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List of Abbreviations

Abbreviation	Explanation
AA	Annual Average (Environmental Quality Standard)
AEVF	Allowable Effective Volume Flux
BEEMS	British Energy Estuarine and Marine Studies
CDO	Combined Drainage Outfall
CWDA	Construction Water Discharge Activity
DCO	Development Consent Order
EA	Environment Agency
EIA	Environmental Impact Assessment
ES	Environmental Statement
EQS	Environmental Quality Standards
GETM	General Estuarine Transport Model
LoD	Limit of Detection
MAC	Maximum Allowable Concentration (Environmental Quality Standard)
OWDA	Operational Water Discharge Activities
SPM	Suspended Particulate Matter
SSC	Suspended Sediment Concentration
SZC	Sizewell C
WFD	Water Framework Directive

1 Background

Sizewell C Limited (hereafter SZC Ltd) has a Development Consent Order (DCO) to build and operate a new Nuclear Generating Station at Sizewell, Suffolk (SZC) (<u>SI 2022/853</u>). Environmental permits are required from the Environment Agency for any discharges to sea. Discharges associated with the operation of Sizewell C (SZC) are permitted under the operational water discharge activities (OWDA) permit (EPR/CB3997/AD). Construction discharges will be permitted under a separate construction water discharge activity (CDWA) permit.

This report details the proposed groundwater dewatering and treated domestic foul water discharges to the marine environment anticipated during the construction period of SZC and provides a risk assessment to inform an application for the CWDA permit.

An initial assessment of groundwater discharges was made in the Environmental Impact Assessment and reported in the Environmental Statement (SZC Ltd, 2020a), with the detailed screening and assessment described in BEEMS TR193 (also appended to the Environmental Statement, SCZ Ltd, 2020b). The exact requirements of the CWDA permit were not known at the time of the DCO determination and therefore these previous assessments were made based on anticipated discharges with the acknowledgment that precise parameters would be required for the CWDA permit process. The purpose of this report is to provide refinement to the assessment of groundwater discharge, including assessing new data and detailed discharge proposals.

1.1 Assessment process and water quality standards

The assessment herein follows the Environment Agency guidance for surface water pollution risk assessment (Environment Agency, 2022). Under this assessment method, potentially polluting discharges are assessed against Environmental Quality Standards (EQS). The EQS values are concentrations of substances which, when exceeded, may pose a risk to the environment.

There are two types of EQS: the annual average (AA) and the maximum allowable concentration (MAC). The AA EQS is the long-term average concentration of a substance and considers the potential chronic effects from persistent exposure. The MAC represents an upper threshold which may cause acute effects. The MAC is sometimes defined as a 95th percentile (whereby the specified value should not be exceeded 95% of the time), although often the MAC is a 100th percentile (whereby the specified value should not be exceeded at any time). This assessment considers EQS values for both the AA and MAC. The EQS values of relevance to groundwater discharge assessment are summarised in Table 1. As detailed in Section 2.2, other potentially hazardous substances, such as hydrocarbons, polychlorinated biphenyls (PCBs), and other organic chemicals, were tested for in the groundwater but found to be below detection limits.

The purpose of the assessment is to identify potentially harmful substances in the proposed construction discharge, to determine if, in the concentrations they will be discharged at, they pose a risk to the environment, and to evaluate the magnitude of potential impacts. A detailed impact assessment (Section 5) is then carried out for any potentially significant impacts.

The first stage of the assessment, as detailed in the guidance (Environment Agency, 2022) is screening. There are two screening tests which are applicable to the Sizewell construction discharges: 'Test 1 for estuarine and coastal waters' and 'Test 5 for estuarine and coastal waters'.

Tests, 2, 3 and 4, do not apply to the circumstances of this proposed discharge. Test 2 checks whether the discharge is to a low water channel; the discharge will be to an open coastal setting and not within a low water channel. Test 3 checks whether the discharge is to a location with restricted dispersion; the discharge point will be in an open coastal setting and not restricted. Test 4 checks the discharge point will be submerged at all states of the tide (less than 1 m below chart datum) and is greater than 50 m from the shoreline; the water depth at the CDO location is approximately -6.2 m Ordinance Datum Newlyn (ODN),

which is approximately -4.6 m chart Datum), the location is approximately 300m offshore of the nearest coastline (Figure 1).

Test 1: This is a simple comparison of the concentration of substances in the discharge to the relevant EQS. Substances below the EQS (either the AA or the MAC) at the point of discharge are not considered a risk and are screened out of further assessment.

Test 5: This test takes into account the flow rate and water depth at the point of discharge to calculate the 'effective volume flux' and compare this to an 'allowable effective volume flux' (AEVF). The steps for this screening test are:

- 1. Multiply the effluent discharge rate (in cubic metres per second) by the release concentration of the chemical and element (in μg/L).
- 2. Subtract the average background concentration (see Section 2.3) of the discharge location from the EQS (both AA and MAC).
- 3. Divide the result of step 1 by the result of step 2.

The results of Test 5 are compared to the AEVF which is based on the water depth in metres, with a maximum of 3.5 (i.e., discharges in water deeper than 3.5 m are assessed against a AEVF of 3.5).

A final screening test considers the total annual load of a particular substance. This test calculates a total annual input in kilograms (kg) of key pollutants and compares this total to the relevant 'significant load limit'. Substances with significant load limits relevant to the groundwater discharges assessment are cadmium (limit 5 kg per year) and mercury (limit 1 kg per year). The annual load is calculated by determining the total volume discharged over a year and multiplying this by the concentration of the substance.

Suspended sediment is not a priority hazardous substance or other pollutant and is not toxic. However, high levels of suspended sediment can lead to environmental impacts on water quality and marine ecology from increased turbidity, deposition and smothering. Suspended sediment is assessed relative to background conditions and the Water Framework Directive turbidity criteria. It should be noted that the threshold applied is not indicative of potential ecological effects, which would be species or habitat specific, but instead considered a precautionary screening level to trigger further investigation.

Determinand	EQS – Annual average (µg/L)	EQS – Maximum Allowable Concentration (MAC) µg/L
Arsenic (dissolved)	25	-
Boron (Total)	7000	-
Cadmium and its compounds (dissolved)	0.2	-
Chromium VI (dissolved)	0.6	32
Copper (dissolved)*	3.76	-
Iron (dissolved)	1000	-
Lead and its compounds (dissolved)	1.3	14
Mercury and its compounds (dissolved)	-	0.07
Nickel and its compounds (dissolved)	8.6	34
Zinc (dissolved)**	7.9	-
Un-ionised ammonia (NH ₃) ²	21	

Table 1. Environmental Quality Standards (EQS) values for relevant hazardous chemicals and elements

* Where dissolved organic carbon (DOC) exceeds 1 mg/L the EQS of copper is equal to 3.76+(2.677X((DOC/2)-0.5)). The base value of 3.76µg/L has been applied as a conservative measure. ** The EQS for Zinc additive (also known as 'maximum permissible addition'); the base value is 6.8 with a recommended 1.1 added

** The EQS for Zinc additive (also known as 'maximum permissible addition'); the base value is 6.8 with a recommended 1.1 added for salt water. While the background Zinc levels in the Greater Sizewell Bay are considerably greater than 1.1 μg/L, the recommended background of 1.1 μg/L has been applied to be conservative.

2 Construction discharges

2.1 Description of the discharge activity

This assessment considers the discharge of groundwater generated during the dewatering process of the SZC construction site. Other discharges which are combined with the groundwater flow are also considered as this will affect the final concentration of substances at the point of discharge. The discharge will be from the 'combined drainage outfall (CDO)' (Figure 1).

The previous assessment (BEEMS TR193) assessed groundwater discharge based on a maximum flow of 124 L/s with concentrations of potentially hazardous chemicals and elements taken from a borehole sampling campaign in 2014.

