chronic PNEC (0.4ngl^{-1} as an average) and the acute PNEC (4ngl^{-1} as the 95th percentile have been calculated and are shown in Table 38.

Table 38: Absolute areas exceeding the Hydrazine PNEC.

Model	**PNEC**		Absolute area of exceedance surface	seabed
Hydrazine_SZC_69ng_May mean	Chronic 0.4 ng l^{-1}	ha	158.11	0.56
Hydrazine_SZC_34ng_May mean	Chronic 0.4 ng l^{-1}	ha	156.88	0.336
Hydrazine_SZC_69ng_May 95th percentile	Acute 4 ng l^{-1}	ha	13.79	0.22
Hydrazine_SZC_34ng_May 95th percentile	Acute 4 ng l^{-1}	ha	17.38	0.00

The chronic PNEC is exceeded at the surface and at the seabed, although for the seabed, an area of less than 1ha is affected 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 69ngl^{-1} release for an area of 0.22ha.

Figure 16 and 15 show the mean predicted hydrazine concentration for a surface plume and at the seabed resulting from a daily hydrazine discharge of 69ngl^{-1} from Sizewell C. Figures 16 and 17 show the 95th percentile hydrazine concentration at the surface and at the bed also for a daily discharge of 69ngl^{-1} hydrazine.

11.4.1 Hydrazine discharge one EPR operational and one in commissioning

The timing of when the cooling water system is fully operational relative to the commissioning of the EPRs is not confirmed at this time. A worst-case assessment for discharge of hydrazine during commissioning with all discharges via the CDO is already made in section 7. Here the assumption is made that one operational EPR and one undergoing commissioning both discharge via the cooling water system. Adopting the discharge scenario with one secondary circuit wastewater storage tank (750m^3) discharging into the cooling water flow of 116m^{3}sec^{-1} (this assumes one EPR operational with lowest volume water extracted under operational conditions) and a 50% hydrazine load discharge via one EPR results in a discharge concentration of 34.45ngl^{-1} (69ngl^{-1}/2). Added to this discharge would be that from wastewater storage tank receiving hydrazine during commissioning and treated to a discharge concentration of 15µgl^{-1} at a discharge rate of 83.3l^{-1}sec^{-1} (adding an additional 10.77ngl^{-1} to the cooling water discharge). The total discharge under this scenario would be 45.22ngl^{-1}. Discharges of hydrazine under this scenario are well represented by the scenarios that are already modelled for the operational discharges and so no further assessment is made here.

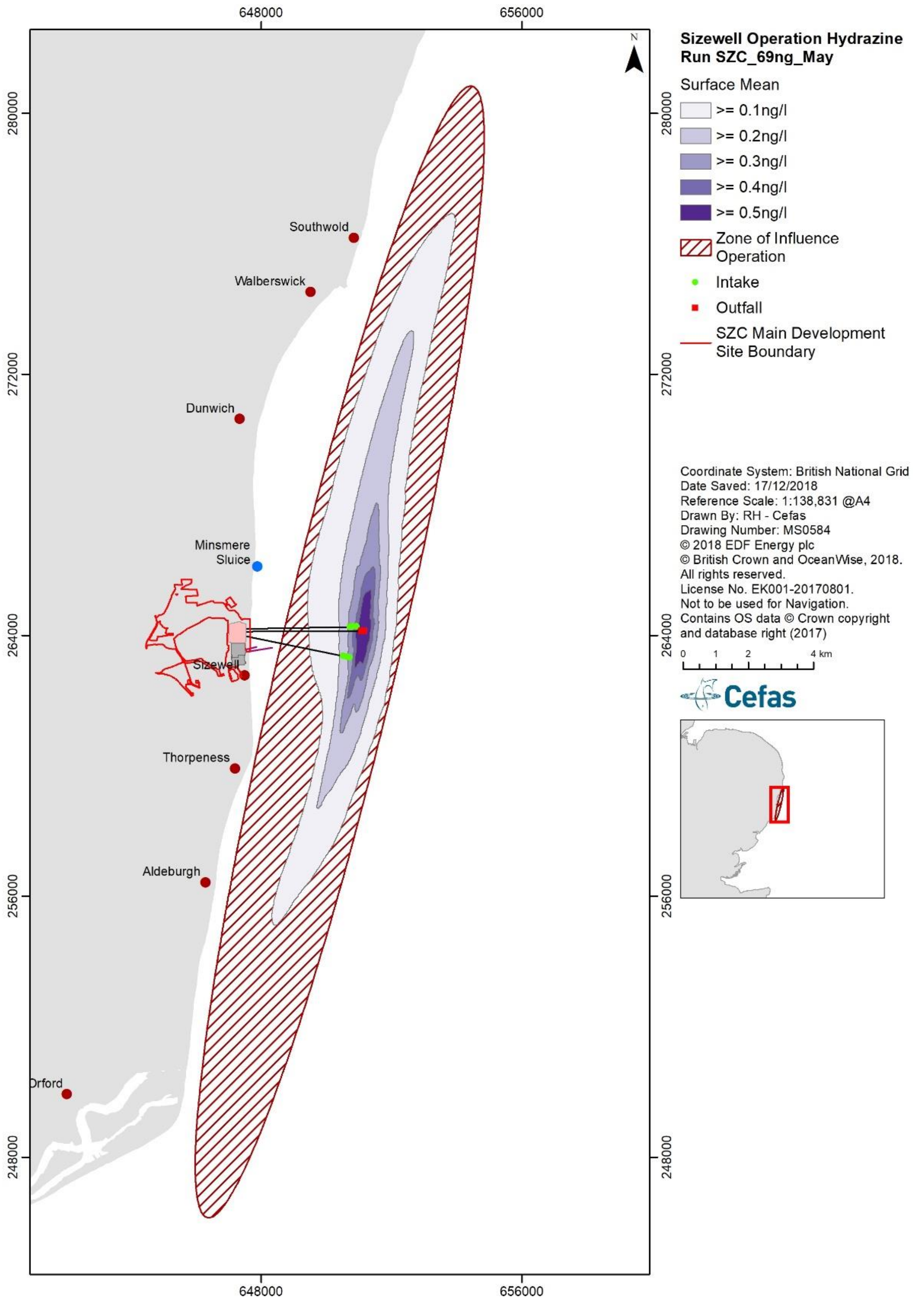

Figure 14: Mean hydrazine concentration at the surface after release of 69 ng l^{-1} in pulses of 2.32h from SZC (run Hydrazine_SZC_69ng_May).

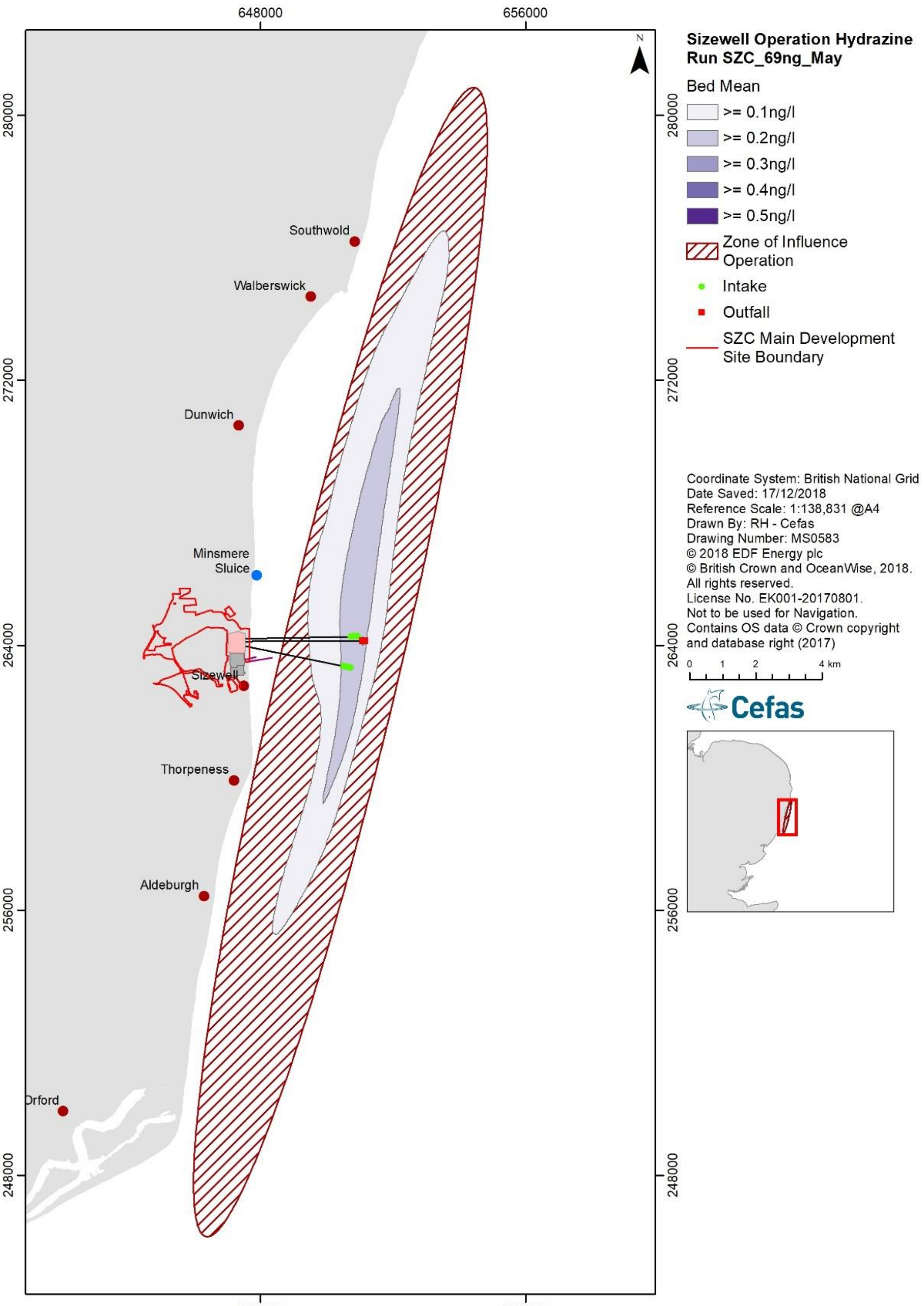

Figure 15: Mean hydrazine concentration at the seabed after release of 69 ng l^{-1} in pulses of 2.32h from SZC (run Hydrazine_SZC_69ng_May).

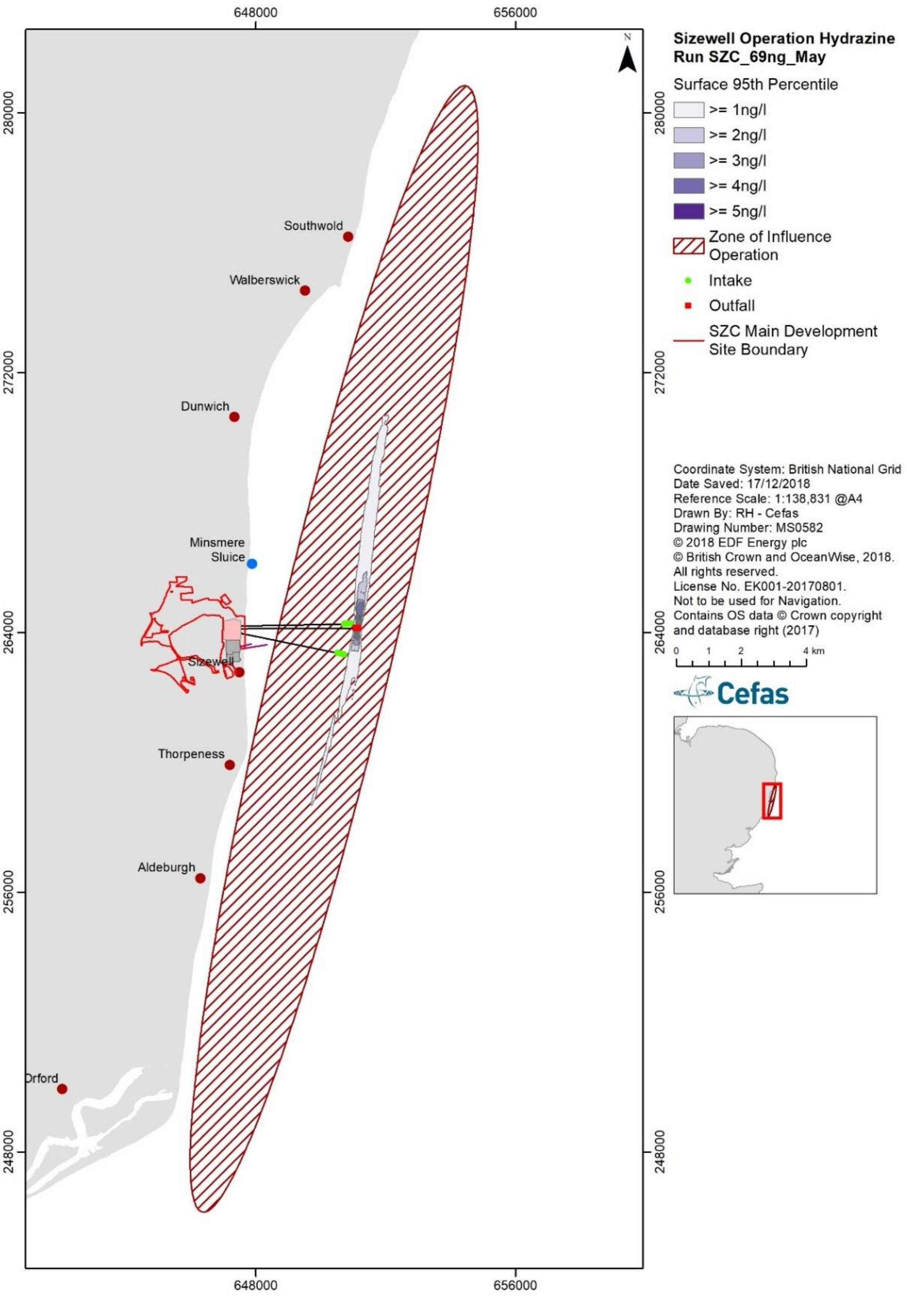

Figure 16: 95th percentile hydrazine concentration at the surface after release of 69ngl^{-1} in pulses of 2.32h from SZC (run Hydrazine_SZC_69ng_May).

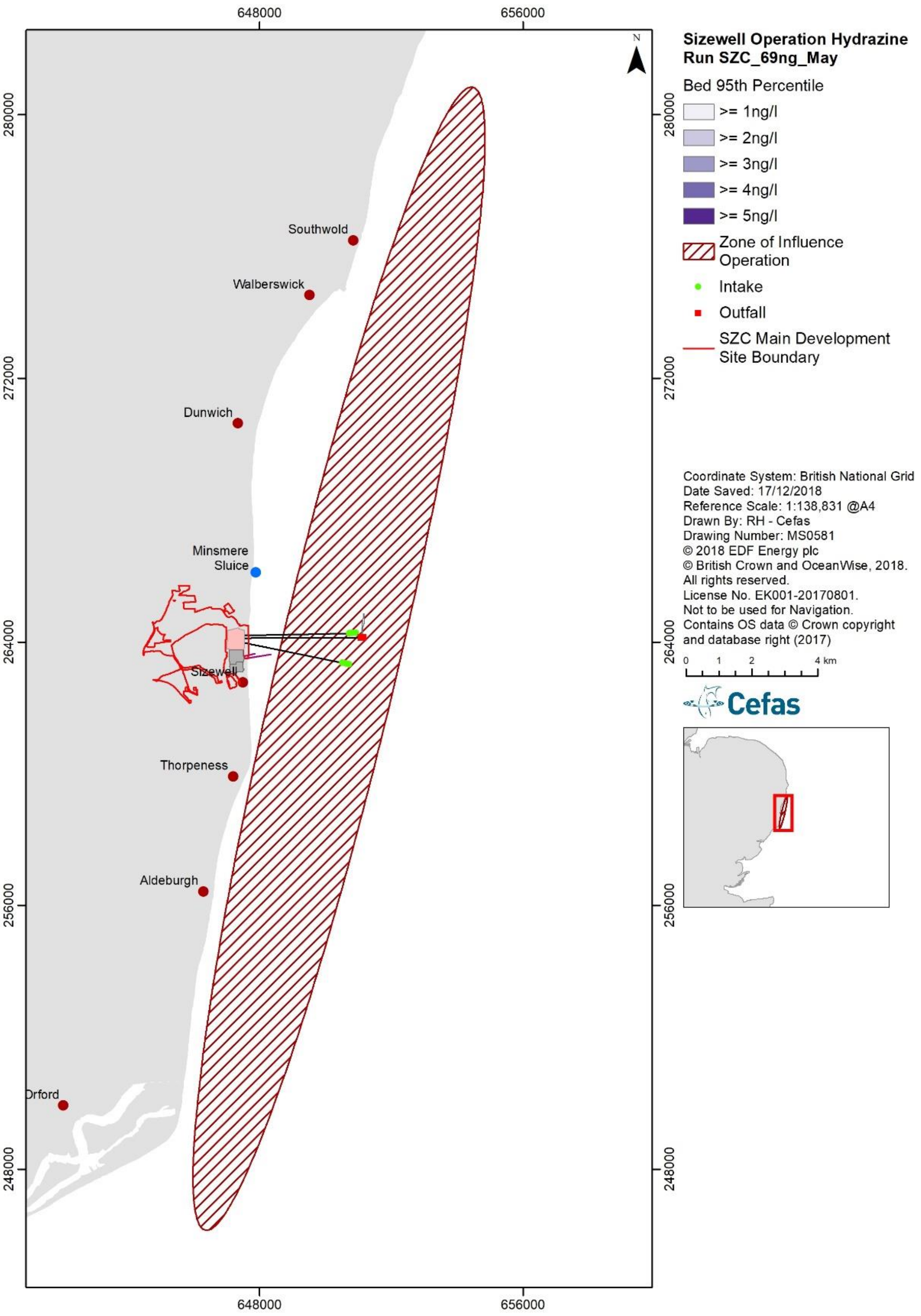

Figure 17: 95th percentile concentration at the seabed after release of 69 ng l^{-1} in pulses of 2.32h from SZC (run Hydrazine_SZC_69ng_May).