The updated assessment herein applies a revised peak flow of 250 L/s for initial dewatering. The increase from 124 L/s to 250 L/s reflects a change in the design parameters which are detailed in the SZC CWDA13 permit application supporting document (SZC, 2025). The peak flow is expected to be maintained for up to up to five months. After this the groundwater flow is expected to be 25-50 L/s for the remainder of the construction period.

Additionally, new groundwater sampling data were collected in 2020 (Section 2.2.2) and therefore concentrations of substances in the discharge have been reviewed. Other parameters are consistent with the previous assessment (BEEMS TR193).

The groundwater will be discharged simultaneously with treated sewage from the construction site and tunnelling effluent. Four scenarios, encompassing worst-case discharges for metals and un-ionised ammonia, are considered in this assessment:

- 1. Peak groundwater discharge at 250 L/s worst-case for metals (and groundwater substances); This has been termed Case A.
- Peak groundwater discharge at 250 L/s plus treated foul water (treated sewage) at 50 L/s = 300 L/s. (Note: applies only to the un-ionised ammonia assessment, as dilution of the metals in the groundwater would decrease the concentration of metals meaning this scenario is less precautionary than Case A for groundwater). This has been termed case A1.
- 3. Post peak groundwater discharge at up to 50 L/s groundwater. This has been termed Case B.
- 4. Post peak groundwater discharge at up to 50 L/s groundwater combined with maximum treated sewage discharges of up to 50 L/s treated sewage = total flow 100 L/s. (Note: applies only to the un-ionised ammonia assessment, as dilution of the metals in the groundwater would decrease the concentration of metals meaning this scenario is less precautionary than Case B for groundwater). This has been termed Case B1.

There are no changes to the parameters of the tunnelling discharges and the worst-case assessment is unaffected by the change to the groundwater parameters. Therefore, the assessment of substances specific to tunnelling (i.e., conditioning chemicals) is not repeated and can be found in BEEMS TR193.

2.1.1 Suspended sediment discharge scenarios

Suspended sediment is not a priority hazardous substance or other pollutant and is not toxic. However high levels of suspended sediment can lead to environmental impacts on water quality and marine ecology from increased turbidity and deposition and smothering.

Waste streams to be discharged via the CDO will be treated for suspended sediment to maintain concentration of suspended sediment at 250 mg/L or below.

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All waste streams could potentially contain suspended sediment. A worst-case scenario has been considered taking the maximum flow of all combined effluent streams and a concentration of 250 mg/L suspended sediment.

The maximum flows, as described in the SZC CWDA13 permit application supporting document (SZC, 2025) are taken as:

- Maximum total average flow = 560.7 L/s from:
 - Surface water run-off = 250 L/s
 - Groundwater = 250 L/s
 - Treated domestic foul water (combined) 24.8+4.5+20.6 = 50 L/s
 - Sweeper tip facility = 6 L/s
 - Bentonite treatment facility 4.7 L/s

It should be noted, as described in Section 2.1, that this scenario is the worst-case for suspended sediment, but not for metals or treated sewage as the additional flows from surface water and treatment facilities would serve to dilute potentially hazardous substances in the groundwater such as metals, and therefore considering the groundwater in isolation is worst-case when considering these substances. For suspended sediment, as the maximum concentration is the same in all waste streams there would be no dilution effect.



Figure 1. Map of discharge location (CDO).

2.2 Potential contaminants (hazardous chemicals and elements)

The previous assessment of groundwater discharges (BEEMS TR193) used concentrations of potentially hazardous chemicals and elements from groundwater sampling of boreholes in 2014. Since then, further groundwater sampling has been completed (in 2020) allowing for the original assessment to be reviewed and updated.

Both the 2014 and 2020 data have been reviewed in the sections below (2.2.1 and 2.2.2. The mean average and 95th percentile concentrations of substances with any values above their respective EQS are included. In common with the previous assessment 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.

When calculating summary statistics for all substances, any values below the method detection limit were adjusted to a value equal to the detection limit. This is conservative as it assumes the substance is present at the detection limit, however the true concentration may be lower.

2.2.1 2014 groundwater test data

In 2014, a series of boreholes was completed to test the groundwater conditions (Atkins, 2016). Samples were assessed for a range of substances including dissolved metals. A range of chemicals such as polycyclic aromatic hydrocarbons, PCBs and various other organic chemicals commonly present as contaminants in groundwater were below respective detection limits. Results of all substances of interest are detailed in Appendix A and summarised in Table 2.These results largely replicate those presented in BEEMS TR193, however there are minor differences as a result of the removal of some data (trip blanks and field blanks). Note that only dissolved metals were measured during this campaign, no analyses of total metals were undertaken.

Un-ionised ammonia values are calculated using the Environment Agency calculator (based on Clegg and Whitfield, 1995). The 'freshwater' value in Table 2 has been calculated based on the average pH of the sample data (7.3) and the average temperature (11.43°C; BEEMS TR131). The 'seawater' value is calculated based on ambient seawater pH (8.05) and an average salinity of 33.3 (BEEMS TR189). Note that the 'seawater' un-ionised ammonia value is hypothetical and could not be realised as the discharged water would need to mix with the seawater to achieve these conditions thus diluting the ammonia. It is calculated only as a conservative maximum to screen for further detailed assessment.

Substance	LoD µg/L	<i>n</i> and (<i>n</i> >LoD)*	Mean concentration µg/L	95 th percentile concentration μg/L
Arsenic (dissolved)	1	147 (78)	3.6	11.7
Cadmium (dissolved)	0.08	147 (16)	0.10	0.19
Chromium (dissolved)**	1	147 (109)	6.6	18.7
Copper (dissolved)	1	147 (54)	1.8	4.1
Iron (dissolved)	20	147 (61)	405	1,500
Nickel (dissolved)	1	147 (69)	2.7	9.9
Lead (dissolved)	1	147 (3)	1.1	1.1***
Mercury (dissolved)	0.01	147 (20)	0.013	0.021
Zinc (dissolved)	1	147 (132)	7.4	17.7
Ammoniacal Nitrogen (N)	10	147 (142)	972	5,577
Un-ionised ammonia (freshwater)	N/A	N/A	4.0	22.9
Un-ionised ammonia (seawater)	N/A	N/A	17.8	102.1

Table 2. 2014 Groundwater sample data summary.

*n = number of samples; n>LoD = number of samples with results greater than the specified limit of detection. ** Cr includes both Cr(III) and Cr(VI); the relative proportions of each oxidative state are not known, therefore it is precautionarily

assumed that all measured Cr is Cr(VI) for comparison with the EQS which is for Cr(VI) only. *** Very few measurements of lead were above the Limit of Detection 'LoD' which resulted in a 95th percentile value lower than the

mean. As a precautionary measure the mean value has been applied instead of the 95th percentile value.

2.2.2 2020 groundwater test data

Further borehole tests were conducted in 2020, results of all substances of interest are detailed in Appendix B and summarised in Table 3. The sampling and analysis are described in Atkins, (2020) with 33 samples collected from an abstraction well in the centre of the development site. This sampling provides more contemporary results, however the target limit of detection (LoD) was not achieved for several substances for numerous samples. This means that for numerous samples the result is given as the maximum LoD which is, in some cases, an order of magnitude higher than the target LoD. It was not possible to repeat the analysis and therefore, as a worst-case assessment, maximum LoD values have been applied to all values reported as 'less than'. However, it should be noted that these are not considered an accurate measure of the substances and reflect only that concentrations are expected to be below these limits. As an example, cadmium is reported as "<2 μ g/L" in many samples, while the target LoD was <0.2 μ g/L. Sampling from 2014 (Section 2.2.1) indicated very low levels of cadmium; nevertheless, the highly precautionary maximum LoD value of 2 μ g/L is taken forward.

The un-ionised ammonia values have been calculated with the same variables as described in Section 2.2.1.

Substance	LoD µg/L (maximum LoD)*	<i>n</i> and (<i>n</i> >LoD)**	Mean concentration µg/L	95 th percentile concentration µg/L
Arsenic (total)	1 (10)	33 (1)	9	10
Cadmium (total)	0.2 (2)	33 (0)	2	2
Chromium (total)***	1 (10)	33 (2)	9	10
Copper (total)	1 (10)	33 (5)	11	23
Iron (total)	10	33 (33)	16,801	18,960
Nickel (total)	1 (10)	33 (1)	9	10
Lead (total)	1 (10)	33 (1)	10	10
Mercury (dissolved)	0.05 (0.5)	33 (0)	0.4	0.5
Zinc (total)	1 (10)	33 (11)	19	55
Ammoniacal Nitrogen (N)	20	33 (33)	1,455	1,938
Un-ionised ammonia (freshwater)	N/A	N/A	6.0	8.0
Un-ionised ammonia (seawater)	N/A	N/A	26.6	35.5

Table 3. 2020 Groundwater sample data summary.

* The Target LoD was exceeded in some samples for certain substances. Where this was the case the maximum LoD is indicated. ***n* = number of samples; *n*>LOD = number of samples with results greater than either the target or maximum LoD (i.e. the number of quantified results)).

*** Cr includes both Cr(III) and Cr(VI), the relative proportions of each oxidative state are not known, therefore it is precautionarily assumed that all meased Cr is Cr(VI) for comparison with the EQS which is for Cr(VI) only.

2.2.3 Summary of groundwater values applied in screening

The sampling from 2014 and 2020 provides numerous data points representing the conditions of the groundwater. The screening process compares a single concentration of the discharge to acceptable limits and therefore the data need to be summarised. Typically, an average would be taken of all the sample points to represent the overall average discharge, however this would assume either mixing prior to discharge or (for AA EQS) rapidly varying concentrations on short time scales irrelevant to the receiving environment. The dewatering process will however gradually extract groundwater and discharge it without substantive mixing and therefore it is possible that there could be prolonged periods where significantly higher than average concentrations are released. To ensure that a reasonable worst-case is assessed and limits on the CWDA permit are not exceeded, the concentrations assessed are the 95th percentile values, from either the 2014 or 2020 sampling, whichever is higher. The same assessment value for each substance is screened against the AA EQS and MAC EQS (where both are applicable).

Substance	95 th percentile concentration µg/L				
Substance	2014*	2020			
Arsenic	11.7	10			
Cadmium	0.19	2**			
Chromium***	18.7	10			
Copper	4.1	23			
Iron	1,500	18,960			
Nickel	9.9	10			
Lead	1.1	10**			
Mercury	0.021	0.5**			
Zinc	17.7	55			
Ammoniacal Nitrogen (N)	5,577	1,938			
Un-ionised ammonia (freshwater)	22.9	8.0			
Un-ionised ammonia (seawater)	102.1	35.5			

Table 4. Concentrations of contaminants in the groundwater applied in the assessment. **Bold** values indicate the higher value taken forward into the screening tests.

* Note that the 2014 values are for 'dissolved' not 'total' metals, however where this value exceeded the 2020 'total' concentration it has been selected as the most conservative assessment value.

** 2020 value is set at the LoD. The 2014 data indicates the true value is likely to be much lower, however this value to taken forward as a precaution.

** Cr includes both Cr(III) and Cr(VI); the relative proportions of each oxidative state are not known, therefore it is precautionarily assumed that all measured Cr is Cr(VI) for comparison with the EQS which is for Cr(VI) only.

2.2.4 Treated sewage

Following BEEMS TR193, the total ammoniacal nitrogen (as N) of treated sewage is not expected to exceed 20,000 μ g/L. This value has been applied to the treated sewage component of the total flow, with the final concentration at the point of discharge calculated based on the relative proportions of treated sewage and groundwater.

2.3 Background levels of contaminants of concern

Background concentration of determinands of interest are derived from dedicated monitoring in the area. For the purposes of this report background data are derived from a monitoring survey during which four stations in the Greater Sizewell Bay (Figure 3) were sampled monthly between March 2014 and September 2015. A total of 63 water samples were collected during this campaign. The average levels of determinands were calculated across all samples and are provided in Table 5. Further detail of the survey and analytical methods can be found in BEEMS TR314.

Determinand	Detection limit µg/L	Average (mean) background concentration µg/L n=57
Arsenic (dissolved)	1	1.07
Cadmium (dissolved)	0.03	0.05
Chromium (dissolved)*	0.5	0.57
Copper (dissolved)	0.2	2.15
Iron (dissolved)	100	100
Nickel and its compounds (dissolved)	0.3	0.79
Lead (dissolved)**	1	1
Mercury and its compounds (dissolved)	0.01	0.02
Zinc (dissolved)	0.4	15.12
Ammoniacal nitrogen (NH₄-N)***	1.4	11.38
Un-ionised ammonia (NH ₃ -N)****	N/A (calculated value)	0.19

Table 5. Background levels of determinands of interest (BEEMS TR314).

* Cr includes both Cr(III) and Cr(VI); the relative proportions of each oxidative state are not known, therefore it is precautionarily assumed that all measured Cr is Cr(VI) for comparison with the EQS which is for Cr(VI) only.

** Lead was below detection in both the 2014/2015 campaign and previous sampling in 2010. The detection limit was lowest in the 2010 campaign (BEEMS TR189) and has been applied as the background value.

***Detection limit of 0.1 µmol for NH4, which is equal to 1.8µg/L of total ammonia or 1.4 µg/L as N.

****95th Percentile – derived from total ammonia respective pH, temperature and salinity the equivalent un-ionised ammonia concentration is derived using the Environment Agency calculator (Clegg and Whitfield, 1995).

2.3.1 Background suspended sediment

Suspended sediments in sea water are the result of both natural processes (e.g., coastal erosion, catchment runoff and resuspension of seabed 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 TR189, BEEMS TR314); and Eggleton *et al.*, (2011) utilised satellite data for a project evaluating natural sediment variability in Regional Environmental Assessment areas in the North Sea and English Channel.

Water sampling campaigns in 2010 – 2011 (BEEMS TR189) and 2014 – 2015 (BEEMS TR314) analysed water samples for suspended sediment concentration from the near surface from regular monthly surveys and intensive tidal cycle (hourly) campaigns. The results of sampling in the nearshore area at Sizewell (inshore of the Sizewell-Dunwich bank) are summarised in Table 6 and Figure 2. The data show considerable variability with values ranging from 9 mg/L to 437 mg/L.

Suspended sediment data have also been obtained from the same nearshore area, but near the seabed (1 m off the bed) from a mini-lander equipped with an optical backscatter turbidity sensor and calibrated with locally collected samples (BEEMS TR098). These data show a similar large variation in suspended sediment between 17 mg/L to 459 mg/L with an estimated average between 72 and 105 mg/L.

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Data from Eggleton *et al.* (2011) are described in BEEMS TR306 where satellite derived suspended particulate matter (SPM¹) data for the period 1/7/2002 to 31/5/2010 were extracted from the data series for a grid cell covering the nearshore area at Sizewell (Table 6). SPM data showed an average mean value at Sizewell during April to August of 31 mg/L (and average monthly maximum 80 mg/L) and during September to March of 73 mg/L (and average monthly maximum 180 mg/L). An annual mean SPM for these data was 55.3 mg/L.