11.5 Proportion un-ionised ammonia in discharge as influenced by temperature

In the operational phase SZC will discharge ammonia from plant conditioning chemicals and the on-site sewage treatment plant. The maximum annual discharge of nitrogen (as ammonia ions NH_4) 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 worst case ammonia discharge of 14,396kg which gives a calculated mean ammonia discharge concentration of 3.9µgl^{-1} (3.06µgl^{-1} NH_4-N) at the outfall assuming a worst case cooling water discharge rate of 116m^{3}s^{-1} (This is the lowest volume of water abstracted under normal operating conditions and represent a worst-case scenario in terms of dilution of contaminants in the CW stream). As a conservative assumption this value has been added to the regional background mean and 95th percentile values to derive the un-ionised ammonia calculation.

Un-ionised ammonia concentrations have been calculated using the Environment Agency provided calculator (Clegg et al.,1995) using the GETM output for temperature elevation due to SZB+C and SZB alone and observed values for background temperature, salinity, pH and background ammonia levels. The regulatory approach for ammonia considers an annual average. The model runs replicate an annual cycle. Results have therefore been derived using an average temperature and average ammonia values. The derived un-ionised ammonia concentrations shown in the top five rows of Table 39 result in even the maximum un-ionised ammonia values being very low, 0.52µgl^{-1} under the influence of the thermal input for SZB+SZC and 0.5µgl^{-1} for that from SZB alone.

Results are also presented for more extreme conditions likely to result in highest un-ionised ammonia with 95th percentile background temperatures and mean ammonia, pH and salinity, and also 95 percentile values of pH and ammonia and the 5 percentile value of salinity with mean temperature and it is these that are also shown in Table 39.

A summary of the annual mean increases in un-ionised ammonia concentration predicted at the surface for Sizewell Bay Table 39 shows that in all cases (including worst cases) for un-ionised ammonia no areas in the model domain exceed the EQS of 21µgl^{-1} as an annual mean.

Table 39: Summary of relative proportion of model domain areas associated annual mean increase of un-ionised ammonia concentration (EQS is 21µgl^{-1} as an annual mean) at the surface

Un-ionised ammonia for mean temperature, mean ammonia, pH, salinity		
	Sizewell B + C	Sizewell B
50 percentile	**0.25**	**0.25**
95 percentile	0.27	0.26
99 percentile	0.29	0.27
Maximum	0.52	0.50
Un-ionised ammonia for 95 percentile temperature, mean ammonia, pH, salinity		
	Sizewell B + C	Sizewell B
50 percentile	0.8	0.46
95 percentile	0.8	0.47
99 percentile	0.9	0.52
Maximum	1.2	0.91
Un-ionised ammonia for mean temp, 95 percentile ph, ammonia , 5 percentile salinity		
50 percentile	0.8	0.81
95 percentile	0.8	0.83
99 percentile	0.9	0.88
Maximum	1.61	1.55

During operation the use of hydrazine, morpholine and/or ethanolamine have the potential to contribute to the ammonia 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 and ethanolamine/morpholine may not readily breakdown to directly release ammonia however estimated maximum ammonia inputs from combined loadings of hydrazine, ethanolamine and morpholine could contribute a 4% increase on the annual loading. This additional potential loading is sufficiently small addition in terms of the assessment results Table 39 so as not to be of significance to background elevation.

11.6 DIN in operational discharges

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 332kg and the maximum annual loading 11,725 kg per year (32.1kg d^{-1}). During the operational phase, maximum daily loading for nitrogen therefore reach approximately 2% of the daily exchange for Sizewell Bay, but the average daily value is low at 0.2% (again indistinguishable from background levels) (BEEMS TR385). The effect of SZB and the proposed SZC on phytoplankton that pass through the power station has been simulated using a phytoplankton box model. 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 and dominates the overall effects. 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. A Combined Phytoplankton and Macroalgae model Box model (BEEMS TR385) run over an annual cycle and incorporating nitrogen and phosphorus inputs showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.11% within the Greater Sizewell Bay. Overall carbon levels decrease ca., 5% due to entrainment mortality and the added nutrients has a very minor influence on this.

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 could contribute 1.3kg/day. This additional potential loading is small relative to the 32kg from other sources and would be insignificant relative to the daily exchange and would not be expected to influence phytoplankton growth above that predicted for other operational inputs of nitrogen.

11.7 Phosphate discharge assessment

Phosphorus also passed the screening assessment but had one of the higher values in screening test 1 based on 24-hour loadings (352.5kg as PO_4). Converting this loading to PO_4-P gives a value of 115kg. The site background PO_4-P concentration is 33.5 µg l^{-1}. A predicted PO_4-P daily exchange in summer between Sizewell Bay and outer tidal excursion and the wider area is 2440kg (BEEMS TR385) therefore the planned daily PO_4-P loading from SZC would represent ~5% of this value but the average daily value is very low at 0.03%. 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 (Foden *et al*., 2009). Although phosphorus is not normally the limiting nutrient for phytoplankton growth in marine systems a further modelled assessment of phytoplankton growth as influenced by operational inputs of phosphorus was conducted BEEMS TR385 to confirm whether there is likely to be any impact during the more critical summer period. When maximum daily inputs of phosphorus and nitrogen during the operational period were assessed using a phytoplankton box model a run conducted over an annual cycle showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.11%.

11.8 Biochemical oxygen demand (BOD) assessment for 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.

Reduction of oxygen concentration will only occur if the rate of consumption due to BOD is greater than the resupply of oxygen through the estimated 10% daily exchange for GSB together with the oxygen transfer across the water surface.

The maximum daily BOD loading based on 1900 staff on site during an outage is 3.8kg. Every 1.5mgl^{-1} BOD is estimated to result in 0.5mgl^{-1} oxygen use (OSPAR Comprehensive studies report, 1997). Therefore 3.8kg BOD would be equivalent to (3.8/3) 1.26kg oxygen required. At a mean salinity adjusted background oxygen concentration of 6.27mgl^{-1} a total of 1.26kg oxygen would be present in 183m^3. Daily water exchange for GSB is ca., 36 million m^3 so in relative terms the demand is very small. Typical values of oxygen flux are 100mmol m^{-2}d^{-1} (Hull, 2016) or 3.2gm^{-2}d^{-1}. This amount of oxygen would also be equivalent to that 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.

11.9 Assessment of coliforms, and intestinal enterococci

During operation the maximum number of staff on site is estimated at 1900 (with 100l^{-1} per head per day effluent production) based on HPC and on numbers present during an outage. Mixing of the treated sewage effluent with the cooling water flow from one EPR (66m^3 s^{-1}) will achieve a dilution of ca.,33000. Assuming the same level of treatment is achieved during operation as for the construction period then application of secondary treatment alone will achieve compliance with the bathing water standards at the point of discharge.

11.10 Fish Recovery and Return modelling assessment

For the following assessments the monitoring data off Sizewell B provides the background parameters against which the inputs estimated from Sizewell C are considered and hence Sizewell B inputs are already factored in.

A Fish Recovery and Return system (FRR) is planned to provide a safe return of the more robust organisms from the drum screens directly into the marine environment. Both band and drum screens will be integrated within the Fish Recovery and Return (FRR) system. Intakes and tunnels will not be chlorinated. Chlorination first occurs after the drum and band screens but routing of the water sources that supply the FRR will mean that it is not chlorinated.

This section describes the impacts associated with the operation of the unmitigated FRR (alternative head designs are being evaluated and these would reduce impingement numbers, so the present assessment is very conservative). The FRR 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 by impingement on the screens and incur high mortality rates. The return of dead and moribund biota retains biomass within the local food web 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, un-ionised ammonia concentration and reductions in dissolved oxygen are considered.

11.10.1 Calculation of moribund biomass discharge from the FRR 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 FRR is 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 (BEEMS TR339 and TR381). 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

1065.5kg per day is predicted to be discharged from the FRRs. Between April to September a period more critical for potential nutrient enrichment the average daily biomass is much lower at 405.2kg per day.

11.10.1.1 Nutrient inputs

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% (Storebakken *et al*., 2000, Walker *et. al*., 2011 and Gende *et al*., 2004). 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 405.2kg 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 ~14kg N and ~2kg P is indicated (see Appendix H).

Average daily nitrogen loading from operational inputs at SZC is 32kg which represents 0.2% of 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 daily exchange.

The daily average operational phosphorus loading is low at ca., 0.03% of the daily exchange for Sizewell Bay and the biomass input from the FRR represents a relatively high addition to this. Nevertheless, the P value only increases to ca., 0.1% of the daily exchange value for combined operational and FRR 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 FRR were combined with the predicted daily inputs during operation and used as source values in the Combined Phytoplankton and Macroalgae Model (BEEMS TR385). A model run over an annual cycle predicts a less than 0.29% difference in annual gross production of carbon and this level of change would not be discriminated above natural background variation. Overall carbon levels decrease ca., 5% due to entrainment mortality and the added nutrients have a small influence on this. 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 FRR is predicted to have a negligible effect on water quality separately and in combination with the operational input and which is not significant (more detail of the calculations is provided in Appendix H).

11.10.1.2 Un-ionised ammonia inputs

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 (Timm and Jorgensen, 2002). This value is used as a proxy in the un-ionised ammonia calculator (Clegg and Whitfield, 1995), (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 NH_3 loading could be at or above the EQS (NH_3-N, 21μgl^{-1}) over an area of 1.2ha around the FRR (including natural background and maximum predicted NH_3-N background from SZC operation with thermal elevation, 1.61μgl^{-1}, section 11.5). If the calculator input values are adjusted to consider 98th percentile temperature and 95th percentile pH which may occur during the summer period, the area of exceedance increases to 3.8 ha.

Considering maximum predicted daily biomass from the FRR during March (3442kg) adjusted for an average March temperature (6.09°C, Cefas, 2013 and BEEMS TR131) an area of 6.7 ha would exceed the EQS.

11.10.1.3 Influence on dissolved oxygen levels

The decaying fish biomass is also likely to contribute to the biological oxygen demand (BOD). An estimate of BOD loading of 3.5 g/g dry mass is derived based on BOD loadings from a study of particulate organic matter from fish cages (Stigbrandt et al., 2001). The source BOD value is used to derive an estimate of the BOD contribution from the daily average biomass (Based on annual mean biomass, 1065.5 kg). The estimate is 1342.5 kg BOD/day.

Any area that exceeds 1.5 mgl^{-1} deviation in BOD from background is expected to generate less than 0.5mgl^{-1} impact/reduction on dissolved oxygen (OSPAR Comprehensive studies report, 1997). Therefore, dividing the BOD loading by 1.5 and multiplying by 0.5 produces an estimate of the total oxygen reduction potential due to the BOD input which is 447.5 kg/day.

Based on a background concentration of 6.96 mg/l dissolved oxygen the calculated O_2 demand requirement (447.5 kg) is equivalent to oxygen available in 64,297 m^3. This volume represents 0.2% of the daily exchange for GSB.

Reaeration at the sea surface would also replenish oxygen levels. Typical values of oxygen flux are 100mmol $m^{-2}d^{-1}$ (Hull, 2016) or 3.2 g $m^{-2}d^{-1}$ therefore daily reaeration across 13.98 ha would be expected to compensate for the estimated daily oxygen consumption by decaying fish biomass.

During March when the highest daily biomass discharge would be predicted to occur via the FRR (3442 kg) oxygen demand would increase to 0.6% of that available from daily exchange and would be equivalent to reaeration over 45.2 ha.

This assessment assumes direct breakdown of all available biomass and no losses through predation. Reduction of oxygen concentration will only occur if the rate of oxygen use due to BOD is greater than daily exchange of the GSB and the oxygen transfer across the water surface.

Therefore as waters off Sizewell are well mixed vertically facilitating reaeration at the surface, the GSB has a relatively high exchange and the background dissolved oxygen levels are high there is unlikely to be a significant extent or duration of oxygen reduction associated with the input loading of BOD from biomass discharged from the FRR. BOD associated with moribund fish is therefore predicted to have a negligible effect on water quality which is not significant. There was no indication of low oxygen levels in monitoring surveys at Sizewell and average background BOD is 2mgl^{-1} and this is assumed to include the influence from SZB.

12 Summary and Conclusion

12.1 Background

The aim of this report is to assess the potential impacts of the Sizewell planned New Nuclear Build on the water quality within the local marine environment and to provide information that will support the assessment and setting of a discharge consent by the statutory regulator (Environment Agency) under the Environmental Permitting Regulations

For marine discharges, the standard approach for determining the potential impacts to water quality from industrial aqueous discharges is to apply the Environment Agency/Defra screening of contaminant contributions from surface drainage sources (Defra and Environment Agency Guidance, 2016) Environment Agency's H1 Environmental Risk Assessment.

The H1 screening methodology is applied here to identify any proposed chemical discharges that represent a potential risk to the marine environment including those which are then subject to detailed modelling to fully evaluate the acceptability of the discharge.

To assess the significance of specific chemical discharges the H1 methodology uses as its reference existing Environmental Quality Standards (EQSs). Where no EQS is available for a given substance then available toxicity test data are used to generate a Predicted No Effect Concentration (PNEC) as a reference for short term acute exposure and longer-term chronic exposure. Where insufficient or no toxicity data can be sourced then the marine background concentration for a substance from monitoring conducted adjacent to the Sizewell site is used as a point of reference.

The Greater Sizewell Bay (GSB) is considered as the initial reference area for the study site extending to Walberswick in the north with the southerly extent 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 on the bank. Sizewell C site discharges from the combined drainage outfall (CDO) which would include those from the construction site and potentially those during cold commissioning and from the Fish Recovery and Returns (FRRs) would also occur within the GSB

12.2 Construction discharge assessment

Temporary and variable discharges to marine water will form part of the surface drainage strategy during the construction phase. The main expected contaminants in these discharges are suspended solids, hydrocarbons, Biochemical Oxygen Demand (BOD), some metals from groundwater sources and ammonia. Sediment in site drainage water will be managed with appropriate technology (e.g. Siltbuster) so that suspended sediment in discharges from the construction site are unlikely to affect the water quality status. Hydrocarbons can be removed from effluent prior to discharge by the incorporation of suitable oil separators within temporary drainage systems and any potential for chemical and oil spills during construction activities will be managed.

The groundwater metals contamination across the construction site varies so a dataset from 2014-2016 has been used to derive the 95th percentile concentration for each of the substances of concern and these are used for initial screening assessment. Groundwater discharge volumes are highest in the first 28 days so screening is conducted both for this period and for the highest volume groundwater discharge likely thereafter. For the first 28 days of construction and the following period chromium concentrations failed this initial screening and the elevated background concentrations of zinc derived from monitoring surveys of the site mean that the screening cannot be appropriately applied for zinc. So, both chromium and zinc were modelled using CORMIX US EPA supported mixing zone model and the validated Sizewell curvilinear GETM model. CORMIX is used to predict the rate of chemical plume dilution and plume geometry from the Combined Discharge Outfall (CDO). The GETM model is a 3D hydrodynamic model with an inbuilt passive tracer to represent zinc and chromium. As a worst case, it was assumed that there was no loss of dissolved metals due to sediment absorption or biological uptake. Using these assumptions, concentrations can be scaled, as the modelled concentration was simply a function of dilution.
Both zinc and chromium were modelled for the first 28 day maximum groundwater discharge. CORMIX shows that for zinc the outfall plume would no longer be detectable within 3 m. For chromium the outfall plume would fall below the EQS within 25 m.

CORMIX output data suggest an initial dilution, for both zinc and chromium, was 47-fold at 25 m from the discharge (i.e. the same size as a single grid cell in GETM). GETM slightly under-predicts the initial dilution with the discharge volume of 124 l s^{-1} entering the model surface layer. The total volume in the upper grid cell is approximately 120 m^3. GETM shows a 40-fold dilution in the first 25 m, meaning the plume extends slightly further. The mean surface area in exceedance of the EQS for Chromium, predicted by GETM, is 5.49 ha. For zinc, the total surface area is 0.11 ha, or 2 grid cells.

Sewage treatment will be available on site to treat sanitary waste from the workforce and treated effluent will contribute to ammoniacal nitrogen and nutrients as well as Biochemical Oxygen Demand (BOD), faecal coliform *Escherichia coli*, Intestinal Enterococci and suspended solids.

Ammoniacal nitrogen inputs to the construction discharge are from groundwater and treated sewage effluent. The percentage of ammoniacal nitrogen that takes the un-ionised form is important to assess as this has a relatively high toxicity and as such has a derived annual average EQS of $21 \mu g l^{-1}$ NH_3-N. Various water quality parameters influence the proportion of ammonia that is un-ionised in seawater and so must be considered in any assessment i.e. higher pH, temperature elevation and reduced salinity all increase the relative proportion of un-ionised ammonia.

The percentage of ammonia in the un-ionised form in the construction discharge was calculated for worst case discharge scenarios during the construction period and under mean and most extreme site values for physicochemical parameters that increase the percentage of the un-ionised ammonia. A mixing figure was used to take account of changing physicochemical conditions as the mainly freshwater discharge from the CDO mixes with seawater and becomes fully saline. The associated change in the un-ionised ammonia concentration in the construction discharge relative to its annual average EQS was also assessed against the level of mixing. The percentage mixing required to reduce the un-ionised ammonia concentration below the EQS was determined. The degree of mixing required in each case was considered in combination with the estimated dilution rates derived from the CORMIX modelling to determine the distance required to achieve un-ionised ammonia concentration below the EQS. The maximum distance to achieve a value below the EQS was 6.3 m which was for a case including treated sewage effluent only contributions.