Based on the satellite data, the SZC Environmental Statement (Chapter 21) (SZC, 2020a) concluded that on average the surface waters at Sizewell would be classed as intermediate turbidity based on the WFD criteria (10 <100 mg/L suspended particulate matter). Following the method applied in the SZC Environmental Statement the long term average suspended sediment background concentration of 55.3 mg/L is considered applicable to the current assessment, noting that there will be considerable variation around this level and at times the natural background suspended sediment will likely exceed the 250 mg/L concentration in the proposed discharge. An assessment threshold has been applied relative to the WFD turbidity criteria (i.e. the level at which the turbidity classification would be changed from 'intermediate' (10<100 mg/L) to 'turbid' (100 – 300 mg/L).

Source	Location	Period	Average	Min.	Max.
TR189	Surface STN5* (Close to SZB outfall)	25/02/2010 – 14/02/2011 (monthly)	104	9	426
Water samples		02/03/2010 – hourly tidal cycle	234	108	437
TR314 Water samples	Surface SZB outfall	01/04/2014- 12/12/2015 (monthly)	90	37	133
TR089 Mini-lander (OBS)	Seabed** (1 m above)	28/11/2008 – 2/03/2009 (continuous)	72 – 105***	17	459
Eggleton, et al., 2011 (satellite)	Surface - 52.22 1.68 (~0.7x1.1km grid cell)	01/07/2002 – 31/05/2010	55.3	Not reported	180

Table 6: Summary of Suspended Sediment Concentration (SSC) background data (mg/L)

* STN5 coordinates - 648 054 mE 263 305mN (BNG)

** =Minilander location (inshore of the Sizewell-Dunwich bank) = 648 612mE 26 3714mN (BNG)

*** = upper and lower range estimates from OBS sensor.

¹ SPM is synonymous with SSC



Figure 2 Suspended solids concentration and turbidity obtained during the tidal cycle survey (spring tide conditions) conducted at Station 5 (SZB outfall) in March 2010.



Figure 3. Map of water quality sampling locations during the 2014/2015 monitoring campaign.

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3 Screening of construction discharges

3.1 Heavy and trace metals

3.1.1 Maximum dewatering (Case A) 250 L/s

Table 7 provides the screening results for a discharge at 250 L/s. The calculations for Test 1 and Test 5 (EVF) are described in Section 1.1. Results for Test 5 are only shown where Test 1 is not passed (i.e. >1). The AEVF for Test 5 in this case is 3.5 as the water depth of the CDO is greater than 3.5 m (ca. -6.2 m ODN). As an example of Test 5 for Cadmium, the calculation is a follows: EVF = (2*0.25)/(0.2 - 0.05).

Chromium, copper, iron, lead and zinc all fail the screening tests, however only for the AA EQS. All metals pass for the relevant MAC EQS. This shows that acute effects are not of concern, however, the scale of the mixing zone needs to be considered further to assess chronic effects (see Section 4).

Notably background levels of zinc are above the EQS and therefore Test 5 cannot be applied. Zinc is therefore only screened against Test 1. It should also be noted that the chromium assessment is based on measurements of all oxidative states of chromium (i.e. Cr(III) and Cr(VI)) while the EQS is based on hexavalent chromium (Cr(VI)) only. The precautionary assumption is that all chromium in the discharges is of the more toxic hexavalent form.

Substance	Concentration µg/L	Background µg/L	EQS AA	EQS MAC	Test 1 AA	Test 1 MAC	Test 5 AA	Test 5 MAC	Pass /Fail
Arsenic	11.7	1.07	25	-	0.5	-	-	-	Pass
Cadmium	2	0.05	0.2	-	<u>10.0</u>	-	3.3	-	Pass
Chromium*	18.7	0.57	0.6	32	<u>31.2</u>	0.6	<u>155.8</u>	-	Fail
Copper	23	2.15	3.76	-	<u>6.1</u>	-	<u>3.6</u>	-	Fail
Iron	18,960	100	1000	-	<u>19.0</u>	-	<u>5.3</u>	-	Fail
Nickel	10	0.79	8.6	34	<u>1.2</u>	0.3	0.3	-	Pass
Lead	10	1	1.3	14	<u>7.7</u>	0.7	<u>8.3</u>	-	Fail
Mercury	0.5	0.02	-	0.07	-	<u>7.1</u>	-	2.5	Pass
Zinc	55	15.12	7.9**	-	7.0	-	-	-	Fail

Table 7. Screening results for groundwater discharge at 250 L/s. Underlined values indicate a failed test.

* Cr includes both Cr(III) and Cr(VI); the relative proportions of each oxidative state are not known, therefore it is precautionarily assumed that all measured Cr is Cr(VI) for comparison with the EQS which is for Cr(VI) only. **Note that the background for Zinc is greater than the EQS and therefore Test 5 cannot be applied. Zinc is assessed further in Section 4.

3.1.2 Main construction (Case B) 50 L/s

This case is comprised of the construction groundwater from dewatering after the peak dewatering phase and is expected to be between 25 and 50 L/s (assumed as 50 L/s). The total flow could be up to 100 L/s with the additional flow from treated sewage, however this component of the flow is not expected to add any heavy or trace metals in significant concentrations. The treated sewage flow would therefore dilute the metals in the main dewatering flow; it has therefore not been included as it is more conservative to assume no dilution. The treated sewage flow is, however, considered in terms of ammonia discharges in Section 3.2.

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Table 8 gives the screening results for the main construction phase dewatering at 50 L/s. Test 1 is independent of the flow and therefore results are the same as Case A. Test 5 shows that the lower flow for this scenario leads to several metals passing Test 5. Chromium and zinc, however, both fail based on the AA EQS. However, as noted in Section 3.1.1, zinc can only be screened against Test 1 due to the elevated background levels.

Substance	Concentration µg/L	Background µg/L	EQS AA μg/L	EQS MAC µg/L	Test 1 AA	Test 1 MAC	Test 5 AA	Test 5 MAC	Pass /Fail
Arsenic	11.7	1.07	25	-	0.5	-	-	-	Pass
Cadmium	2	0.05	0.2	-	<u>10.0</u>	-	0.7	-	Pass
Chromium*	18.7	0.57	0.6	32	<u>31.2</u>	0.6	<u>31.2</u>	-	Fail
Copper	23	2.15	3.76	-	<u>6.1</u>	-	0.7	-	Pass
Iron	18,960	100	1000	-	<u>19.0</u>	-	1.1	-	Pass
Nickel	10	0.79	8.6	34	<u>1.2</u>	0.3	0.1	-	Pass
Lead	10	1	1.3	14	<u>7.7</u>	0.7	1.7	-	Pass
Mercury	0.5	0.02	-	0.07	-	<u>7.1</u>	-	0.5	Pass
Zinc	55	15.12	7.9**	-	<u>7.0</u>	-	-	-	Fail

Table 8. Screening results for groundwater discharge at 50 L/s. Underlined values indicate a failed test.

* Cr includes both Cr(III) and Cr(VI); the relative proportions of each oxidative state are not known, therefore it is precautionarily assumed that all measured Cr is Cr(VI) for comparison with the EQS which is for Cr(VI) only.

**Note that the background for Zinc is greater than the EQS and therefore Test 5 cannot be applied. Zinc is assessed further in Section 4.

3.1.3 Total annual load

As described in Section 1.1, for certain substances there are significant load limits on the total mass released per year. Cadmium and mercury are the only relevant substances with significant load limits, of 5 kg per year and 1 kg per year respectively. A conservative estimate of the annual total mass of both cadmium and mercury is provided in Table 9. This is worst-case as it assumes that the maximum flow rate is continuous, whereas in practice the flow is likely to often be below this maximum and may not occur consistently 7 days per week for a full year. As with the concentration screening in Section 3.1.2, the flow from groundwater has been applied (between 250 L/s and 50 L/s) to calculate the total mass, as the other elements of the flow (treated sewage) are not expected to contribute these metals to the discharge.

Notably as described in Section 2.2.2, in the 2020 dataset, the target LoD was not achieved for many cadmium and mercury samples. Therefore, when applying the worst-case maximum reported LoD the assessed concentration is likely to be inaccurate and considerably higher than the true concentration. The 2014 data, while older, provided more precise LoD's and indicate a much lower concentration of both cadmium and mercury.

For Cadmium, applying the 2014 data the annual load is estimated to be 0.8 kg (~16% of the 5 kg limit), and theoretically the 250 L/s discharge could occur continuously for 365 days without exceeding the limit, equating to 1.498 kg/year or ~30% of the 5 kg limit. Applying the 2020 data at face value results in considerably higher estimates due to the low precision LoD for many samples. With the 2020 data (assuming a concentration of 2.0 μ g/L equivalent to the maximum LoD), the estimated total cadmium load would be 8.4 kg (168% of the 5 kg limit). However as noted above this result is not considered reliable due to the influence of the high LoD in many samples.

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For mercury, using the 2014 measurements the annual load is considerably below the significant load limit, totalling 0.088 kg/year which equates to less than 9% of the annual limit under the assessed profile and less than 20% of the limit if the 250 L/s discharge continued for a full year. However, using the 2020 mercury value, which was set at the maximum LoD of $0.5 \mu g/L$, the total annual load would exceed the limit totalling 2.11 kg/year (211%). Notably the achieved mercury detection limit in 2020 was significantly higher than the target detection limit (described in Section 2.2.2) and more than 20 times higher than the reported values in 2014. It is reasonable to assume therefore that mercury will be present in the discharge at levels below $0.5 \mu g/L$ (the maximum LoD from the 2020 dataset) and therefore it is highly likely that the actual total load will be substantially lower than that calculated from the 2020 dataset.

Given the considerable range in estimates for the total annual load, it will be important to obtain accurate monitoring measurements of the mercury and cadmium content and establish accurate total load discharges to ensure the annual load limits are not exceeded. This could be achieved during the initial peak dewatering and forecast based on actual data for a full year. Monitoring must achieve the target limit of detection, ideally $0.05 \mu g/L$ or lower for mercury and $0.2 \mu g/L$ or lower for cadmium. If actual concentrations are elevated and the total load limits are forecast to be exceeded, mitigation will be required (such as flow control, cessation of the discharge or treatment² of the effluent).

After the initial peak dewatering period, the flow rate will be lower and therefore the total loads will be reduced. As such, after the first year, the annual loads will be substantially reduced and will be considerably below the allowable limits.

Substance	Rate 1 (flow + duration)	Rate 2 (flow + duration)	Concentration µg/L	Annual Load (kg)	Limit (kg)	Ratio
Cadmium (2020)		50 L/s 212.5 days*	2.0	8.424	5	1.68
Cadmium (2014)	250 L/s		0.19	0.800	5	0.16
Mercury (2020)	152.5 days		0.5	2.106	1	2.11
Mercury (2014)			0.021	0.088	1	0.09

Table 9. Total annual load of cadmium and mercury.

* This is conservative as it assumes maximum post peak groundwater flow for the remainder of the year.

3.1.4 Maximum screening concentrations of metals

The groundwater sampling provides an estimate of the anticipated concentrations of metals in the groundwater; however, the actual values may vary as the groundwater level is lowered and possibly with groundwater from tunnelling activities which will be from a marine location. To avoid permit variations for insignificant changes, the maximum levels of metals which would pass the screening tests have been calculated. It should be noted that these are not direct measurements, but indicate the upper limits of the screening thresholds with the particular flow rates and water depth of the discharge. These have been calculated by reversing the Test 5 calculation to determine the concentration for a EVF of 3.5. It should be noted cadmium and mercury levels could not be sustained at the maximum levels for prolonged periods as this may exceed the total annual load limits (refer to Section 3.1.3).

Table 10 provides the results of the equivalent concentrations for a EVF of 3.5 based on the peak flow of 250 L/s (Case A). Four metals; arsenic, cadmium, nickel, and mercury, could be discharged at average concentrations higher than those measured in the groundwater without exceeding the screening thresholds.

²It should be noted that any future proposed treatment would need to be in line with permitted processes under the WDA permit or permitted under a variation or specific permit.

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Table 11 provides the equivalent concentrations for a EVF of 3.5 based on the typical flow of 50 L/s (Case B). Due to the lower flow, and therefore lower mass of substances released, the allowable maximum limits are higher. During the main construction period, the permissible limits for all metals except chromium and zinc could be set higher than the borehole test data whilst remaining below the screening limits. Furthermore, the screening thresholds are based on annual averages, and therefore peak concentrations, providing they are below relevant MAC EQS screening tests, could be higher providing the average concentration is below the AA screening maximum.

Table 10. Maximum possible screening thresholds for Test 5 based on the peak flow of 250 L/s (Case A). Underlined values indicate substances which could vary from the observed test data without failing screening tests.

Substance	EVF	AA EQS µg/L	Test concentration μg/L	EVF 3.5 concentration µg/L
Arsenic	3.5	25	11.7	<u>335</u>
Cadmium	3.5	0.2	2	<u>2.1</u>
Chromium*	3.5	0.6	18.7	0.42
Copper	3.5	3.76	23	22.5
Iron	3.5	1000	18,960	12,600
Nickel	3.5	8.6	10	<u>109</u>
Lead	3.5	1.3	10	4.2
Mercury	3.5	0.7**	0.5	<u>0.7</u>
Zinc	3.5	7.9	55	<u>N/A***</u>

* Cr includes both Cr(III) and Cr(VI); the relative proportions of each oxidative state are not known, therefore it is precautionarily assumed that all measured Cr is Cr(VI) for comparison with the EQS which is for Cr(VI) only. ** Mercury does not have an AA EQS, and therefore the MAC is applied.

*** The background concentration of Zinc is above the EQS and therefore a value cannot be calculated.

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Table 11. Maximum possible screening thresholds for Test 5 based on the typical construction flow of 50 L/s. Underlined values indicate substances which could vary from the observed test data without failing screening tests.

Substance	EVF	AA EQS μg/L	Test concentration μg/L	AVF concentration µg/L
Arsenic	3.5	25	11.7	<u>1,675</u>
Cadmium	3.5	0.2	2	<u>10.5</u>
Chromium*	3.5	0.6	18.7	2.1
Copper	3.5	3.76	23	<u>112.7</u>
Iron	3.5	1000	18,960	<u>63,000</u>
Nickel	3.5	8.6	10	<u>546.7</u>
Lead	3.5	1.3	10	<u>21</u>
Mercury	3.5	0.07**	0.5	<u>3.5</u>
Zinc	3.5	7.9	55	<u>N/A***</u>

* Cr includes both Cr(III) and Cr(VI); the relative proportions of each oxidative state are not known, therefore it is precautionarily assumed that all measured Cr is Cr(VI) for comparison with the EQS which is for Cr(VI) only.

** Mercury does not have an AA EQS, and therefore the MAC is applied.

*** The background concentration of Zinc is above the EQS and therefore a value cannot be calculated.

3.2 Un-ionised ammonia

The updated assessment of un-ionised ammonia retains the same assumptions on sewage flow and ammoniacal nitrogen concentration as applied in BEEMS TR193. The contribution of ammoniacal nitrogen from the groundwater has been reviewed with the newly available 2020 data. Notably, the 2014 data indicated higher ammoniacal nitrogen levels in the groundwater compared with the 2020 data. Therefore, the assessment is updated for the revised flow rates with all other parameters matching the previous analysis in BEEMS TR193.

The partitioning between ammonium (NH₄⁺) and un-ionised ammonia (NH₃) is controlled by environmental variables, principally, pH, temperature and salinity. 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. A greater percentage of ammonia will also be in the un-ionised form when the salinity is lower. Un-ionised ammonia concentrations have been calculated using the Environment Agency calculator (following the formulas in Clegg & Whitfield,1995).