To assess the contribution of DIN and phosphorus from the construction discharges (including additional inputs during commissioning) the predicted source inputs were combined and used in a phytoplankton box model to indicate the potential influence on phytoplankton growth. 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 construction, so that no change in phytoplankton growth beyond natural variability would be observed.

A model run over an annual cycle predicts 0.13% percent difference in annual gross production (BEEMS TR385) of carbon and this level of change would not be discriminated above natural background variation.

The background Biochemical Oxygen Demand (BOD) near to the Sizewell B cooling water discharge based on monitoring has a mean value of 2 mg l^{-1}. Dissolved oxygen levels at the site are ‘high’ with a mean DO concentration of 7.5 mg l^{-1} adjusted to an equivalent salinity of 35 this is equivalent to 6.27 mgl^{-1}. 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 that which is exchanged across GSB and the oxygen transfer across the water surface. Typical values of oxygen flux are 100mmol $m^{-2}d^{-1}$ or 3.2 g $m^{-2}d^{-1}$. For a sewage discharge rate of 13.3 l s^{-1} and BOD of 40mgl^{-1} and taking account of groundwater contributions a daily BOD of 121kg was calculated which is equivalent to oxygen requirement of 40.6kg. This demand is very small relative to oxygen transferred as part of the daily exchange for GSB. Also, this amount of oxygen would be transferred across 1.2ha in a day.

Based on this assessment, the discharges of BOD during construction would be of negligible significance for dissolved oxygen modification.

Under bathing water regulations discharges containing faecal bacteria must be treated to ensure that the concentration of key indicator organisms will meet a designated standard for coastal and transitional waters for which Good status requires that the colony forming unit (cfu) counts for intestinal enterococci are ≤200 cfu/100 ml and for *Escherichia coli* are ≤500 cfu/100 ml.
The predicted numbers of *Escherichia coli* and intestinal enterococci in sewage effluent was calculated following different stages of sewage treatment with known reduction factors. The numbers after the final treatment stage were used in a modelling assessment taking account of dilution. CORMIX estimates show that the concentration of Intestinal Enterococci is likely to exceed the bathing water standard (200 cfu/100ml) only within 66m of the discharge for the 30ls^{-1} case, without UV treatment (secondary treatment only). For the larger discharge volume (72ls^{-1}) the bathing water standards are exceeded for 460 m. With UV treatment, even at the higher discharge volume, exceedance is limited to within less than 1 metre of the discharge.

The offshore cooling water infrastructure consists of two subterranean intake tunnels and one outfall tunnel. Tunnels would be excavated by tunnel boring machines (TBMs) from land.

During the transport of spoil material, groundwater and TBM chemicals can leach from the conveyor belts and fall to the tunnel floor. Wastewater on the tunnel floor would be discharged via the CDO. Discharges would be treated with a silt-buster or similar technology to minimise sediment inputs but there would be residual concentrations of soil conditioning chemicals present.

The total discharge volume during Case E is approximately 34ls^{-1} of which ca.,6l s^{-1} is contributed by soil conditioning water and chemicals. It is uncertain whether similar chemical use to that planned for HPC will occur during tunnelling for Sizewell C but representative worst case use and discharge scenarios are modelled based on HPC to allow assessment of the potential influence of discharges upon water quality at Sizewell.

The underlying geology at Sizewell differs from Hinkley Point and a bentonite slurry tunnelling method is anticipated at Sizewell. Bentonite is on a list of substances that do not normally need to be strongly regulated as, from assessment of their intrinsic properties, the OSPAR Commission considers that they pose little or no risk to the environment. Although during operation of TBMs bentonite recovery systems are used (as bentonite is a valuable resource in the tunnelling process) the potential release into the receiving waters is assessed. The total volume of wastewater including groundwater generated during tunnelling is estimated as 34.3l^{-1} per second and the resulting bentonite concentration would therefore be 8.8mgl^{-1}which was modelled using GETM. The concentration of bentonite in suspension is orders of magnitude lower than baseline suspended sediments concentrations predicted during construction, with 95th percentile concentrations of 10µgl^{-1} restricted to sea surface areas of 10.8ha. Data on survival of organisms exposed to bentonite suspensions indicate that the limited areas affected, and the low discharge concentrations are likely to have negligible effects on water quality.

In some TBM soil conditioning applications several different surfactant chemicals may be required. The use and discharge of two surfactant chemicals the anti- clogging agent BASF Rheosoil 143 and the soil conditioning additive CLB F5 M that are planned for use with the HPC tunnelling operation and that present higher risk quotients in terms of chemical properties are modelled for Sizewell. As with the groundwater metals, the release and mixing of TBM chemicals in the construction discharge was modelled by considering them as passive tracers (no decay rate). As such, a single model run was carried out with single tracer at a release rate of 34.3 l s^{-1} with an initial concentration of 100µgl^{-1}. The results were then scaled to the appropriate concentrations for each chemical, as the modelled concentration was simply a function of dilution.

For the soil conditioning chemical discharges, the total Rheosoil plume areas at the EQS (40 µgl^{-1} as a mean and 95th percentile) were calculated. There is no exceedance at the bed and only very limited areas of exceedance at the surface 1.01ha for a mean assessment. There was no exceedance of the EQS for CLB F5 M at the seabed and the area at the surface exceeding the EQS were relatively small with 3.14ha exceeding the EQS for a mean assessment.

12.3 Commissioning Discharge Assessment

When the cooling water system is commissioned a range of tests would be conducted and conditioning of the entire plant undertaken with demineralised water and various chemical additives. This process will generate wastewater containing several chemicals that will be discharged through the CDO.

Testing of the primary and secondary circuits requires them to be filled and flushed several times each. The maximum daily discharge volume is 1500m^{3}d^{-1}, equivalent to the contents of the two 750m^3 tanks that serve this waste stream. NNB GenCo proposes to empty each tank once a day, although not at the same time. No operational cooling system will be available for the disposal and dilution of commissioning phase effluents during the cold flush testing (CFT) stage for the first unit to be constructed during the phased development of the SZC site. Therefore, the only available discharge route for this wastewater stream will be through the CDO. If there is overlap in the period when each EPR is being commissioned this would increase discharge duration and load, but discharge concentration may be similar.

Four main chemicals are considered as part of the commissioning discharge. Phosphate loading and nitrogen from un-ionised ammonia addition were assessed in combination with the nitrogen and phosphorus inputs during construction using a phytoplankton growth model as described earlier. Un-ionised ammonia, ethanolamine (a water treatment chemical) and hydrazine were also screened for toxicity against their respective EQS or PNEC values in H1 Test 1. All failed the initial screening test and un-ionised ammonia and hydrazine failed the initial dilution assessment (Test 5) and so were modelled using CORMIX and GETM. Un-ionised ammonia did not exceed its EQs within 25 metres of the discharge.

Hydrazine, an oxygen scavenger used in power plants to inhibit corrosion in steam generation circuits was also modelled.

Prior to the release of hydrazine from the holding tanks, hydrazine would be treated to reduce the discharge concentration. Various treatment options are under investigation and it is anticipated that a discharge concentration of 15µgl^{-1} is achievable as a representative upper bounding concentration equivalent to a 95th percentile. As a discharge concentration of 15µgl^{-1} exceeds the EQS and fails the Test 5 dilution test this discharge concentration is modelled using GETM.

Modelling of the discharges from the commissioning of the EPRs when the cooling water system is unavailable assumes a maximum discharge rate of 83.3l^{-1} per second from a total holding volume of 1500m^3. For the commissioning release of hydrazine, a release concentration of 15µgl^{-1} released in daily pulses of 5.0 h starting at 12:00. This discharge period is enough to empty the total volume of both treatment tanks. To investigate the potential interaction of the hydrazine discharge concentration with relevant environmental sensitivities the results of both simulations are compared against three criteria: The likelihood that hydrazine enters the Minsmere Sluice and this also considers potential barriers to Eel movement; levels of hydrazine at the seabed over the Coralline Crag; the area of intersection of the acute hydrazine plume with Little Tern foraging areas.

To assess the spatial extent of the hydrazine plume and compare the resulting concentrations with the PNEC values (chronic and acute), the mean and 95th percentile of the hydrazine concentrations was extracted from the 31-day model run. For hydrazine the chronic PNEC value is 0.4ngl^{-1} for long term discharges (mean of the concentration values) and the acute PNEC value is 4ngl^{-1} for shorter term discharges (represented by the 95th percentile).

The area of hydrazine concentration exceeding the derived acute and chronic PNECs is less at the bed than the surface. At the surface 12.9 and 30.5ha exceed the acute and chronic PNEC respectively. At the surface the exceedance for the 200ngl^{-1} Canadian standard is 0.34 ha with no exceedance at the bed.

At no times are concentrations of hydrazine above the Chronic PNEC 0.4 ngl^{-1} at the Minsmere Sluice. at the surface or bed when hydrazine is released at 12:00 with a release concentration of 15µgl^{-1}. In all the cases, the plume does not stay in the vicinity of the sluice from after one high tide to the next (approximately 12h later). Since the Minsmere sluice only opens for half an hour after high tide, this means that the hydrazine plume does not coincide in time with the sluice opening. The hydrazine plume is transported northward towards Minsmere during the falling tide, meaning that the sluice water supply that is periodically used to add additional saltwater to the Minsmere salt marshes is unlikely to be exposed to hydrazine. The likelihood of any hydrazine exposure in the sluice water would also be made considerably less likely due to rapid degradation of hydrazine with half-life of ca.,30 minutes. Information on fish sensitivity to hydrazine is limited but the information available suggests that sublethal effects may occur at concentrations ca. 800,000 times higher than peak instantaneous concentrations modelled at the sluice (0.12 ng/l. The fact that the sluice opens for a half hour after high tide also means that species moving through the sluice at this time are unlikely to encounter peak concentrations. The short residence time of the hydrazine plume in proximity to the sluice and the rapid degradation rate of hydrazine also limit the likelihood of exposure of species moving via the sluice.

A similar assessment was conducted for the coralline crag. The model results show that at a 15µgl^{-1} release concentration the chronic PNEC is not exceeded at the seabed only at a concentration of 0.46ngl^{-1} for a period of 0.25h at the surface. At the seabed, the acute PNEC is not exceeded with all release concentrations, meaning Sabellaria (as a benthic feature) would not be exposed to acute or chronic concentrations. The peak concentration of hydrazine at the seabed, with a 15µgl^{-1} release concentration, is 0.46 ngl^{-1}, and is below the acute PNEC and marginally above the chronic PNEC.

In the Greater Sizewell Bay, there are three breeding colonies of little terns at Dingle, Minsmere and Slaughden and Little Terns have a foraging range of 2.4 km offshore and 3.9 km north and south. The hydrazine plume never intersects with the Dingle colony to the north and the Slaughden colony to the south. At a release concentration of 15µgl^{-1}, the instantaneous area of intersection between the hydrazine plume and the Minsmere colony regularly exceeds 1%, for both the 12:00 and 18:00 release. Whilst the plume intersection with 15µgl^{-1} release concentration regularly exceeds 1% of the foraging range, the duration of the plume is short, with concentrations exceeding the acute PNEC for no longer than 4 hours.

During the latter stages of commissioning that is hot functional testing (HFT) the objective is to test the reactor and associated systems under pressure, temperature, flow and chemical conditioning as close to normal operating conditions as practicable. Due to the current stage of the project and the long lead time until commissioning takes place, detailed information on the nature of the discharges during HFT is limited, but it is assumed that HFT can be considered as running the systems under normal operating conditions. It would therefore be expected that the assessment for operational discharges would also apply to that during HFT.

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 SZC cooling water (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 Total Residual Oxidant (TRO) dose of 0.2mgl^{-1} in critical sections of the CW plant and at the inlet to the condensers.

Testing of this system will be undertaken during the commissioning phase, but it is assumed that this would only occur once the full cooling water system was in place and operational.

12.4 Operational Discharge Assessment

Potential discharges to the marine environment have been assessed for the operational phase of the planned SZC. For large cooling water discharges that are discharged to estuaries or coastal waters a specific screening assessment recommended by Defra and Environment Agency, (Clearing the Waters for All, 2016) is applied.

The annual and daily load of each of the chemicals used during operation enables derivation of a predicted concentration in the cooling water discharge and this is compared to the relevant quality standard or other acceptable alternative reference for the substance. In the first phase of screening for operational chemicals chlorine and hydrazine fail screening and are assessed using more detailed modelling. As chlorination of seawater produces chlorination byproducts and bromoform was found to be the most dominant of detected in laboratory simulations using Sizewell seawater it was also modelled in the cooling water discharge.

For the daily and annual discharge assessments of the cooling water inputs during operation several other substances including metals exceed the EQS screening criteria. However, in many cases these are screened out of further assessment as they are considered to have negligible likely effects as the actual discharge concentrations are below method detection limits, the concentrations are several orders of magnitude below their EQS (or PNEC or site background values) and/or the substances have low bioconcentration potential and are readily degradable.

The thermal elevation of the cooling water discharge can also influence the proportion of un-ionised ammonia present and as this represents a potential worst case for un-ionised ammonia this was modelled in support of the un-ionised ammonia assessment.

As sewage effluent also potentially contributes to the cooling water discharge during operation the influence of the biochemical oxygen demand and the numbers of intestinal enterococci and *Escherichia coli* likely to be present after treatment relative to the bathing water standard were also assessed.

During the operational phase the requirement to treat the cooling water to prevent biofouling of the condensers results in the discharge of chlorine produced oxidants (or Total Residual Oxidants, TRO) at a predicted concentration of 150µgl^{-1} at the outfall heads. To provide protection to the marine environment chlorine has an EQS of 10µgl^{-1} TRO set as a maximum allowable concentration and expressed as a 95th percentile. The predicted TRO concentration in the cooling water discharge, based on an empirical demand/decay formulation derived from experiments with Sizewell seawater has been modelled using the GETM Sizewell model. Two scenarios were considered: chlorination of SZB plus SZC operating in combination, and chlorination of SZB only. For each model run a month-long simulation was analysed and the mean and 95th percentile of the TRO concentration were extracted. The total area of the plume that exceeds a concentration threshold of 10µgl^{-1} was at a maximum for SZB and SZC operating in combination covering an area of 726ha at the surface and 167ha at the bed. For SZC alone 338ha of the surface and only 2ha at the seabed are affected at a 95th percentile TRO of 10µgl^{-1}.

A Fish Recovery and Return system (FRR) is planned to provide a safe return of the more robust organisms directly into the marine environment. This system will not be chlorinated and therefore no discharge assessment is required.

A consequence of the chlorination of the cooling water system is the formation of chlorination by-products (CBP's) because of complex chemical reactions in seawater. In laboratory studies carried out with chlorinated Sizewell seawater the only CBP that was detected was bromoform. Bromoform is lost through volatilization to the atmosphere, with the loss rate a function of the thermal stratification and values obtained from the scientific literature. The volatilisation loss equation was coupled into the GETM Sizewell model. Since bromoform is a product of chlorination, the same scenarios as for TRO were considered: chlorination of SZB plus SZC operating in combination and chlorination of SZB 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 5µ l^{-1} as a 95th percentile has been used. This value was based on the results of a toxicological review and the application of Quantitative Structure Activity Relationships. A maximum of 358ha at the surface and 130ha at the seabed is affected by a bromoform concentration in the discharge plume from SZB and SZC in combination that exceeds the 5µgl^{-1} PNEC. For SZC alone a total area of 52ha at the surface and <1ha at the seabed exceeds the PNEC.

Hydrazine discharges exceed the acute and chronic quality standard (PNEC) values for both 24 hour and annual loadings. The worst-case daily discharges from the discharge tanks KER (Nuclear Island tanks), TER (additional capacity tanks) and SEK (Conventional Island tanks) have been assessed in relation to an annual hydrazine discharge of 24 kg per annum into the cooling water flow. It is assumed that the annual discharge of hydrazine would be discharged over 365 days i.e. no outages and a worst case daily mean hydrazine discharge of 66.6 g into a 116 m^3 s^{-1} cooling water flow (concentration in treatment tank of 0.089 or 0.044 mgl^{-1} depending on whether one or two holding tanks are used). Assuming no treatment, the daily discharge concentration in the CW flow would be 69ngl^{-1} over 2.3h if one tank was used or 34ng l^{-1} over a 4.6h period if two tanks were used. To understand the impact of different discharge rates from the treatment tanks two discharge scenarios were studied for SZC: the first one considering a hydrazine discharge of 69ngl^{-1} in daily pulses of 2.32h starting at 12pm, and the second one of 34.5ng l^{-1} of hydrazine discharged in daily pulses of 4.63h duration starting at 12pm. The amount of mass that is released in each of these scenarios is the same. For each model run 28 days were analysed (two tidal cycles) and the mean and 95th percentile of the hydrazine concentrations was extracted. For hydrazine there is a chronic PNEC value of 0.4ngl^{-1} for long term discharges (mean of the concentration values) and an acute PNEC value of 4ngl^{-1} for shorter term discharges (represented by the 95th percentile).

The total area exceeding the chronic PNEC at the seabed (0.4ngl^{-1} as an average) is less than 1ha if hydrazine is released in the short or longer pulse scenarios. At the surface the area of exceedance of the chronic PNEC is very similar for short or longer pulses (ca.,158 and 157ha, respectively).

The acute PNEC (4ngl^{-1} as the 95th percentile) is only exceeded at the seabed if hydrazine is released in short pulses and then for only for 0.22ha. At the surface, the area of exceedance for both scenarios is ca.,14ha if hydrazine is released in 2.3h pulses and ca.,17ha if hydrazine is released in 4.6h pulses.