The discharged source will be primarily freshwater with different properties to the seawater it will mix with. Therefore, the proportion of un-ionised ammonia will change as the discharge mixes with the surrounding seawater. The partitioning of ammonia to un-ionised ammonia with increasing pH can lead to a rapid increase in un-ionised ammonia potentially exceeding the dilution effect from the mixing (depending on background conditions). A theoretical worst-case can be calculated in which the seawater conditions (pH, salinity) are applied to un-ionised ammonia calculation without any dilution of total ammonia via mixing. This is unrealistic as for the seawater conditions to be reached mixing must occur; however, it provides an initial screening point to trigger further investigation. Mixing curves for un-ionised ammonia (e.g. BEEMS TR193 Figure 9) can be calculated where there is concern over the un-ionised ammonia discharge.

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Table 12 provides the calculated final mix concentration of ammoniacal nitrogen based on the relative contributions of groundwater and treated sewage. The values have been used in the screening presented in Table 13. Screening results are provided for both the freshwater (i.e. conditions in the discharge) and the hypothetical immediate seawater conditions. As noted above this is not a realistic case and un-ionised ammonia levels would be lower than those calculated due to the dilution with seawater. Total ammonia has been converted to un-ionised ammonia based on either salinity of 1, pH of 7.3 and a temperature of 11.43 °C (freshwater) or salinity of 33, pH of 8.05 and temperature of 11.43 °C (seawater) (see Section 2.2.1).

All un-ionised ammonia cases pass the screening and therefore do not require further assessment. The Test 5 results are considerably below the AEVF of 3.5, even when applying immediate seawater conditions without accounting for dilution.

Following the same approach described in Section 3.1.4, during Case A (peak dewatering) the total unionised ammonia could theoretically be as high as 291 μ g/L (circa 16,000 μ g/L ammoniacal nitrogen in seawater conditions) whilst still passing Test 5. During the main construction period, when flows are lower, the maximum un-ionised ammonia whilst still passing Test 5 would be 728 μ g/L (Case B1) (circa 40,000 μ g/L ammoniacal nitrogen in seawater conditions). If the ammoniacal nitrogen content of the ground water is as estimated from the boreholes, the ammoniacal nitrogen content of the treated sewage flow could theoretically be up to 73,500 μ g/L (resulting in un-ionised ammonia based on instant seawater conditions of 723 μ g/L). If the treated sewage were to be discharged undiluted with groundwater, accounting for the reduced total flow rate (i.e. 50 L/s), the maximum un-ionised ammonia content, while still passing test 5 could be up to 1,456 μ g/L (approximately 79,000 μ g/L ammoniacal nitrogen based on seawater conditions).

Notably, the discharge will be freshwater and therefore actual un-ionised ammonia concentrations would be considerably lower as the portioning to un-ionised ammonia is less in freshwater (due to the lower pH). As such, higher source concentrations may be permissible, however, mixing with the seawater would then need to be accounted for.

Case	Groundwater flow L/s	Groundwater ammoniacal Nitrogen µg/L	Treated sewage flow L/s	Sewage ammoniacal Nitrogen µg/L	Final Flow L/s	Final ammoniacal Nitrogen Concentration μg/L
Α	250	5,577	0	0	250	5,577
A1	250	5,577	50	20,000	300	7,981
B1	50	5,577	50	20,000	100	12,789
Max*	50	5,577	50	73,500	100	39,539

Table 12. Total flow and ammoniacal nitrogen concentration of the groundwater and treated sewage discharges.

* Note: this is a hypothetical maximum within the screening limits calculated from a AEVF of 3.5.

Table 13. Screening results for un-ionised ammonia from groundwater discharge and treated sewage. Underlined values indicate a failed test.

Scenario	Un-ionised ammonia Concentration µg/L	Background µg/L	EQS AA µg/L	Test 1 AA	Test 5 AA	Pass /Fail
Case A – Freshwater	23	0.19	21	<u>1.1</u>	0.3	Pass
Case A – Seawater	102	0.19	21	4.9	1.5	Pass
Case A1 – Freshwater	33	0.19	21	<u>1.6</u>	0.4	Pass
Case A1 – Seawater	146	0.19	21	7.0	1.8	Pass
Case B1 – Freshwater	53	0.19	21	2.5	0.3	Pass
Case B1 – Seawater	234	0.19	21	11.1	1.1	Pass
Maximum - Seawater	723	0.19	21	34.5	3.5	Pass

3.3 Suspended sediment

Table 14 gives the results of the screening assessment for suspended sediment discharges. While there is no EQS for suspended sediment the screening method described in Section 1.1 has been applied to determine the potential risk of this parameter in the discharge. A threshold of 100 mg/L has been applied based on the turbidity classification class (intermediate 10 - 100 mg/L), this therefore sets the threshold as maintaining the average turbidity class as 'intermediate'.

The results show that Test 1 is not passed (as the 250 mg/L proposed discharge is greater than the applied 100 mg/L threshold). Test 5 however is passed under all scenarios indicating that the suspended sediment in the discharge will disperse rapidly and is unlikely to pose a risk to the marine environment.

As the screening test (Test 5) is passed, modelling of the discharge is not considered necessary, however as further assurance the suspended sediment discharge can be compared to nearfield CORMIX modelling for the 250 L/s scenario (detailed in Section 4.2). The dilution requirements of a 250 mg/L discharge mixing with an average background of 55.3 mg/L to a limit of 100 mg/L would be 4.4 times (i.e. 3.3 parts seawater mixing with 1 part discharge). The CORMIX modelling for a 250 L/s discharge described in detail in section 4.2 and illustrated on Figure 5, shows that dilution requirement is met within several meters of the discharge point. This further supports the conclusion of the screening tests that the suspended sediment discharge poses a negligible risk to the marine environment.

It should be noted that, as described in Section 2.3.1, the natural background SSC varies considerably as result of natural physical processes. Monitoring data shows background SSC ranges from less than 10 mg/L to over 400 mg/L and can vary considerably over the course of a single tidal cycle. As such, the proposed 250 mg/L SSC in the discharge is not beyond the natural range experienced at the site.

Case	Total flow L/s	SSC mg/L	Background mg/L	Threshold** mg/L	Test 1	Test 5
Combined*	560.7	250	55.3	100	2.5 (fail)	3.1 (pass)
Peak GW	250	250	55.3	100	2.5 (fail)	1.4 (pass)
Main GW	50	250	55.3	100	2.5 (fail)	0.2 (pass)

Table 14: Screening results for suspended sediment from all CDO discharges.

* Comprises surface water, groundwater, foul water, and waste water treatment facilities (refer to section 2.1.1)

** The threshold applied relates to a change in WFD class from intermediate to turbid water (i.e. not exceeding the intermediate turbidity class of 10 – 100 mg/L). As noted in Section 2.3.1 natural background variability in the Sizewell area ranges from >10 mg/L to >400 mg/L.

4 Modelling of potentially significant discharges

4.1 Modelling methods

Substances which do not pass the screening tests require further investigation with modelling to determine the extent of the mixing zone (i.e. the area in excess of the EQS). For relatively small discharges, nearfield modelling can be sufficient to demonstrate the size of the mixing zone. The distance to which nearfield modelling can be applied depends on the conditions in the model; however, it is particularly useful for mixing zones which are likely to be close to or smaller than the resolution of full-scale hydrodynamic models. For the purposes of SZC, the full-scale hydrodynamic model (General Estuarine Transport Model (GETM), described below) has a resolution of 25 m by 25 m, therefore mixing zones smaller than this would not be apparent in the GETM model.

Nearfield modelling has been carried out using the CORMIX US EPA supported mixing zone model³ applying the same hydrodynamic model parameters as used in BEEMS TR193. CORMIX is a steady state model producing an instantaneous plume for a particular set of tidal conditions. To determine the range of plume sizes over a tidal cycle, four conditions have been modelled: rising tide (peak flood), falling tide (peak ebb), high tide and low tide.

CORMIX can be used to determine the range at which a substance falls below EQS based on the dilution required to reach the specified level (inclusive of background levels). To simplify the model interpretation, CORMIX has been used to determine the dilution of the discharge over distance. The dilution curve produced from CORMIX has then been examined to determine the range at which sufficient dilution is achieved to reach the EQS for each substance of interest. Given there is no reaction or decay assumed for metals, this approach enables several substances to be interpreted for a single set of model runs.

Dilution (S) is defined in the CORMIX manual (Doneker and Jirka, 2007) as the initial concentration (C_0) over dilution at point C, so S=C₀/C. This dilution factor therefore gives the number of parts in total rather than the ratio of the discharge to the seawater (i.e. an unmixed discharge has a dilution factor of 1 and a 50% mixed discharge, which has a 1:1 ratio, has a dilution factor of 2). Dilution factors referenced in this report follow the same definition for consistency with the CORMIX outputs.

The mixing range is interpreted from the CORMIX trajectory distance (s), which is defined as the distance along the centreline trajectory as $s=(x^2+y^2+z^2)^{1/2}$. the range is calculated from a starting point of 0 which replicates the graphical outputs from CORMIX (e.g. Figure 14).

Where mixing zones extend beyond the nearfield area, full-scale hydrodynamic modelling is required to examine the size of the mixing zone. The Sizewell calibrated and validated GETM model has been used for this purpose. The GETM model setup, calibration and validation are described in BEEMS TR229, BEEMS TR301 and BEEMS TR302 and this model was approved by the Environment Agency for thermal plume modelling of the SZC discharges. The GETM model is a 3D hydrodynamic model with an inbuilt passive tracer used to represent metals in the discharge. 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 TR229. The GETM model domain used a discrete grid with dimensions of 25 m by 25 m (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 (250 L/s) is 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. For the purposes of chemical plume modelling, the GETM model is run for a full month to simulate dispersion over a full range

³ CORMIX Version 12.0GT HYDRO1 Version 12.0.1.0 January 2023

of tidal conditions. The simulation was carried out for the period 1st of May to 31st of May, of the reference year 2009, to encompass a full spring neap cycle.

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 is a function of dilution. The GETM model does not include additional mixing to waves and is therefore a conservative estimate of the plume size.

4.2 CORMIX (nearfield) modelling

The highest EVF results were from Case A, as this represents the largest flow and therefore greatest overall mass of substances in the discharge. The maximum flow rate of 250 L/s has therefore been modelled to represent the worst-case.

The dilution required to reach the EQS for substances which failed the screening tests is given in Table 7. This has been calculated as follows;

- Step 1 Discharge concentration minus the background concentration.
- Step 2 Discharge concentration minus the EQS.
- Step 3 Step 2 divided by step 1 (to give the percent mixing required to reach EQS).
- Step 4 Step 3 divided by (100 minus step 3) (to give the dilution ratio, add 1 for dilution factor).

For example, for chromium the steps are:

- ▶ 18.7 0.57 = 18.13
- ▶ 18.7 0.6 = 18.10
- 18.10/18.13*100 = 99.83 (percent mixing required to reach EQS)
- 99.83/(100-99.83) = 603+1 = 604 (dilution factor required to meet EQS)

The background concentration of zinc is above the EQS and therefore it is not possible for any discharge to dilute to below the EQS. For zinc the background concentration is greater than the EQS concentration so it is not possible to mix the discharge below the EQS. In this situation, following consultation with the Environment Agency⁴, the criteria modelling is based on the background concentration plus 3% of the relevant EQS. This approach is consistent with the Environment Agency internal guidelines for freshwater in the absence of specific marine guidance for this circumstance (K. Edwards Pers. Comm. pre-application meeting 08/10/2024). As such for zinc, the adjusted threshold is $15.12+0.237=15.357 \mu/L$.

The CORMIX results are detailed in Appendix C, and are summarised on Figure 4 and Figure 5. The dilution curves show the range at which the EQS would be achieved for the case modelled. This represents an instantaneous plume in a single direction and not a plume area (which can be described by the GETM model, see Section 4.3). An approximation of the plume footprint, based on the worst-case tidal conditions can be calculated based on the tidal ellipse with a factor of 5.9 (i.e. the long axis is 5.9 times the short axis) as defined in BEEMS TR306.

The CORMIX modelling shows that for copper, iron and lead, based on the assessed concentrations and a discharge of 250 L/s, the mixing zone will be constrained to the immediate area around the outfall and will fall to the EQS levels within 20 m (or within 212 m², 0.02 ha based on the tidal ellipse). These small mixing zones are expected to have negligible effects on the water quality and biological receptors in the Greater Sizewell Bay.

For chromium and zinc the range to EQS estimated by CORMIX was 750 m and 317 m respectively. The mixing zones for these metals are therefore best characterised by full-scale hydrodynamic modelling

⁴ Pre-application meeting on the 08/10/2024 and subsequently confirmed via email from K. Edwards to SZC on 14/11/2024.

(GETM) which can reproduce the average and upper percentile plumes in 3D over a series of tidal conditions.

Table 15. CORMIX results showing the maximum distance required to reach EQS for substances which fail the initial screening tests. The maximum range is on a falling tide.

Substance	Concentration µg/L	Background µg/L	EQS (AA) µg/L	Mixing to EQS (%)	Dilution factor to EQS	Range to EQS (m)
Chromium*	18.7	0.57	0.6	99.83	604	750
Copper	23	2.15	3.76	92.28	12.95	6
Iron	18,960	100	1000	95.23	20.96	12
Lead	10	1	1.3	96.67	30.00	17
Zinc	55	15.12	15.357**	99.41	168.27	317

* Cr includes both Cr(III) and Cr(VI), the relative proportions of each oxidative state are not known, therefore it is precautionarily assumed that all meased Cr is Cr(VI) for comparison with the EQS which is for Cr(VI) only.

**Note that the background for Zinc is greater than the EQS and therefore, as described in Section 4.2, the assessment threshold of the background plus 3% of the EQS is instead applied.



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Figure 4. CORMIX results of dilution and range with a 250 L/s flow (only falling tide and rising tide shown, as high tide and low tide have small trajectories). Points show the dilution required for selected metals to reach EQS.



Figure 5. CORMIX results of dilution and range with a 250 L/s flow; excerpt of Figure 4 showing the initial dilution conditions.

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4.3 GETM modelling

Chromium and zinc were investigated further with full hydrodynamic modelling using the calibrated and validated Sizewell GETM model (described in Section 4.1). GETM was run with a month-long simulation to replicate a full range of tidal conditions. Plume extents are calculated based on the mean average for comparison with the AA EQS (95th or 100th percentiles are relevant to MAC EQS levels however the MAC for chromium is not exceeded and there is no MAC for zinc). Both sea surface and bottom concentrations were extracted from the model.

Table 16 details the areas of the mixing zones predicted by GETM for chromium and zinc. As predicted by the CORMIX modelling (Section 4.2) the maximum plume is for chromium. The extents of the plumes are shown on Figure 6 and Figure 7 for chromium and zinc, respectively.

Table 16. GETM model results for Chromium and Zinc. Mean areas are shown with reference to the AA EQS.

Substance	AA EQS µg/L	Surface area > EQS (km ²)	Bottom area >EQS (km ²)
Chromium*	0.6	0.221	0
Zinc	15.357**	0.035	0

* Cr includes both Cr(III) and Cr(VI); the relative proportions of each oxidative state are not known, therefore it is precautionarily assumed that all measured Cr is Cr(VI) for comparison with the EQS which is for Cr(VI) only.