Modelling that takes account of the site background un-ionised ammonia and the calculated additional input of un-ionised ammonia in the discharge was conducted. Sizewell temperature salinity and pH data were used to simulate average and worst-case combinations with respect to the percentage of un-ionised ammonia. For average and extreme combinations tested for un-ionised ammonia show that no areas exceed the EQS of 21µg l^{-1} as an annual mean. The 24-hour discharge figure for un-ionised ammonia is just over a third of the EQs at 7.92µg l^{-1} but the site background concentration is low (maximum 5.2µgl^{-1}). For annual discharges the screening assessment passed initial assessments but to provide more detailed assessment of the thermal influence on proportion of un-ionised ammonia the mean ammonia discharge at the outfall was added to regional background mean and 95th percentile values to derive the un-ionised ammonia calculation. All cases (including worst cases) for un-ionised ammonia show that no areas exceed the EQS of 21µgl^{-1} as an annual mean.

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 332kg and the maximum annual loading 11,725 kg per year (32.1kg d^{-1}). During the operational phase, maximum daily loading for nitrogen therefore reach approximately 2% of the daily exchange for Sizewell Bay, but the average daily value is low at 0.2% (again indistinguishable from background levels) (BEEMS TR385).

For operational loadings phosphorus also passed the screening assessment but had one of the higher values in the screening test based on 24-hour loadings (352.5 kg as PO_4). Converting this loading to PO_4-P gives a value of ca.,115kg. The predicted PO_4-P daily exchange in summer between Sizewell Bay and outer tidal excursion and the wider area is 2440 kg (BEEMS TR385) therefore the planned daily PO_4-P loading from SZC would represent ca.,5% of this value but the more representative average daily value is very low at 0.03%. 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

The effect of SZB and the proposed SZC during operation on phytoplankton that pass through the power station has been simulated using a phytoplankton box model. 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.

Based on the DIN and phosphorus loading during operation the phytoplankton growth Box model run over an annual cycle showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.11%. However overall carbon levels decrease ca., 5% due to entrainment mortality and the added nutrients have a very minor influence on this.

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. And reduction of oxygen concentration will only occur if the rate of consumption due to BOD is greater than the oxygen replenished by the daily exchange rate of GSB and the oxygen transfer across the water surface. The maximum BOD loading is 3.8 kg per day based on a maximum 1900 staff on site this is calculated to be equivalent to an oxygen requirement of 1.26 kg which would be present in a volume of 183m^3. This volume is extremely small relative to the exchange for the GSB. An equivalent supply of oxygen to offset this demand would also be transferred across just over 1000m^2 in a day. 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.

Assessment of the sewage treatment level provided by secondary treatment and assuming dilution in the flow from a single operational EPR the estimated numbers of E.coli and intestinal enterococci in the discharge will meet the bathing water standard for Good status at the point of discharge.

For the period April to September nutrient limitation is more evident and phytoplankton growth is increasing, therefore the total biomass of moribund biota that potentially may be discharged from the FRR has been estimated. The additional loading of nutrients phosphorus and nitrogen added to the waters off Sizewell by the decaying biomass are considered low enough so as not to affect the assessment of negligible influence on phytoplankton growth when considered in addition to the operational input of these nutrients. For the combined nutrient data a model run over an annual cycle predicts a less than 0.29% difference in annual gross production (BEEMS TR385) of carbon and this level of change would not be discriminated above natural background variation. However, carbon levels decrease ca., 5% due to entrainment mortality and the added nutrients has a very minor positive influence on this.

Evaluation of the daily average un-ionised ammonia loading contributed by decaying biomass following discharge from the FRR estimates that it could be at or above the un-ionised ammonia annual average EQS of 21µgl^{-1} NH_3-N, (taking account of natural background and input from SZC operation with thermal influence included) over an area of 1.2ha around the FRR. During the winter period the higher biomass loadings would increase the area above the EQS to 6.7ha.

The influence of biomass decay on the BOD was also assessed and daily re aeration over an area of 14ha would be enough to meet this additional demand when considered with that of the operational discharge and this takes no account of water exchange for the Greater Sizewell Bay. Therefore, biomass decay is expected to have a negligible influence on dissolved oxygen concentration.

12.5 Conclusions

This report assesses the construction, commissioning and operation of two UKEPR units for the proposed SZC development.

A H1 type screening assessment together with more detailed modelling as required of the discharges during the construction and operation periods has been completed. The assessment includes representative discharges of soil conditioning chemicals that may potentially be applied during TBM operation. The results of the assessments show that resultant environmental concentrations of discharge chemicals during the construction period are likely to have a relatively localised influence on marine water quality.

During the commissioning phase the cold flush discharges from EPR unit 1 and 2 would be made via the construction drainage system to the marine environment in a low volume flow. Several chemicals are likely to be discharged during commissioning, the most significant of which is hydrazine which has a high toxicity. Based on hydrazine wastewater treatment an indicative discharge concentration and rate was modelled. The potential area affected by concentrations in excess of the acute and chronic PNEC values for hydrazine were lower at the seabed with mean values exceeding the chronic PNEC of over 30.5ha at the surface and over 12.9ha at the surface exceeding the acute PNEC as a 95th percentile assessment. Three assessments were made also to determine potential influence of hydrazine on the Minsmere sluice, the Coralline crag habitat and areas of offshore bird foraging for coastally based breeding colonies. The hydrazine plume is transported northward towards Minsmere during the falling tide, meaning that the sluice water supply that is periodically used to add additional saltwater to the Minsmere salt marshes is unlikely to be exposed to hydrazine. The likelihood of any hydrazine exposure in the sluice water would also be made considerably less likely due to rapid degradation of hydrazine with a half-life of ca.,30 minutes. The passage of Eels into or out of the saltmarshes via the sluice is unlikely to be affected by the presence of hydrazine as hydrazine plumes would only intersect the sluice during an ebbing tide when water levels would be falling and the sluice would be closed. The predicted peak concentrations of hydrazine in proximity to the sluice in any case are ca. 800,000 times below levels shown to cause sublethal effects in fish so Eels moving to or from the saltmarshes in the vicinity of the sluice would also not be exposed to significant concentrations of hydrazine.

In terms of the coralline crag the peak hydrazine concentration at the seabed over the crag does not exceed the acute PNEC and only exceeds the chronic PNEC for 15 minutes a day. In the Greater Sizewell Bay, the hydrazine plume never intersects foraging areas for two of the three SPA breeding colonies of birds. Whilst the plume intersection with 15µgl^{-1} release concentration regularly exceeds 1% of the foraging range for the little Tern colony, the duration of the plume is short, with concentrations exceeding the acute PNEC for no longer than 4.5 hours.

During operation the larger volume discharges for example of chlorinated cooling water, chlorination byproducts (specifically bromoform) and hydrazine have more potential for larger scale influences on the water quality of the Greater Sizewell Bay. In terms of water quality, the influence of these discharges is relatively more limited but further assessment of areas of overlap with ecology receptors will be relevant. The FRR will potentially discharge dead organisms. An assessment of potential nutrient and oxygen demand from the decaying biota indicates that in combination with operational influence on the same parameters there is low likelihood of influence on phytoplankton growth or upon water quality.

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14 Appendix A Groundwater analysis 2014-2016

Table 40: Levels of detection for physical parameters, inorganic chemicals and metals measured in groundwater sampled from boreholes on the SZC New Build construction site

Determinand	Accred.	SOP	Units	LOD
pH	U	1010		
Electrical Conductivity	U	1020	µS/cm	1
Suspended Solids At 105C	U	1030	mg/l	5
Biochemical Oxygen Demand Low Level	N	1090	mg O2/l	1
Chemical Oxygen Demand Low Level	N	1100	mg O2/l	1
Alkalinity (Total)	U	1220	mg CaCO3/l	10
Chloride	U	1220	mg/l	1
Ammoniacal Nitrogen	U	1220	mg/l	0.01
Ammonium	U	1220	mg/l	0.01
Nitrite	U	1220	mg/l	0.02
Nitrate	U	1220	mg/l	0.5
Phosphate	U	1220	mg/l	0.05
Phosphorus (Total)	N	1220	mg/l	0.02
Sulphate	U	1220	mg/l	1
Total Oxidised Nitrogen	U	1220	mg/l	0.2
Cyanide (Free) Low-Level	N	1300	mg/l	0.005
Calcium	U	1415	mg/l	5
Potassium	U	1415	mg/l	0.5
Magnesium	U	1415	mg/l	0.5
Sodium	U	1415	mg/l	0.5
Arsenic (Dissolved)	U	1450	µg/l	1
Boron (Dissolved)	U	1450	µg/l	20
Cadmium (Dissolved)	U	1450	µg/l	0.08
Chromium (Dissolved)	U	1450	µg/l	1
Copper (Dissolved)	U	1450	µg/l	1
Nickel (Dissolved)	U	1450	µg/l	1
Lead (Dissolved)	U	1450	µg/l	1
Zinc (Dissolved)	U	1450	µg/l	1
Mercury Low Level	U	1460	µg/l	0.01
Iron (Dissolved)	N	1470	µg/l	20
Total Organic Carbon	N	1610	mg/l	1

Table 41: Levels of detection for total petroleum hydrocarbons and polycyclic aromatic hydrocarbons measured in groundwater sampled from boreholes on the SZC New Build construction site

Determinand	Accred.	SOP	Units	LOD
Total TPH >C6-C40	U	1670	µg/l	10
Naphthalene	N	1700	µg/l	0.01
Acenaphthylene	N	1700	µg/l	0.01
Acenaphthene	N	1700	µg/l	0.01
Fluorene	N	1700	µg/l	0.01
Phenanthrene	N	1700	µg/l	0.01
Anthracene	N	1700	µg/l	0.01
Fluoranthene	N	1700	µg/l	0.01
Pyrene	N	1700	µg/l	0.01
Benzo[a]anthracene	N	1700	µg/l	0.01
Chrysene	N	1700	µg/l	0.01
Benzo[b]fluoranthene	N	1700	µg/l	0.01
Benzo[k]fluoranthene	N	1700	µg/l	0.01
Benzo[a]pyrene	N	1700	µg/l	0.01
Indeno(1,2,3-c,d)Pyrene	N	1700	µg/l	0.01
Dibenz(a,h)Anthracene	N	1700	µg/l	0.01
Benzo[g,h,i]perylene	N	1700	µg/l	0.01
Total Of 16 PAH's	N	1700	µg/l	0.2

Table 42: Levels of detection for volatile organic compounds measured in groundwater sampled from boreholes on the SZC New Build construction site

Determinand	Accred.	SOP	Units	LOD
Dichlorodifluoromethane	U	1760	µg/l	1
Chloromethane	U	1760	µg/l	1
Vinyl Chloride	N	1760	µg/l	1
Bromomethane	U	1760	µg/l	5
Chloroethane	U	1760	µg/l	2
Trichlorofluoromethane	U	1760	µg/l	1
1,1-Dichloroethene	U	1760	µg/l	1
Trans 1,2-Dichloroethene	U	1760	µg/l	1
1,1-Dichloroethane	U	1760	µg/l	1
cis 1,2-Dichloroethene	U	1760	µg/l	1
Bromochloromethane	U	1760	µg/l	5
Trichloromethane	U	1760	µg/l	1
1,1,1-Trichloroethane	U	1760	µg/l	1
Tetrachloromethane	U	1760	µg/l	1
1,1-Dichloropropene	U	1760	µg/l	1
Benzene	U	1760	µg/l	1
1,2-Dichloroethane	U	1760	µg/l	2
Trichloroethene	N	1760	µg/l	1
1,2-Dichloropropane	U	1760	µg/l	1
Dibromomethane	U	1760	µg/l	10
Bromodichloromethane	U	1760	µg/l	5
cis-1,3-Dichloropropene	N	1760	µg/l	10
Toluene	U	1760	µg/l	1
Trans-1,3-Dichloropropene	N	1760	µg/l	10
1,1,2-Trichloroethane	U	1760	µg/l	10
Tetrachloroethene	U	1760	µg/l	1
1,3-Dichloropropane	U	1760	µg/l	2
Dibromochloromethane	U	1760	µg/l	10
1,2-Dibromoethane	U	1760	µg/l	5
Chlorobenzene	N	1760	µg/l	1
1,1,1,2-Tetrachloroethane	U	1760	µg/l	2
Ethylbenzene	U	1760	µg/l	1
m & p-Xylene	U	1760	µg/l	1
o-Xylene	U	1760	µg/l	1

Table 43: Levels of detection for volatile organic compounds measured in groundwater sampled from boreholes on the SZC New Build construction site

Determinand	Accred.	SOP	Units	LOD
Styrene	U	1760	µg/l	1
Tribromomethane	U	1760	µg/l	1
Isopropylbenzene	U	1760	µg/l	1
Bromobenzene	U	1760	µg/l	1
1,2,3-Trichloropropane	N	1760	µg/l	50
N-Propylbenzene	U	1760	µg/l	1
2-Chlorotoluene	U	1760	µg/l	1
1,3,5-Trimethylbenzene	U	1760	µg/l	1
4-Chlorotoluene	U	1760	µg/l	1
Tert-Butylbenzene	U	1760	µg/l	1
1,2,4-Trimethylbenzene	U	1760	µg/l	1
Sec-Butylbenzene	U	1760	µg/l	1
1,3-Dichlorobenzene	N	1760	µg/l	1
4-Isopropyltoluene	U	1760	µg/l	1
1,4-Dichlorobenzene	U	1760	µg/l	1
N-Butylbenzene	U	1760	µg/l	1
1,2-Dichlorobenzene	U	1760	µg/l	1
1,2-Dibromo-3-Chloropropane	U	1760	µg/l	50
1,2,4-Trichlorobenzene	U	1760	µg/l	1
Hexachlorobutadiene	U	1760	µg/l	1
1,2,3-Trichlorobenzene	U	1760	µg/l	2
Methyl Tert-Butyl Ether	N	1760	µg/l	1

Table 44: Levels of detection for Polychlorinated bipheyls measured in groundwater sampled from boreholes on the SZC New Build construction site

Determinand	Accred.	SOP	Units	LOD
PCB 28	N	1815	µg/l	0.01
PCB 52	N	1815	µg/l	0.01
PCB 101	N	1815	µg/l	0.01
PCB 118	N	1815	µg/l	0.01
PCB 153	N	1815	µg/l	0.01
PCB 138	N	1815	µg/l	0.01
PCB 180	N	1815	µg/l	0.01
Total PCBs (7 congeners)	N	1815	µg/l	0.01
Total Phenols	U	1920	mg/l	0.03

15 Appendix B Supporting ecotoxicity data for PNEC derivation

The following sections provide details of the ecotoxicological data used to inform the risk of an impact from various chemical components of site discharges during different phases of the new build power station development. The reference source for the information on hydrazine, morpholine and ethanolamine is EDF 2008.

PNEC values for hydrazine,

The PNECs given below were obtained:

- based on bibliographic research into ecotoxicological data available in the literature in 2006,
- based on a critical review of these data and their categorisation by level of admissibility. The findings are categorised based on the living organisms studied, as well as their relevance, assessed after studying the original publication that presented them;
- depending on the various methods used, i.e. either the uncertainty factors method given in the EU Technical guidance,2003 or the species sensitivity distribution (SSD) or ACT-SSWD methods, for Acute to Chronic Transformation – Species sensitivity Weighted Distribution2,3.

This work by EDF R&D was submitted to INERIS for a second opinion in 2006. The values used are derived from this joint work. They are the same as those used by IRSN.

Available ecotoxicity data for hydrazine

The bibliographic analysis was conducted by consulting the following databases: Aquire, Biological abstracts, Chemical abstracts, Dose-1998, ECDIN-1993, EINEC-1998, Environmental bibliography, HSDB-1997 (Hazardous Substances Data Bank), IRIS on-line (Integrated Risk Information System, U.S.EPA, http://www.epa.gov/iris/subst/0528.htm), IUCLID version 4.0-2001, Medline, OHM/TADS-1997, Pascal biomed, Pascal sciences et techniques, and Toxline. All of the ecotoxicological data regarding algae, vertebrates (fish, etc.) and invertebrates (crustaceans, etc.) have been listed.

A few of the lowest chronic and acute ecotoxicological values, selected as admissible after reading the publications, are given for each taxonomic group in the table below. A datum ultimately considered valid (EC_{50} for *Dunaliella tertiolecta*) has been added. As a reminder, for the use of statistical methods, the sample of data used is larger than the one shown below.

Table 45: Acute and chronic toxicity data used for derivation of respective PNECs for hydrazine

Species	**Taxonomic group**	**Exposure times**	**DC_{50}-EC_{50}-IC_{50} mg l^{-1}**	**NOEC mg l^{-1}**	**Authors**
Pseudokirchneriella subcapitata	Algae (freshwater	72 hrs	0.006	0.001	Harrah, 1978
Dunaliella tertiolecta	Algae (seawater)	48 hrs	0.0004		Dixon et al, 1979
Hyalella azteca - (amphipod)	Crustacean (freshwater)	48 hrs	0.04		Fisher et al., 1980b - Anonymous, 1998
Daphnia pulex	Crustacean (freshwater)	48 hrs	0.16		Velte, 1984
Daphnia pulex	Crustacean (freshwater)	96 hrs	0.19		Velte, 1984
Ictalurus punctatus	Fish (freshwater)	96 hrs	1		Fisher et al., 1980b - Anonymous, 1998 - IUCLID, 2001; - Dose, 1998; Richardson, 1992
Lepomis macrochirus	Freshwater fish (vertebrate)	96 hrs	1.08		Fisher et al., 1978 ; Fisher et al., 1980a
Notemigonus crysoleucas	Freshwater fish (vertebrate)	96 hrs	1.12		Fisher et al., 1980b -
Lepomis macrochirus	Freshwater fish (vertebrate)	72 hrs	1.2		Hunt et al., 1981, cited by Velte, 1984
Asillidae - (isopod)	Crustacean	96 hrs	1.3		Fisher et al., 1980b - Anonymous, 1998
Ambystoma opacum and Ambystoma maculum(salamander)	Amphibian (vertebrate)	96 hrs	2.12		Slonim, 1986
Gasterosteus aculeatus	Freshwater fish (vertebrate)	96 hrs	3.4		Harrah, 1978; Klein and Jenkins, 1978
Poecilia reticulata	Freshwater fish (vertebrate)	96 hrs	3.85		Slonim, 1977
Ambystoma opacum and Ambystoma maculum(salamander)	Amphibian (vertebrate)	96 hrs	4.11		Slonim, 1986
Pimephales promelas	Freshwater fish (vertebrate)	96 hrs	4.5		Cowen et al., 1981
Pimephales promelas	Freshwater fish (vertebrate)	96 hrs	5.98		Velte, 1984

PNEC obtained using uncertainty factors method

For this substance, INERIS currently recommends strictly applying the Technical Guidance Document, 2003 rules, and therefore the uncertainty factors method. Using this method, the chronic PNEC is obtained by applying an expansion factor of 1000 to the lowest EC_{50} in Pseudokirchneriella subcapitata at 6µgl^{-1}(Harrah, 1978).

The value of chronic PNEC of hydrazine in fresh water used in the impact study is therefore 6/1000= 0.006 µg l^{-1} or 6ngl^{-1}.

PNEC obtained using uncertainty statistical method

Though the PNEC derived from statistical calculations is merely additional information for the analysis, it is presented anyway:

The ACT-SSWD statistical method makes it possible to calculate HC5_5%, which protects 95% of species, with a confidence interval of 95%. This HC5_5% value may be likened to a PNEC.

By using all the data about hydrazine for the three freshwater categories of algae, vertebrates (fish, etc.) and invertebrates (crustaceans, etc.), and weighting them all equally, a HC5_5% of 5.0 µg l^{-1} is obtained.

The 3.7 µg l^{-1} value obtained for acute HC5_5% (see next section) may seem contradictory, because it is on the same order of magnitude as the chronic value. This is explained by the presence of a value penalising algae in the data set used (EC10 72 hrs for 0.003 mg l^{-1} of *Pseudokirchneriella subcapitata*). Owing to the lifespan of this sort of organism, the algae tests are chronic in nature. Strictly speaking, there is no acute test for algae. Therefore, the same data needs to be used for both acute and chronic PNEC, if this important taxon in the aquatic environment is to be taken into consideration.

As a precaution, it will therefore be assumed that the hydrazine PNEC values derived from statistical calculations are the same for both acute and chronic toxicity. The lower of the two values (which are on the same order of magnitude), i.e. 3.7 µg l^{-1}, is therefore used.

Chronic seawater PNEC

As there are not enough ecotoxicological values available for hydrazine in marine species, there is no way to calculate a seawater PNEC based on them. The TGD makes it possible to use ecotoxicological data from freshwater species to assess the seawater PNEC of a substance. If so, an additional factor of 10 is applied to the value of the freshwater PNEC, in order to take account the many uncertainties which govern the environmental impact of chemicals in marine environments (i.e. an expansion factor of 10,000, in our situation). However, owing to expert opinion (as hydrazine cannot bioaccumulate and is nonpersistent), a suggestion has been made to adopt expansion factors of 1000 and 100 instead for the chronic and acute seawater PNECs, while still holding EC_{50} to be valid for 0.4 µg l^{-1} of *Dunaliella tertiolecta*).

The chronic PNEC of hydrazine in seawater used in the impact study is therefore equal to 0.4/1000 0.0004 µg l^{-1}, or 0.4 ng l^{-1}.

Acute freshwater PNEC

Using all of the acute data on hydrazine for the three freshwater categories of algae, vertebrates (fish, etc.) and invertebrates, and weighting each one equally, a HC5_5% (likened to a PNEC) of 3.7 µg l^{-1} is obtained using the ACT-SSWD statistical method. Using the TGD's uncertainty factors method as currently recommended by INERIS, the chronic PNEC is obtained by applying an expansion factor of 100 to the lowest EC50 in 6 µg l^{-1} of *Pseudokirchneriella subcapitata* (Harrah, 1978).

The value of acute PNEC of hydrazine in fresh water used in the impact study is therefore 6/100= 0.06 µg l^{-1}, or 60 ng l^{-1}.

Acute seawater PNEC

As stated above, an expansion factor of 100 is applied to EC50 for 0.4 µg l^{-1} of *Dunaliella tertiolecta*.

The value of acute PNEC of hydrazine in fresh water used in the impact study is therefore 0.4/100= 0.004 µg l^{-1}, or 4 ng l^{-1}.

GLOSSARY

PNEC: Predicted No Effect Concentration
EC50: Half maximal effective concentration
IC50: Half maximal inhibitory concentration
LD50: Lethal dose for 50% of organisms
HC: Hazard Concentration
NOEC: No Observed Effect Concentration

Available ecotoxicology data for morpholine

The PNECs given below were obtained:

- based on a bibliographic search of the ecotoxicological data available in the literature in 2001, the summary prepared by GRNC4, and three series of tests conducted by the CIT5 laboratory (at the request of EDF R&D), as the bibliographic analysis had demonstrated a lack of data;
- based on a critical review of this data and categorising them by level of admissibility. The findings are categorised based on the living organisms studied, as well as their relevance, assessed after studying the original publication that presented them;
- based on the uncertainty factors method described in the TGD6.

This work by EDF R&D was submitted to INERIS for a second opinion in 2006. The values used are derived from this joint work.

The sources of information used to gather the ecotoxicology values are the work of GRNC and the IUCLID database (2000).

As the bibliographic analysis had demonstrated a lack of data, three series of tests were conducted (at the request of EDF R&D) by the CIT laboratory (a 72-hour growth inhibition test on algae, a 21-day microcrustacean reproduction inhibition test, a 28-day offspring weight gain test on fish).

The test on *Microcystis aeruginosa* (Bringmann and Kühn, 1978) was added, because the value was ultimately considered valid after a second opinion was given.

A few of the lowest ecotoxicological values in fresh water, selected and considered admissible after reading the publication, are given for each organism in Tables 35 and 36 below.

Table 46: Chronic toxicity data used for derivation of respective PNECs for morpholine

Organism	Species	Chronic toxicity mg l^{-1}	Authors
Algae	Selenastrum capricornutum	80 (NOEC 24-144hrs)	Adams et al., 1985
	Scenedesmus subspicatus	20 (NOEC 72hrs)	CIT,2003
	Microcystis aeruginosa (cyanobacterium)	1.7 (TT 8d considered to be NOEC)	Bringmann and Kühn, 1978
Crustacean	Daphnia magna	2.56 (NOEC 21d)	CIT,2003
Fish	Oncorhynchus mykiss	>or= 100 (NOEC 28d)	CIT,2003

Table 47: Acute toxicity data used for derivation of respective PNECs for morpholine

Organism	Species	Acute toxicity mg l^{-1}	Authors
Algae	Selenastrum capricornutum		Calamari et al., 1982
Shellfish	Daphnia magna	100(EC50 24hrs)	Bringmann and Kühn, 1978
Fish	Leuciscus idus	240 (LD_{50} 48hrs)	Juhnke and Ludermann, 1978
Fish	Oncorhynchus mykiss	>or= 100 (NOEC 28d)	Calamrai et al., 1982

Chronic freshwater PNEC

The uncertainty factors method given in the TGD is applied, meaning that the PNEC is deduced from the listed and adopted NOEC data, and particularly the lowest one to which an uncertainty factor is applied based on the number of data points for each trophic level.

The data shows that there are three NOECs for three different trophic levels. In accordance with the TGD, a factor of 10 has been applied to the algae NOECs (the lowest of the three trophic levels), which is equal to 1.7mgl^{-1} (see table above).

Thus, the **chronic PNEC of morpholine in fresh water** used in the impact study is 1.7/10 = 0.170mg l^{-1}, or **170µgl^{-1}**.

Chronic seawater PNEC

Regarding marine environment, only acute data for fish exist (LD_0 for 96hrs on *Chelon engeli* at 100mgl^{-1} (McCain and Peck, 1976). In such cases, the TGD suggests applying an additional expansion factor of 10 to the chronic freshwater PNEC in order to set a chronic seawater PNEC.

Thus, the **chronic PNEC of morpholine in seawater** used in the impact study is 170/10 = **17µg l^{-1}**.

Acute freshwater PNEC

The uncertainty factors method described in the TGD is applied, meaning that the PNEC is deduced from the listed and adopted LD50 data, particularly the lowest one, 28mgl^{-1} (EC50- 96hrs for Selenastrum capricornutum), to which an uncertainty factor of 100 is applied. Thus, the **acute PNEC of morpholine in fresh water** used in the impact study is 28/100 = 0.280mgl^{-1}, or **280 µg l^{-1}.**

Acute seawater PNEC

The TGD suggests applying an additional expansion factor of 10 to the acute freshwater PNEC in order to set an acute seawater PNEC, whenever there is too little seawater data. Thus, **the chronic PNEC on morpholine in seawater** used in the impact study is 280/10 = **28 µg l^{-1}**.

Additional information

Morpholine is readily biodegradable at 93 % after 28 days in a non-GLP Guideline study following protocol OECD 301 E (modified OECD screening test; 10 -d window kept; inoculum: effluent from municipal wwtp) [BASF AG 1990, Report No. 1901337].

According to a MITI study (corresponding to OECD 305C), morpholine does not significantly accumulate in aquatic organisms (BCF < 2.8) [CITI, 1992].

Calculated logKoc-values of 0.8666 and -0.61967 are available based on estimates from MCI and log Kow respectively (BASF SE, KOCWIN v2.00, 2010). The molecule is not expected to adsorb to suspended solids and sediment based upon the log Koc as calculated for the uncharged molecule.
https://echa.europa.eu/registration-dossier/-/registered-dossier/13364/5/3/2

GLOSSARY
PNEC: Predicted No Effect Concentration
EC50: Half maximal effective concentration
IC50: Half maximal inhibitory concentration
LD50 , LD0: Lethal dose for 50% (0%) of organisms
HC: Hazard Concentration
NOEC: No Observed Effect Concentration
TT: Toxicity Threshold may be considered to be a NOEC

Available ecotoxicology data for ethanolamine

The PNECs given below were obtained:

- based on bibliographic research into ecotoxicological data available in the literature in 2006,
- based on a critical review of this data and categorising them by level of admissibility. The findings are categorised based on the living organisms studied, as well as their
- using various methods, i.e. either the uncertainty factors method given in the TGD8, or the SSD or ACT-SSWD methods, for Acute to Chronic Transformation – Species sensitivity Weighted Distribution9, 10 The SSWD method is a variant of the SSD method suggested in the TGD, if the dataset allows.

This work by EDF R&D was submitted to INERIS for a second opinion in 2006. The values used are ultimately less than those derived from this initial shared work. This choice is conservative.

The bibliographic analysis was conducted by consulting the following databases: Aquire, Biological abstracts, Chemical abstracts, Dose-1998, ECDIN-1993, EINEC-1998, Environmental bibliography, HSDB-1997 (Hazardous Substances Data Bank), IRIS on-line (Integrated Risk Information System, U.S.EPA, http://www.epa.gov/iris/subst/0528.htm), IUCLID version 4.0-2001, Medline, OHM/TADS-1997, Pascal biomed, Pascal sciences et techniques and Toxline. All of the ecotoxicological data available at the time of the search regarding algae, vertebrates, and invertebrates was listed. A few of the lowest chronic and acute ecotoxicological values, selected as admissible, are listed for each organism in the table below. As a reminder, for statistical methods after reading the publication, the data sample used is larger than this one.

Table 48: Chronic toxicity data used for derivation of respective PNECs for ethanolamine

Organism	Species	Chronic toxicity mg l^{-1}	Authors
Freshwater algae	Desmodesmus subspicatus	4 (NOEC)	IUCLID, 2000
Freshwater algae	Microcystis aeruginosa	1.6 (TT 8 days)	Bringmann and Kuhn, 1978
Freshwater crustacean	Daphnia magna	7.8 (NOEC 21day)	EDF R&D, 2006 (ref. HP77-2006-003970-FR)
Marine invertebrates	Hydractinia echinata	128.28 (3hrs)	Chicu et al., 2000 – Personal communication, 2006
Marine crustaceans	Crangon crangon	>100 (NOEC)	Portmann and Wilson, 1971, ECDIN, 1993
Freshwater fish	Salvelinus fontinalis	1.77 (NOEC 100d)	Groth et al, 1986-IUCLID 2000

Table 49: Acute toxicity data used for derivation of respective PNECs for ethanolamine

Organism	Species	Chronic toxicity mg l^{-1}	Authors
Freshwater algae	Desmodesmus subspicatus	8.42 (72 hrs)	Eisentraeger et al., 2003
Freshwater algae	Desmodesmus subspicatus	15 (72 hrs)	IUCLID, 2000
Marine algae	Isochrysis galbana	80 (96 hrs)	Roseth et al, 1996
Freshwater crustacean	Daphnia magna	65 (48 hrs)	IUCLID, 2000
Marine invertebrates	Hydractinia echinata	128.28 (3hrs)	Chicu et al., 2000 – Personal communication, 2006
Freshwater amphibians	Xenopus laevis	220 (48 hrs)	De Zwart and Sloof, 1987
Freshwater fish	Lepomis macrochirus	329.16 (96hrs)	Wolverton et al,1970
Freshwater fish	Brachydanio rerio	3683.4 (96 hrs)	Groth et al, 1993 – IUCLID 2000
Freshwater fish	Carassius auratus	170 (96hrs)	IUCLID, 2000

Chronic freshwater PNEC

The TGD's requirements are applied, and the uncertainty factors method is used. There are chronic NOECs for freshwater species at three different trophic levels. In accordance with the TGD, a factor of 10 was applied to the lowest of the chronic NOECs available, which is equal to 1.6 mg l^{-1} (tested on Microcystis aeruginosa).

The **chronic PNEC of ethanolamine in fresh water** used in the impact study is therefore 1.6/10 = 0.16 mg l^{-1}, or **160 µg l^{-1}**.

Chronic seawater PNEC

For the marine environment, little marine ecotoxicological data exists (2 acute values). In such cases, the TGD suggests applying an additional expansion factor 10 times the ecotoxicological value chosen in order to assess the freshwater PNEC. However, in the TGD, the application of higher uncertainty factors to deduce marine PNECs is mainly justified by the fact that the food webs in marine ecosystems are often more complex than that of freshwater ecosystems. Greater safety factors for the marine environment are therefore relevant for bioaccumulative and persistent substances. This is not true of ethanolamine. It is therefore suggested to adopt the same PNEC values for seawater as for freshwater.

Thus, the **chronic PNEC of ethanolamine in seawater value** used in the impact study is **160 µg l^{-1}**.

Acute freshwater PNEC

The uncertainty factors method described in the TGD is applied based on current INERIS recommendations, meaning that the PNEC is deduced from the listed and adopted EC50 data, and particularly the lowest value of 8.42 mg l^{-1} (EC50-72hrs for Desmodesmus subspicatus), to which an uncertainty factor of 100 is applied.

As a result, an acute PNEC of ethanolamine in fresh water of 8.42/100=0.084 mg l^{-1} is obtained, which is less than the chronic PNEC of ethanolamine in fresh water. It is therefore proposed to adopt the same value for both acute and chronic PNEC.

Thus, the **acute PNEC of ethanolamine in fresh water** value used in the impact study is 28/100 = **160 µg l^{-1}.**

Though the PNEC derived from statistical calculations is merely additional information for the analysis, it is presented anyway: It is possible to use the SSWD technique developed jointly by EDF R&D and INERIS (see references above), with an acute dataset, in order to take into account the diversity of data available and to obtain a more realistic view of the various species' sensitivity to the substance being studied. Using all of the acute data on ethanolamine for the three freshwater categories of algae, invertebrates and vertebrates, and weighting each one equally, a HC5_5% (likened to a PNEC) of 2.8 mg l^{-1} is obtained.

Acute seawater PNEC

For the same reasons as given in the section above, the acute PNEC of ethanolamine in seawater used in the impact study is therefore **160 µg l^{-1}**.

GLOSSARY
PNEC: Predicted No Effect Concentration
EC50: Half maximal effective concentration
IC50: Half maximal inhibitory concentration
LD50 , LD0: Lethal dose for 50% (0%) of organisms
HC: Hazard Concentration
NOEC: No Observed Effect Concentration
TT: Toxicity Threshold may be considered to be a NOEC

16 Appendix C Extract from the Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015

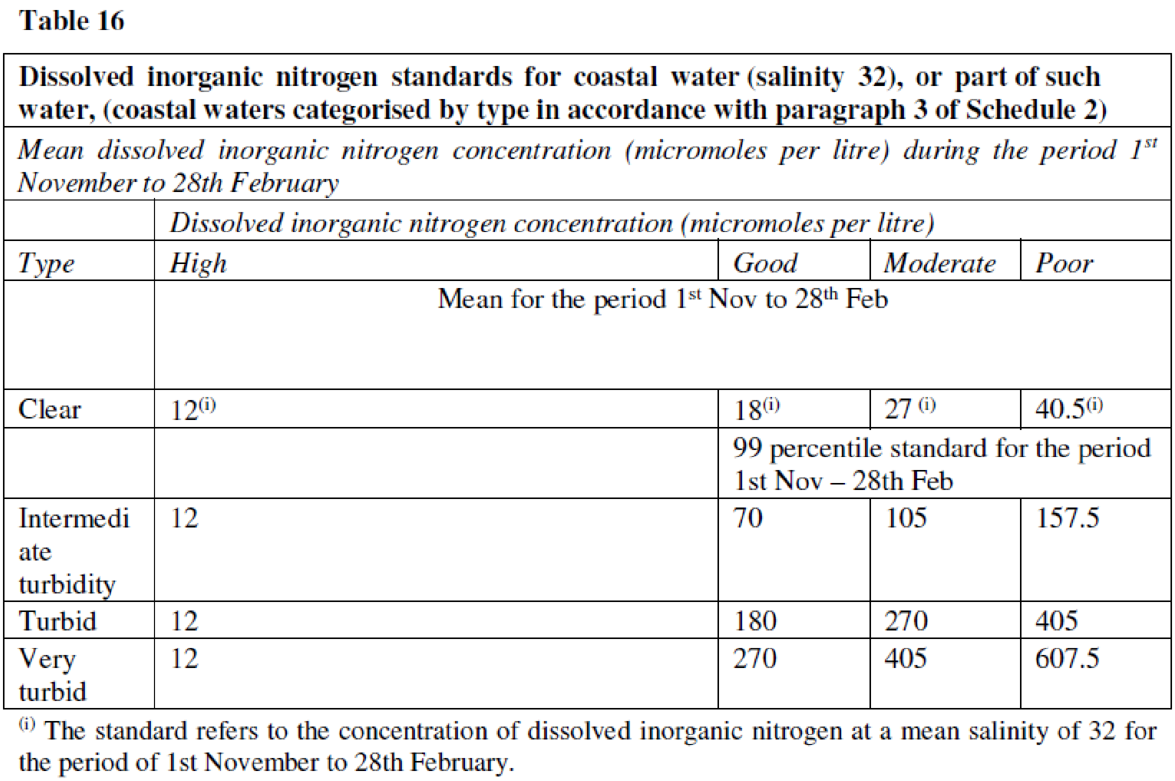

Table 16

Dissolved inorganic nitrogen standards for coastal water (salinity 32), or part of such water, (coastal waters categorised by type in accordance with paragraph 3 of Schedule 2)				
Mean dissolved inorganic nitrogen concentration (micromoles per litre) during the period 1st November to 28th February				
	Dissolved inorganic nitrogen concentration (micromoles per litre)			
Type	*High*	*Good*	*Moderate*	*Poor*
	Mean for the period 1st Nov to 28th Feb			
Clear	12(i)	18(i)	27 (i)	40.5(i)
		99 percentile standard for the period 1st Nov – 28th Feb		
Intermediate turbidity	12	70	105	157.5
Turbid	12	180	270	405
Very turbid	12	270	405	607.5

(i) The standard refers to the concentration of dissolved inorganic nitrogen at a mean salinity of 32 for the period of 1st November to 28th February.

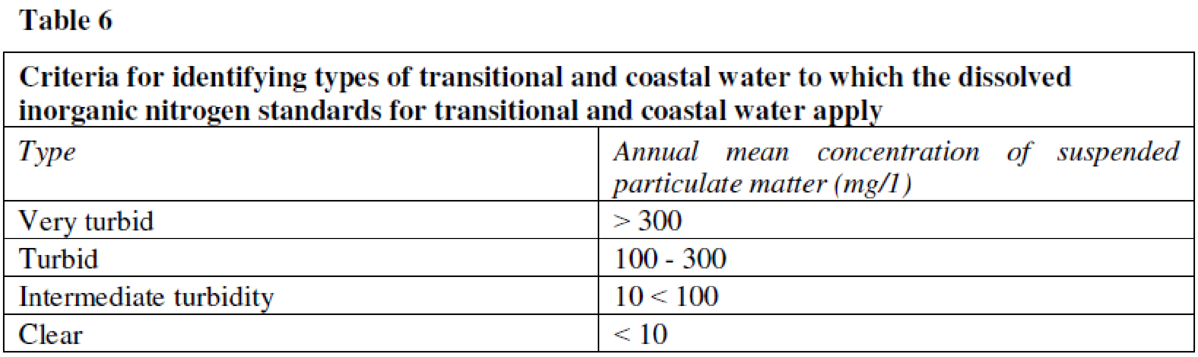

Table 6

Criteria for identifying types of transitional and coastal water to which the dissolved inorganic nitrogen standards for transitional and coastal water apply	
Type	*Annual mean concentration of suspended particulate matter (mg/l)*
Very turbid	> 300
Turbid	100 - 300
Intermediate turbidity	10 < 100
Clear	< 10

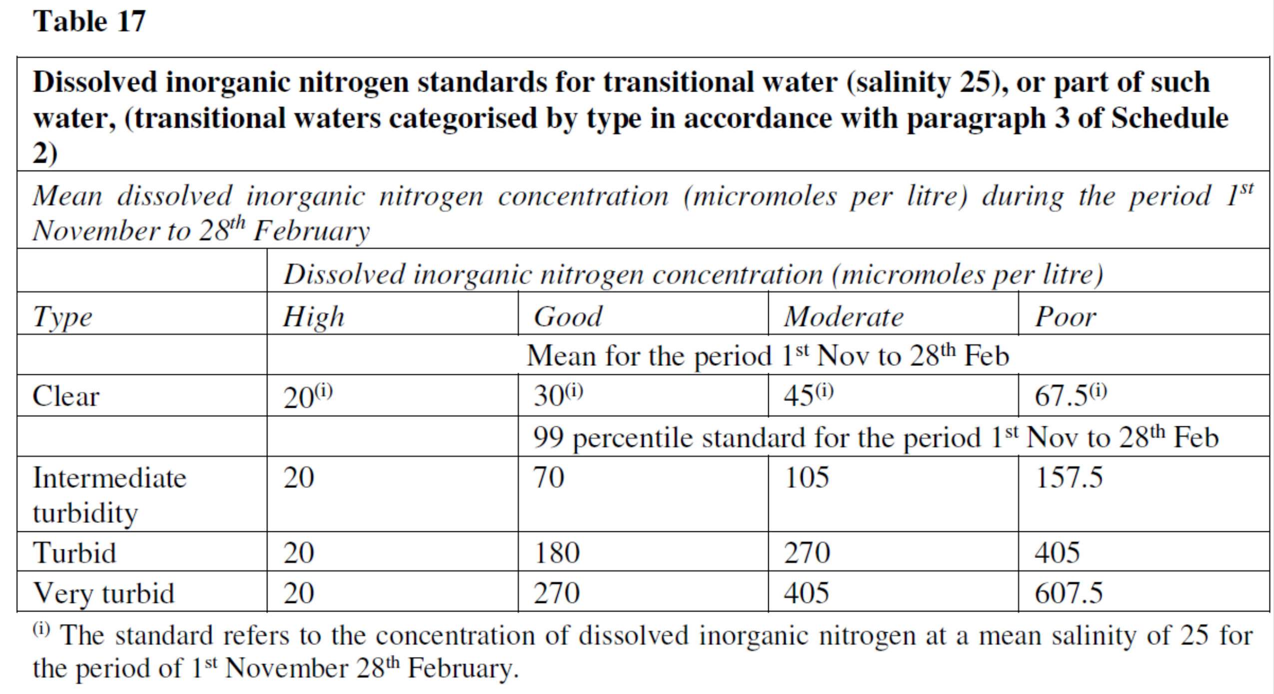

Table 17

Dissolved inorganic nitrogen standards for transitional water (salinity 25), or part of such water, (transitional waters categorised by type in accordance with paragraph 3 of Schedule 2)

Mean dissolved inorganic nitrogen concentration (micromoles per litre) during the period 1st November to 28th February

	Dissolved inorganic nitrogen concentration (micromoles per litre)			
Type	*High*	*Good*	*Moderate*	*Poor*
		Mean for the period 1st Nov to 28th Feb		
Clear	20(i)	30(i)	45(i)	67.5(i)
		99 percentile standard for the period 1st Nov to 28th Feb		
Intermediate turbidity	20	70	105	157.5
Turbid	20	180	270	405
Very turbid	20	270	405	607.5

(i) The standard refers to the concentration of dissolved inorganic nitrogen at a mean salinity of 25 for the period of 1st November 28th February.

17 Appendix D CORMIX modelling used in support of discharge assessment for the CDO

The results of the CORMIX simulations are presented as dilution curves, with dilution plotted against distance from the source along the centreline of the plume jet. CORMIX calculates the distance at which plume concentrations drops below a designated Water Quality Standard.

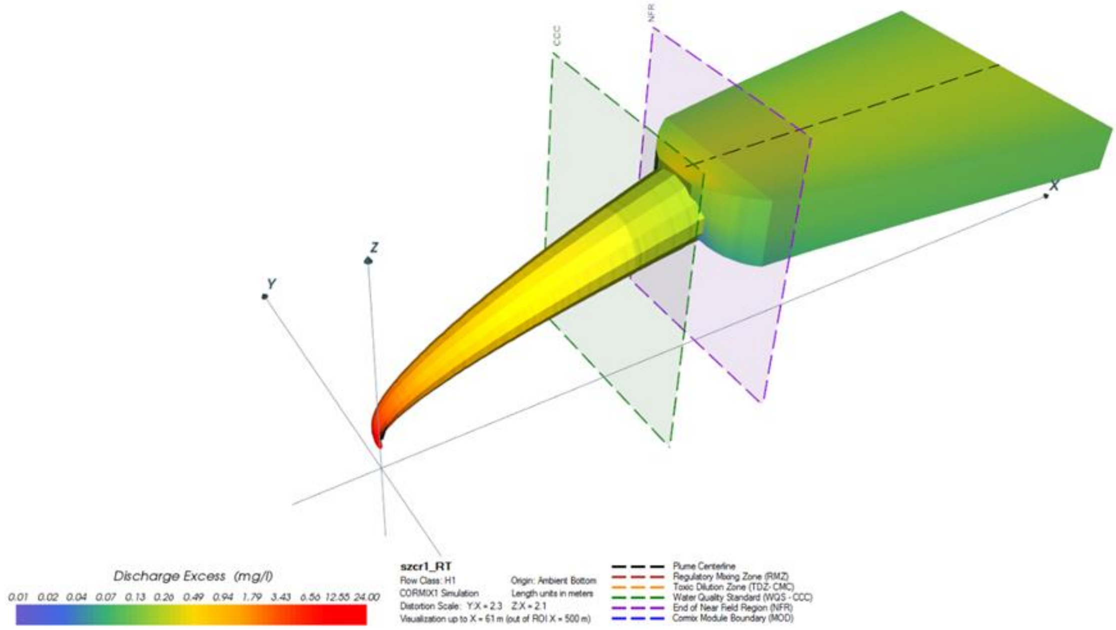

Figure 18: CORMIX output at rising mid tide, showing the buoyant nature of the plume 124 ls^{-1} discharge.

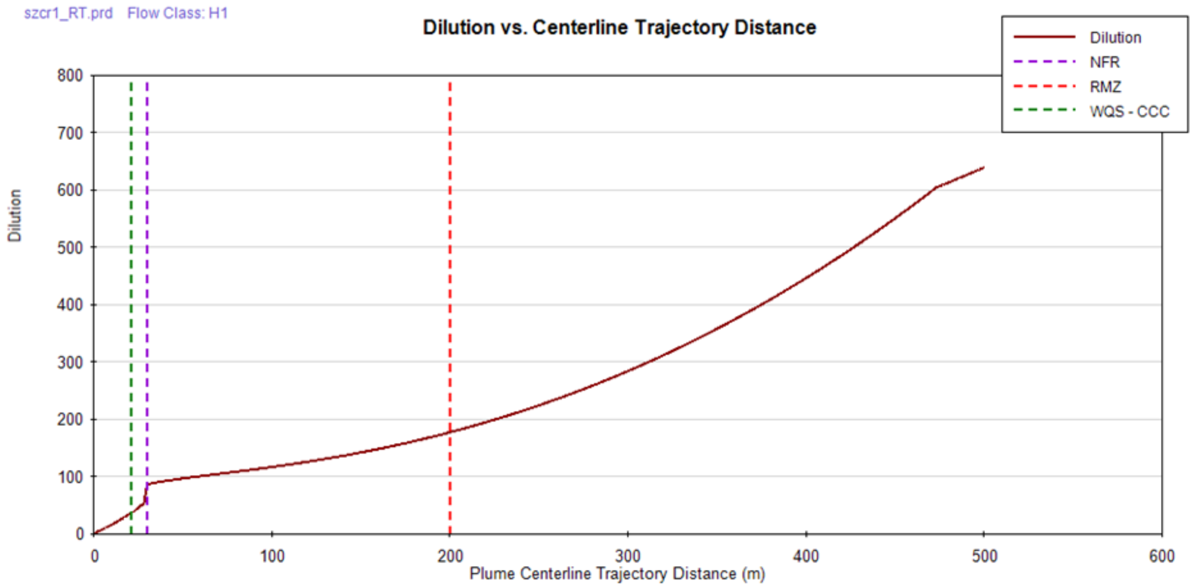

Figure 19: Dilution curve for a 124 l s^{-1} discharge at the CDO. Relevant for Case A.

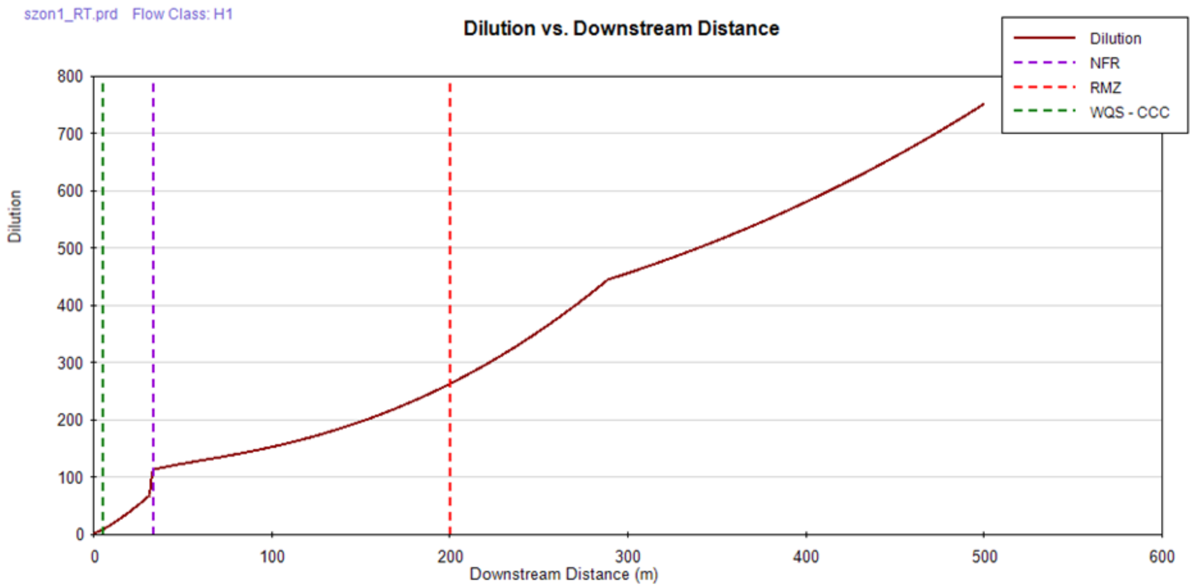

Figure 20: Dilution curve for a 72 l s^{-1} discharge at the CDO. Relevant for Case D1.

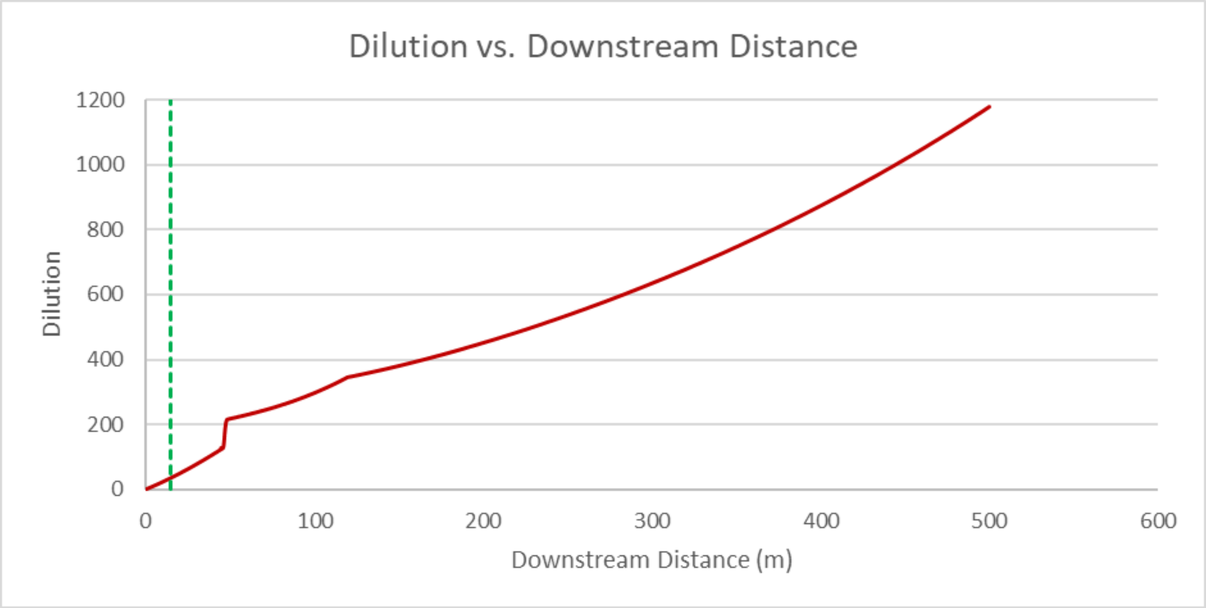

Figure 21: Dilution curve for a 30 l s^{-1} discharge at the CDO. Relevant for sewage only.

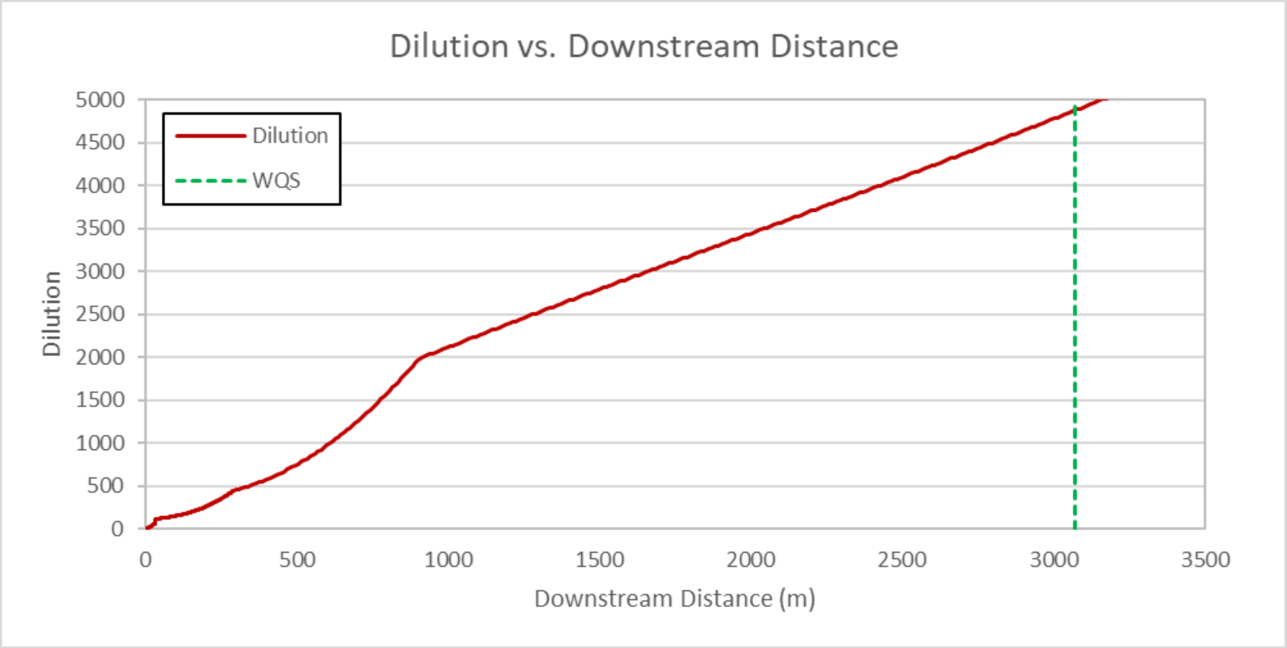

Figure 22: Dilution curve of E.coli for a 72 l s^{-1} discharge at the CDO. Relevant for Case D1.

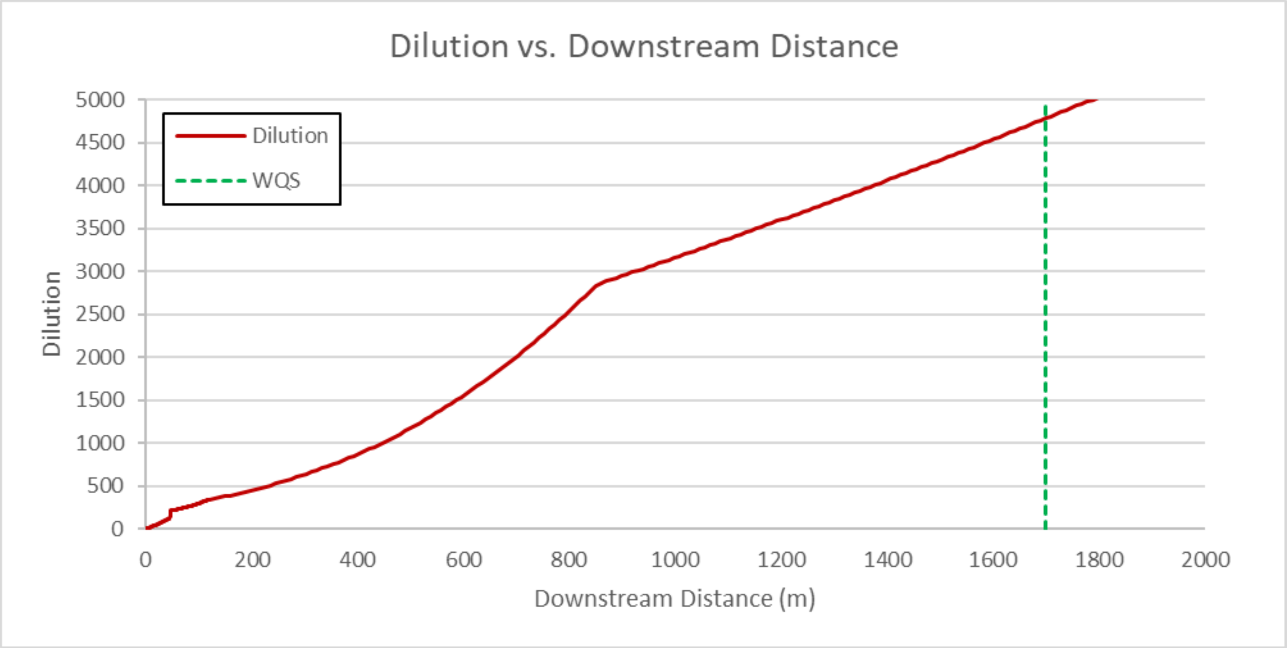

Figure 23: Dilution curve of E.coli for a 30 l s^{-1} discharge at the CDO. Relevant for Case D.

18 Appendix E Sizewell seawater monitoring data

Background concentration data for various chemical determinands measured in Sizewell seawater in surveys conducted in 2010 and in 2014/15 and that are referenced as part of the screening assessment are included in the following Tables.

E1 Various physical and chemical parameters measured at Sizewell for marine water quality that provide site background values

Tables below are taken from BEEMS Technical Report TR189 and supplemented with data from TR314

Table 50: Sizewell spatial survey water sample analysis for Lithium (data from BEEMS TR189)

Lithium (mg l^{-1})	**Lithium (mg l^{-1})**	**Lithium (mg l^{-1})**	**Lithium (mg l^{-1})**
0.05	0.09	0.06	0.07
0.05	0.07	0.07	0.05
0.07	0.06	0.09	0.07
0.03	0.09	0.07	0.05
0.06	0.07	0.06	0.07
0.06	0.03	0.08	0.07
0.06	0.06	0.08	0.06
0.05	0.06	0.08	0.07
0.07	0.06	0.07	0.07
0.05	0.05	0.05	0.05
0.05	0.06	0.09	0.09
0.06	0.05	0.05	0.07
0.07	0.06	0.05	0.08
0.07	0.06	0.07	0.06
0.07	0.07	0.05	0.07
0.06	0.07	0.09	
0.07	0.07	0.08	
Mean overall concentration	**0.065**		

Table 51: Sizewell spatial survey water sample analysis for suspended solids (data from BEEMS TR189)

Site	Suspended solids Surface (mg l^{-1})	Suspended solids near bed (mg l^{-1})
1	26, 56	73
2	102, 48	-
3	187, 53	167
4	131,53	-
5	(9 -144)	203
6	58,84	-
7	100,57	95
8	96, 69	-
9	68, 65	80
10	17, 28	75, 778
11	(28 – 244)	-
12	52, 86	53, 115
Mean concentration	**74.1**	**182.1**

Table 52: Sizewell spatial survey water sample analysis for Biochemical Oxygen Demand (BOD) (data from BEEMS TR189)

BOD (mg l^{-1})	**BOD (mg l^{-1})**	**BOD (mg l^{-1})**	**BOD (mg l^{-1})**	**BOD (mg l^{-1})**
<2	<2	8.5	<2	<2
2	5.5	<2	<2	<2
<2	<2	<2	<2	<2
<2	<2	3	<2	<2
<2	<2	<2	2	<2
<2	<2	<2	<2	<2
7.5	<2	3	2	<2
<2	<2	<2	<2	<2
<2	<2	<2	<2	<2
8.5	<2	<2	<2	<2
<2	<2	<2	<2	<2
<2	4.5	<2	<2	<2
3.5	1	<2	<2	
<2	<2	<2	<2	
Overall Mean	**2 mg l^{-1}**			

Table 53: Sizewell spatial survey water sample analysis for Chemical Oxygen Demand (COD) (data from BEEMS TR189)

COD (mg l^{-1})	**COD (mg l^{-1})**	**COD (mg l^{-1})**	**COD (mg l^{-1})**	**COD (mg l^{-1})**
230	270	200	230	300
200	280	200	200	250
185	320	260	200	240
240	250	240	190	300
2.5	125	210	240	230
2.5	320	280	220	230
1100	120	270	230	200
240	210	220	230	50
230	235	280	220	250
180	2.5	150	240	210
280	2.5	200	225	240
280	975	50	190	280
270	250	210	280	
370	210	205	200	
Overall Mean	**239 mg l^{-1}**			

Table 54: Sizewell spatial survey water sample analysis for aluminium as Al (dissolved) (data from BEEMS TR189)

Aluminium (mg l^{-1})	**Aluminium (mg l^{-1})**	**Aluminium (mg l^{-1})**	**Aluminium (mg l^{-1})**	**Aluminium (mg l^{-1})**
<0.01	0.01	0.01	0.01	0.02
<0.01	0.06	0.17	<0.01	0.01
0.01	0.01	<0.01	<0.01	0.02
<0.01	<0.01	0.01	<0.01	0.01
<0.01	0.01	0.02	0.01	0.01
0.02	<0.01	0.01	<0.01	<0.01
<0.01	<0.01	0.01	<0.01	0.01
<0.01	0.01	0.01	<0.01	0.01
<0.01	<0.01	<0.01	<0.01	0.01
<0.01	<0.01	0.01	0.01	<0.01
0.01	0.04	0.01	0.01	
0.01	<0.01	0.02	0.01	
0.01	<0.01	0.01	0.01	
0.02	<0.01	0.01	0.01	
Overall Mean	**0.012 mg l^{-1}**			

Table 55: Sizewell spatial survey water sample analysis for manganese as Mn (dissolved) (data from BEEMS TR189)

Manganese (mg l^{-1})	Manganese (mg l^{-1})	Manganese (mg l^{-1})	Manganese (mg l^{-1})	Manganese (mg l^{-1})
<0.002	<0.002	<0.002	<0.002	<0.002
<0.002	<0.002	<0.002	<0.002	<0.002
<0.002	<0.002	<0.002	<0.002	<0.002
<0.002	<0.002	<0.002	<0.002	<0.002
<0.002	<0.002	<0.002	<0.002	<0.002
<0.002	<0.002	<0.002	<0.002	0.002
<0.002	<0.002	<0.002	<0.002	<0.002
<0.002	<0.002	<0.002	<0.002	<0.002
<0.002	<0.002	<0.002	<0.002	<0.002
<0.002	0.009	<0.002	<0.002	<0.002
<0.002	<0.002	<0.002	<0.002	<0.002
<0.002	<0.002	<0.002	<0.002	
<0.002	0.003	<0.002	<0.002	
<0.002	0.002	<0.002	<0.002	
Overall Mean	**0.002 mg l^{-1}**			

Table 56: Sizewell spatial survey water sample analysis for chloride (data from BEEMS TR189)

Chloride (mg l^{-1})	**Chloride (mg l^{-1})**	**Chloride (mg l^{-1})**	**Chloride (mg l^{-1})**	**Chloride (mg l^{-1})**
14200	12500	11900	13600	12300
14200	15100	16900	10200	14300
14800	16400	15700	16300	15500
15400	16000	16400	11500	13000
10100	12400	14400	12900	15300
14800	11000	13800	14900	10600
17200	13400	13100	13600	10600
17000	15100	18000	16400	14500
15600	11600	14000	13400	16600
13200	10400	11300	15800	13700
16400	14000	17300	14300	10700
16200	14200	15200	11600	12900
15000	17800	12900	16600	
14800	13000	12700	14200	
Overall Mean	**14,128 mg l^{-1}**			

Table 57: Sizewell spatial survey water sample analysis for sulphate (data from BEEMS TR189)

sulphate (mg l^{-1})	sulphate (mg l^{-1})	sulphate (mg l^{-1})	sulphate (mg l^{-1})	sulphate (mg l^{-1})
2570	2700	2750	2830	2630
2620	3900	2610	2610	2800
2860	1730	2650	2670	3200
3060	2730	2500	2600	2820
2720	2890	2690	2630	3130
2610	2750	2530	2780	2700
2500	2630	3810	2600	2620
2810	2930	2870	2730	2760
2590	2970	2630	2780	2820
2670	2760	3150	2710	3240
2620	2700	2630	3080	2940
2630	2530	2780	2780	2690
2460	2800	3110	2760	
2810	2610	3240	2870	
Overall Mean	**2778 mg l^{-1}**			

Table 58: Sizewell spatial survey water sample analysis for sodium

Sodium (mg l^{-1})	Sodium (mg l^{-1})	Sodium (mg l^{-1})	Sodium (mg l^{-1})	Sodium (mg l^{-1})
10200	10500	11300	10600	11400
10300	11500	9640	10200	10100
9880	288	9950	11200	9510
11000	11300	9200	10200	11000
10700	11400	10900	10400	9430
10400	11600	10600	10800	9610
10200	11100	11400	10200	11800
11500	9870	10900	11100	10500
9740	10100	11200	9570	10300
11000	11100	11700	11400	9830
9790	9580	11500	9400	11600
9970	10100	10100	10100	11200
9460	11600	11600	11600	
11000	10100	8900	10000	
Overall Mean	**10,400 mg l^{-1}**			

Table 59: Sizewell spatial survey water sample analysis for Dissolved oxygen, salinity and pH. All data part of survey in 2009/10 and reported in TR189

Station	Date acquired	Time (GMT)	Sample depth (m)	Dissolved oxygen (%)	Salinity (PSU)	pH
1	07/04/2010	11:40	0			
1	07/04/2010	11:50	4.8			
1	06/12/2010	12:30	0	98.5	34.4	8.4
2	25/02/2010	09:45	0	106	31.8	7.86
2	15/12/2010	12:10	0	99.2	34.1	7.97
3	25/02/2010	10:38	0	108	31.9	7.93
3	25/02/2010	11:25	3.7	107	31.8	7.95
3	06/12/2010	11:40	0	100.8	34	8.2
4	25/02/2010	12:20	0	119	32.2	7.89
4	15/12/2010	12:40	0	100.2	34.1	8.08
5	25/02/2010	13:05	0	118	32.3	8.03
5	25/02/2010	13:25	4.4	112	32.2	7.93
5	02/03/2010	11:00	0	91.7	31.5	7.42
5	02/03/2010	12:00	0	98.3	32	7.96
5	02/03/2010	13:00	0	93	31.8	7.93
5	02/03/2010	14:00	0		31.9	7.9
5	02/03/2010	15:00	0		32.6	7.96
5	02/03/2010	16:00	0		32.5	8.01
5	02/03/2010	17:00	0		32.4	7.97
5	02/03/2010	18:00	0		32.2	8.04
5	02/03/2010	19:00	0		32.2	7.92
5	02/03/2010	20:00	0		32.3	7.88
5	02/03/2010	21:00	0		31.9	7.87
5	02/03/2010	22:00	0		32	7.92
5	02/03/2010	23:00	0		31.9	7.87
5	08/04/2010	17:30	0	104.5	33.4	8.16
5	21/04/2010	09:45	0	102.9		8
5	19/05/2010	08:45	0	102.9	33.7	8.15
5	07/06/2010	11:10	0	108.3	33.9	8.23
5	22/06/2010	09:15	0	99.3	32.8	8.12
5	06/07/2010	01:20	0	103.4	32.2	8.06
5	20/07/2010	13:45	0	94.3	33	8.02
5	11/08/2010	09:20	0	98.4	34.2	7.77
5	18/08/2010	10:15	0	97.6	34.3	7.85
5	09/09/2010	10:00	0	94	33.8	7.07
5	14/09/2010	10:45	0	97.2	30.2	8.27
5	28/09/2010	10:50	0	97.2	33.6	8.16

Station	Date acquired	Time (GMT)	Sample depth (m)	Dissolved oxygen (%)	Salinity (PSU)	pH
5	14/10/2010	10:15	0	96.9	32.2	8.06
5	15/11/2010	12:00	0	108.8	32.3	8.03
5	06/12/2010	11:08	0	100.9	34.1	8.17
5	15/12/2010	11:40	0	99.8	34.1	8.12
5	17/01/2011		0	102.7	34.4	8.12
5	31/01/2011	14:00	0	112.6	33.5	8.02
5	14/02/2011	13:30	0	112.5	34.5	8.1
6	07/04/2010	13:15	0			
6	15/12/2010	11:15	0	98.7	34.2	8.05
7	08/04/2010	16:15	0	105	33.2	8.15
7	08/04/2010	16:30	7	107.8	33.1	8.14
7	31/01/2011	11:20	0	101.3	33.4	8
8	08/04/2010	15:45	0	109.4	32.8	8.11
8	31/01/2011	10:55	0	101.7	33.3	8.05
9	08/04/2010	14:00	0	101.8	32.7	8.12
9	08/04/2010	14:30	5	104.4	33.4	8.1
9	17/01/2011	14:30	0	100.1	34.1	8.13
10	07/04/2010	10:20	0			
10	07/04/2010	10:30	11			
10	31/01/2011	09:20	0	99.4	33.3	7.89
10	14/02/2011	11:00	10	103	35.2	8.03
11	07/04/2010	13:45	0			
11	21/04/2010	10:45	0	100.8		7.99
11	19/05/2010	09:45	0	100.1	33.8	8.18
11	07/06/2010	10:35	0	109.1	34	8.23
11	22/06/2010	09:45	0	95	33	8.16
11	06/07/2010	10:00	0	94.3	31.6	8.02
11	20/07/2010	13:00	0	102.6	33.1	8.09
11	11/08/2010	10:08	0	97.8	34.3	8.01
11	18/08/2010	11:10	0	97.3	34.5	7.98
11	09/09/2010	10:45	0	95.3	34.3	7.22
11	14/09/2010	10:15	0	97.4	30.2	8.29
11	28/09/2010	10:00	0	98.5	33.8	8.14
11	14/10/2010	11:15	0	95.8	32.3	8.05
11	15/11/2010	11:15	0	97.6	32.2	8.08
11	06/12/2010	10:30	0	97.5	34.2	7.97
11	15/12/2010	10:38	0	97	34.1	8.13
11	17/01/2011	16:00	0	99.8	34.6	8.12
11	31/01/2011	10:10	0	98.5	33.4	8.04

Station	Date acquired	Time (GMT)	Sample depth (m)	Dissolved oxygen (%)	Salinity (PSU)	pH
11	14/02/2011	12:45	0	101.4	34.5	8.08
12	08/04/2010	11:30	0	108.6	33.2	8.07
12	08/04/2010	13:00	17	102.5	33.6	8.11
12	17/01/2011	12:20	14	100.3	34.2	8.21
12	17/01/2011	12:20	0	100.1	34.3	8.1
				Dissolved oxygen (%)	**Salinity (PSU)**	**pH**
			Mean	**101.63**	**33.12**	**8.02**
			95 percentile	**112.40**	**34.50**	**8.23**
			5 percentile	**94.30**	**31.72**	**7.83**
			50 percentile	**100.20**	**33.30**	**8.05**

Table 60: Sizewell spatial survey water sample analysis for Dissolved inorganic nitrogen (DIN) µgl^{-1} Shaded cells show the winter DIN values used to derive the site background. All data part of survey in 2014/15 and reported in TR314

Sampling period	**SZ B intake**	**SZ C intake/outfall**	**SZ B outfall**	**WFD site SZ3**
SIZE01/14	468, 441, 441	447, 440	463, 462, 427	483
SIZE02/14	367, 358, 379	349, 346, 364	385, 357, 357	399
SIZE03/14	349, 322, 287	280, 307, 307	316, 312, 287	321
SIZE04/14	213, 190, 179	199, 227, 192	211, 188, 182	183
SIZE05/14	57, 29	53, 34	64, 43, 42	85
SIZE06/14	106, 81, 78	77, 76, 70	85, 88, 92	109
SIZE07/14	116, 120, 118	120, 116, 113	134, 130, 134	99, 111
SIZE09/14	91, 71, 76	87, 78, 63	94, 95, 90	95, 88
SIZE10/14	200,213, 217	183, 183, 185	190, 218, 217	214, 206
SIZE11/14	**337**	**337**	**364**	**367**
SIZE11/14	**358**	**316**	**363**	**371**
SIZE11/14	**339**	**312**	**340**	**-**
SIZE01/15	**-**	**-**	**-**	**298, 312**
SIZE02/15	**419**	**399**	**409**	**427**
Winter 99% values	**426**			
Winter Mean	**357**	**Annual Mean**	**232**	
Winter Min	**298**			
Winter Max	**427**			

Table 61: Sizewell spatial survey water sample analysis for phosphate (PO4-P) µgl^{-1}. All data are part of survey in 2014/15 and are reported in TR 314

Sampling period	**SZ B intake**	**SZ C intake/outfall**	**SZ B outfall**	**WFD site SZ3**
SIZE01/14	71, 61, 121	46, 42	99, 60, 56, 71	47
SIZE02/14	33, 110, 27	29, 38, 26	28, 27, 25	32
SIZE03/14	19, 19, 17	20, 20, 18	23, 21, 20	22
SIZE04/14	1, 6, 9	4, 8	4, 11, 10	11
SIZE05/14	42, 210	37, 33	64, 36, 4	127
SIZE06/14	30, 79, 13	116, 13, 12	44, 39, 17	100
SIZE07/14	19, 17, 17	33, 18, 17	21, 21, 20	18, 20
SIZE09/14	18, 13, 13	17, 12, 11	16, 14, 17	17, 15
SIZE10/14	22, 19, 22	24, 22, 23	25, 23, 23	27, 25
SIZE11/14	24, 26, 26	26, 25, 25	26, 26, 27	189, 38
SIZE01/15				24, 25
SIZE02/15	28	26	27	29
Overall Mean	**33.5**			

19 Appendix F Dissolved inorganic nitrogen loading over the first three years of the construction period

The construction schedule profile developed for HPC was adapted to include information about groundwater dewatering known for SZC construction. The discharge rates for groundwater and for treated sewage effluent from site coupled with the mean DIN contributions from groundwater 1021µgl^{-1} and treated sewage effluent 5000µgl^{-1} were used to derive DIN loading for the first three years of construction (Table 62). Based on a maximum discharge rate (unlikely to persist for whole period) DIN loading for the first three years is also shown to provide an upper bounding value (Table 63).

Table 62: DIN loadings calculation for SZC over first three years of the construction period based on average discharge concentrations and flow rates

Construction Year	**DIN loading calculation based on sewage discharge rate 13.3ls^{-1}**	**Calculated total**
Year 1	365*24*3600[1](1021[2]*33.69[3]+5000[4]*13.31[5])/(1000*1000000)[6]	3183.61
Year 2	365*24*3600(1021*22.46+5000*13.31)/(1000*1000000)	2822.06
Year 3	365*24*3600(1021*18.82+5000*13.31)/(1000*1000000)	2704.95

[1]calculation of per second discharge; [2] mean DIN for treated sewage effluent; [3] average dewatering rate, litres per second for year one; [4] ammoniacal nitrogen as N from treated sewage effluent; [5] treated sewage effluent flow rate per second; [6] conversion from micrograms to kilograms.

Table 63: DIN loadings calculation for SZC over first three years of the construction period based on maximum discharge flow rate of 30lsec^{-1}

Construction Year	**DIN loading calculation based on sewage discharge rate 30ls^{-1}**	**Calculated total**
Year 1	365*24*3600[1](1021[2]*33.69[3]+5000[4]*30[5])/(1000*1000000)[6]	5815.3
Year 2	365*24*3600(1021*22.46+5000*30)/(1000*1000000)	5453.7
Year 3	365*24*3600(1021*18.82+5000*30)/(1000*1000000)	5336.6

[1]calculation of per second discharge; [2] mean DIN for treated sewage effluent; [3] average dewatering rate, litres per second for year one; [4] ammoniacal nitrogen as N from treated sewage effluent; [5] treated sewage effluent flow rate per second; [6] conversion from micrograms to kilograms.

20 Appendix G Coliforms, intestinal enterococci in construction discharge and compliance with bathing water and shellfish standards

For the construction discharge following either sewage treatment at a secondary or tertiary (UV) level the distance from the discharge point, at which enough dilution occurs to be below relevant microbiological standard levels, has been estimated using CORMIX for Case D ($30ls^{-1}$) sewage discharge and Case D1 ($72ls^{-1}$). Results are shown below in Table 64.

Table 64 Estimate of minimum distance from point of discharge at which microbiological standards for bathing waters are met following different levels of sewage treatment for the construction discharge from SZC

Species	**Standard cells/ 100ml**	**Discharge concentration cells / 100ml**	**2^{ndry} treatment 2 log reduction**	**Dilution required to meet bathing water standard**	**Maximum potential distance from the discharge at which meets bathing water standard**		**UV treatment reduction 5.4 log reduction**	**Dilution factor required for discharge to meet bathing water standard**	**Maximum distance from the discharge at which it meets bathing water standard**
					$30\ l\ s^{-1}$	**$72\ l\ s^{-1}$**			
E.coli	500	240,000,000[1]	2400000	4800	~1.7 km	~3.1 km	955.5	1.9	<1 m pass immediately on discharge, for both cases.
Entero-cocci	200	13,600,000	136000	680	~66 m	~460 m	54.1	0.3	<1 m pass immediately on discharge, for both cases.

[1] Cell numbers/100ml are based on data in support of the Hinkley Point C development (pers. Comm. EDF);

21 Appendix H Calculations of values associated with FRR

This section provides the supporting data and calculation used to derive the values for the FRR assessment. The values are the outputs of the modelling approach used to estimate impingement at SZB, and are the same values that form the basis of the final impingement estimates. In TR339, only the final annual estimates for SZB are given.

Mean daily estimated numbers impinged were modelled using data collected during onshore impingement sampling between 2009 and 2017 at SZB. Full details of the modelling approach are given in Beems Technical Report TR339. The mean estimated daily values for SZB were raised to predicted daily values for SZC on the ratio of the pumping capacities of the two stations (i.e. the SZB daily mean values were multiplied by (131.86/51.5 cumecs). Next, survival through the FRR was considered, as some of the more robust species will not all die during their passage through the cooling water systems. In this case, the same values of FRR survival that were used to predict impingement at SZC were used (Beems Technical Report TR406). The resulting numbers lost to impingement were converted to weight using the mean length of each species in the impingement samples and published length-weight relationships. The size distributions used are shown in Beems Technical Report TR339. The length-weight relationships used were taken from Silva et al (2013).

Table 65 Sizewell B mean daily estimated number of fish impinged

Species	MeanJAN	MeanFEB	MeanMAR	MeanAPR	MeanMAY	MeanJUN	MeanJUL	MeanAUG	MeanSEP	MeanOCT	MeanNOV	MeanDEC
Sprat	57550	14569	5879	813	1203	494	825	467	600	483	1470	6820
Herring	2001	5508	12363	6412	362	75	462	282	608	1337	1378	2174
Whiting	5296	3684	2552	1354	685	258	314	430	1337	1734	2416	3944
Bass	1354	3415	1085	30	7	3	3	8	9	25	206	1414
Sand gobies	292	98	101	56	42	11	71	334	1393	848	840	805
Sole	19	105	398	794	650	131	110	150	471	224	127	31
Dab	296	140	85	78	21	10	21	35	475	283	279	195
Anchovy	0	0	33	33	318	318	111	111	6	6	3	3
Thin-lipped grey mullet	316	316	52	52	1	1	0	0	1	1	73	73

Table 66 Sizewell C mean daily estimated number of fish impinged

Species	MeanJAN	MeanFEB	MeanMAR	MeanAPR	MeanMAY	MeanJUN	MeanJUL	MeanAUG	MeanSEP	MeanOCT	MeanNOV	MeanDEC
Sprat	147350	37301	15052	2081	3081	1265	2113	1196	1537	1237	3764	17461
Herring	5124	14103	31654	16418	927	193	1184	721	1556	3422	3527	5567
Whiting	13560	9432	6534	3466	1753	661	803	1101	3424	4439	6187	10097
Bass	3468	8743	2777	77	17	7	7	21	24	65	529	3621
Sand gobies	748	250	258	144	108	27	182	856	3568	2170	2150	2062
Sole	50	268	1019	2032	1665	335	282	384	1205	573	325	78
Dab	757	358	217	200	54	25	53	89	1216	724	713	499
Anchovy	0	0	86	86	815	815	284	284	14	14	7	7
Thin-lipped grey mullet	810	810	132	132	1	1	0	0	3	3	186	186

Table 67 Sizewell C mean daily estimated weight of fish impinged with an FRR fitted

Species	mean weight at length (kg)	MeanJAN	MeanFEB	MeanMAR	MeanAPR	MeanMAY	MeanJUN	MeanJUL	MeanAUG	MeanSEP	MeanOCT	MeanNOV	MeanDEC
Sprat	0.009	1389.17	351.67	141.90	19.62	29.05	11.93	19.92	11.28	14.49	11.66	35.49	164.62
Herring	0.095	484.56	1333.65	2993.45	1552.60	87.64	18.21	111.93	68.18	147.17	323.66	333.59	526.46
Whiting	0.050	343.96	239.27	165.74	87.92	44.47	16.76	20.38	27.94	86.85	112.59	156.95	256.13
Bass	0.095	166.92	420.82	133.66	3.71	0.84	0.36	0.35	1.03	1.14	3.11	25.45	174.31
Sand gobies	0.001	0.23	0.08	0.08	0.04	0.03	0.01	0.05	0.26	1.08	0.66	0.65	0.62
Sole	0.015	0.15	0.81	3.08	6.13	5.02	1.01	0.85	1.16	3.63	1.73	0.98	0.24
Dab	0.018	2.85	1.35	0.82	0.75	0.20	0.09	0.20	0.34	4.58	2.73	2.69	1.88
Anchovy	0.008	0.00	0.00	0.70	0.70	6.69	6.69	2.33	2.33	0.12	0.12	0.06	0.06
Thin-lipped grey mullet	0.041	16.66	16.66	2.71	2.71	0.03	0.03	0.00	0.00	0.07	0.07	3.83	3.83
Total daily biomass kg		2404.49	2364.30	**3442.14**	1674.20	173.98	55.08	156.02	112.52	259.14	456.32	559.67	1128.14

[1]Maximum daily biomass value for March used for calculation (3442.1kg); [2]Average biomass period April to September (405.2kg)

21.1.1 Calculation of moribund biomass FRR and potential nutrient input and influence on dissolved oxygen levels

The total biomass of moribund biota that potentially may be discharged from the FRR 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 (BEEMS TR339 and TR381). The derived Sizewell C data indicate that the highest biomass discharged occurs during the winter months December to March but is also high in April. Mean annual daily biomass is 1065.5kg per day and from April to September is 405.2 kg per day. Estimates of tissue concentration for nitrogen and phosphorus from several studies are shown in Table 68.

Table 68 Phosphorus and nitrogen concentration data for fish tissue derived from several studies and which is used in calculation of potential nutrient loadings released during decay of dead fish released from the FRR

Nutrient	**g/kg**	**Percentage (wet weight)**	**Average daily biomass (405.2kg) nutrient content April to September**	**Average Daily biomass (1065.5kg) nutrient content (January - December)**	**Literature Source**
P content	3.74-4.7 (ww)	0.47	(405.20/100) x0.47=1.9kg	-	Storrebakken et al., 2000
P content		0.45-0.5	2.03kg	5.33	Gende et. al., 2004
P content		0.64 (dry weight)	0.93kg	-	Wang et. al., 2013
N content		3.2-3.5	14.18kg	37.29	Walker et. al., 2011
N content		3.4	13.78kg	-	Gende et. al., 2004
N content		7.4 (dry weight)	10.79kg	-	Wang et. al., 2013

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 also become more limited in supply and become a limiting factor for algal growth. Average daily biomass from April to September is 405.2kg and multiplying this by the maximum estimates of phosphorus and nitrogen (Table 68) give maximum daily loadings of 14.18kg N and 2.03kg P per day.

Based on the mean annual biomass (1065.5kg) maximum daily predicted loadings are 37.29kg N and 5.33 kg P per day.

Un-ionised ammonia is calculated for the same period April to September as increasing temperatures and increasing growth and reproduction of species make this a more critical period. The ammonia, NH_4 concentration derived from a study of cod tissue is used to derive an equivalent value for fish biomass:405.20 (kg) fish biomass x 125 =
Total mg NH_4-N (50650). This value was used in the un-ionised ammonia calculator along with average background conditions for Sizewell (pH 8.05, salinity 33.3 and temperature 11.43°C) to derive an equivalent un-ionised ammonia value= 926,824 µg NH_3-N
Volume litres required to dilute this mass of NH_3-N to the EQS of 21 μgl^{-1} NH_3-N minus natural background: 926,824/(21-1.6)=47,774.4 litres
47,774.4 litres is equivalent of an area of 109.4m x 109.4m x depth 4m = 1.20ha

Using the same biomass loading a similar calculation was made but adjusting the average background conditions for the un-ionised ammonia calculator to 98th percentile temperature (19.4°C),95th percentile pH (8.23) and 50th percentile salinity to represent extreme summer conditions. This adjustment results in un-ionised ammonia load of 2,513,781 µg NH3-N and an equivalent area exceeding the EQS of 193.8m x193.8m=3.76ha that exceeds the EQS.

For the winter period the highest biomass discharged is predicted for March (3442.14kg). This loading is equivalent to NH_4-N of 3442.14 x 125= 430,267.5 mg NH_4-N. The total NH_4 loading generated when used as a source value in the un-ionised ammonia calculator with an average temperature for March of 6.09°C and 5th percentile salinity and 50th percentile pH= 5,198,601µg NH_3-N. This loading of un-ionised ammonia is equivalent to an area exceeding the EQS of 258.8m x258.8m=6.70ha.

For BOD calculation the annual daily average is used = 1065.5kg biomass
BOD generated from this biomass is estimated based on an equivalent value of 3.5g BOD/kg dry weight of fish tissue (Stigebrandt *et al*., 2001).
The estimate of BOD load per day is:

(i) 1065.5 x (3.5 x dry weight/wet weight conversion 0.36)= 1342.5kg BOD

Total oxygen reduction potential based on OSPAR information BOD of 1.5mgl^{-1} = 0.5mgl^{-1} oxygen reduction:

(i) 1342.5/1.5=447.5kg/ day O_2 reduction
(ii) Based on a background dissolved oxygen level 6.96mg/l this is equivalent to oxygen present in 64,297 m^3.
(iii) The daily volume exchange of 10% of GSB = 36,380,000 m^3
(iv) 64,297/36,380,000=0.18% of daily exchange
(v) Also, daily reaeration contributes 3.2gm^{-2}d^{-1}

Therefore, reaeration over 447.51/0.0032= 139846.87m^{-2} (13.98ha) would meet this daily oxygen demand.

For BOD calculation the maximum daily value (March) is used = 3442.1kg biomass
BOD generated from this biomass is estimated based on an equivalent value of 3.5g BOD/kg dry weight of fish tissue (Stigebrandt *et al*., 2001).
The estimate of BOD load per day is:

(ii) 3442.1 x (3.5 x dry weight/wet weight conversion 0.36)= 4337.1kg BOD

Total oxygen reduction potential based on OSPAR information BOD of 1.5mgl^{-1} = 0.5mgl^{-1} oxygen reduction:

(vi) 4337.1/1.5=1445.7kg/ day O_2 reduction
(vii) Based on a background dissolved oxygen level 6.96mg/l this is equivalent to oxygen present in 207,715 m^3.
(viii) The daily volume exchange of 10% of GSB = 36,380,000 m^3
(ix) 207,715/36,380,000=0.57% of daily exchange
(x) Also, daily reaeration contributes 3.2gm^{-2}d^{-1}

Therefore, reaeration over 1445.7/0.0032= 451,780m^{-2} (45.2ha) would meet this daily oxygen demand.