**Note that the background for Zinc is greater than the EQS and therefore, as described in Section 4.2, the assessment threshold of the background plus 3% of the EQS is instead applied.

4.3.1 Interaction with the desalinisation intake and discharges

Discharges associated with the proposed temporary desalination plant are described in BEEMS TR552. The CDO discharge may overlap with both the desalination intake and desalination outfall and therefore combined effects need to be considered.

4.3.1.1 Interaction with the desalination intake

The desalination intake is planned to be approximately 270 m south and slightly offset to the east of the CDO. Any excess metals in the plume of the CDO discharge (where it overlaps) would be abstracted by the desalination intake and concentrated through the desalination process. BEEMS TR552 considered the potential of an excess of 0.016 μ g/L of chromium associated with the CDO discharge at the desalination intake location; chromium from the updated GETM modelling described herein shows a seabed maximum excess of 0.037 μ g/L at the desalination intake. However, the average over the time series is 0.014 μ g/L (Figure 8). Given the background chromium levels of 0.57 μ g/L, the excess amounts on average are 2.5% with a maximum uplift of 6.5%.

BEEMS TR552 demonstrated that the desalination discharge, adjusted for excess chromium from the CDO at 0.016 μ g/L, would have an immaterial difference to the desalination discharge concentration. Given the very low level of excess chromium at the seabed the implications for the desalination intake and discharge are considered negligible.

The maximum excess zinc at the desalination intake is 0.11 μ g/L, and on average 0.04 μ g/L, which is below the level of detection and therefore would be indistinguishable from the background conditions.

4.3.1.2 Combined effects of the CDO and desalination discharges

The discharges from the CDO and desalination outfall may occur simultaneously. Notably the CDO discharge is buoyant and creates a surface plume whereas the desalination plume is dense and results in a plume at the bed, therefore there is a vertical offset. The maximum surface plume from the CDO extends close to, but not quite overlapping the desalination plant outfall. As a worst-case it is possible that the plumes from the two discharges may occur simultaneously without any overlap, and therefore the combined area in

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excess of the relevant EQS would be the sum of the two areas (noting the vertical offset described above). Overlapping plume areas may marginally increase the concentration but the total area in excess of the EQS could not be larger than the total of the two separate plumes combined.

The largest estimated plume footprint for metals (for zinc) discharged from the desalination plant is up to $0.630 \text{ ha} (0.0063 \text{ km}^2)$ at the bed, combined with the surface CDO plume (0.035 km^2) for zinc, a total area of the Greater Sizewell Bay of 0.041 km^2 may be exposed to average zinc levels above the EQS.

The chromium plume was the largest plume from the CDO (up to 0.22 km²), however chromium from the desalination plant discharge is expected to be very low, with a maximum footprint of 0.001 ha (0.00001 km²) and therefore combined effects would be negligibly larger.







Figure 7. GETM model results for zinc based on the mean mixing zone at 3% of the EQS above the baseline (surface).



Figure 8. Excess chromium and zinc from the CDO discharge at the location of the desalination intake (seabed).



Figure 9. In-combination CDO plume and desalination plume model results for zinc (refer to BEEMS TR552 for details desalination discharge assessment). Note CDO plume is modelled with GETM and is a buoyant surface plume, the desalination plume is modelled with CORMIX and is a dense bed plume, and therefore there is a vertical offset not illustrated on this map.

5 Impact assessment of construction discharges

5.1 Water Framework Directive

This section considers the discharges in relation to the Water Framework Directive (WFD). The purpose of this evidence is to feed into a more comprehensive WFD assessment which would be part of the CWDA permit application. This section focuses on the habitats assessment described in the WFD guidance (Environment Agency, 2023).

The scoping test for habitats under the WFD guidance requires a detailed assessment if the footprint (i.e. plume size in this case) of the activity is:

- 0.5 km² or larger,
- ▶ 1% or more of the water body's area (≥1.47 km² for the Suffolk Coastal water body which is 147.387 km²),
- within 500 m of any higher sensitivity habitat, and/or
- 1% or more of any lower sensitivity habitat (EA Water Body summary table 2023⁵; Suffolk coastal water body; 'Cobbles, gravel and shingle' 19.30 km²; 'Intertidal soft sediment' 8.16 km²; 'rocky shore' 0.02 km² and 'subtidal soft sediments' 105.69 km²).

The maximum plume extent is for chromium with potentially up to 0.22 km² in excess of the EQS. The scoping is therefore assessed against the chromium plume as the worst-case.

None of the four habitat scoping criteria are exceeded by the chromium plume footprint:

- 0.22 km² maximum footprint < 0.5 km² or larger.
- ▶ 1% or more of the water body's area (≥1.47 km² for the Suffolk Coastal water body which is 147.387 km²). 0.22 km² <1.47 km².
- within 500 m of any higher sensitivity habitat greater than 1 km from nearest higher sensitivity habitat (Sabellaria reef on circalittoral rock A4.22) - Figure 6.
- 1% or more of any lower sensitivity habitat. There is no excess of the EQS at the seabed where these habitats occur. The maximum surface plume is 0.22 km² over subtidal soft sediments which equates to 0.2%.

⁵ Downloaded from Environment agency (2023) December 2023.

https://assets.publishing.service.gov.uk/media/6523e902244f8e000d8e7241/wfd water body summary table 2023 update submissio n.xlsx

6 Conclusion

The expected discharge of groundwater associated with the construction of SZC has been reassessed with newly available data and parameters. Two groundwater sampling datasets have been reviewed and the highest levels of potential contaminants have been taken forward into the assessment. An updated peak flow rate of 250 L/s has also been applied.

Two main discharge scenarios have been considered: the peak construction groundwater flow of 250 L/s and the main construction period, with a flow of 50 L/s. Both scenarios have also been considered with a simultaneous treated sewage flow of up to 50 L/s. Applying the Environment Agency's screening tests for discharges to estuarine and coastal waters showed that arsenic, cadmium, nickel and mercury all pass the screening and therefore do not require detailed assessment. Consideration of ammonia discharges (as unionised ammonia), during both the peak dewatering period and the main construction period with treated sewage flows, also passed the screening tests. Suspended sediment in the discharge, which will be treated to a limit of 250 mg/L, was screened against a threshold of 100 mg/L based on no change of the WFD turbidity class. It was noted that the natural background suspended sediment varies considerably at Sizewell and is often in excess of 250 mg/L meaning the discharge is within the natural background variance, although greater than the long-term background average. When considering a scenario including all effluent flows and long-term average background surface suspended sediment concentration, the discharge passed the screening test and therefore suspended sediment in the discharge is not considered to pose a risk to water quality.

Based on the annual average EQS levels, maximum screening concentrations have been calculated to show the envelope of the screening assessment for arsenic, cadmium, nickel, mercury and ammonia. The maximum screening levels are based on the annual average and passing the screening tests. Therefore, permissible maximum levels could be higher, either by allowing a mixing zone and assessing the impact of it, or by ensuring that peak concentrations do not exceed the MAC screening tests and the annual average concentration does not exceed the AA screening maximum.

Chromium, copper, iron, lead and zinc were examined further using modelling to characterise the extent of mixing zones (i.e., the area in which the EQS is exceeded). Nearfield modelling using CORMIX demonstrated that for copper, iron and lead the mixing zones would be highly constrained, with plumes exceeding respective EQS levels extending no further than 20 m from the discharge point.

The CORMIX modelling indicated that chromium and zinc mixing zones could extend beyond the near field area and therefore are best characterised by full-scale hydrodynamic modelling using GETM. GETM is able to model the 3D plume extent over a spring-neap cycle to determine areas of excess (i.e. mixing zones). GETM modelling for chromium and zinc demonstrated that average mixing zones at the surface, where the AA EQS is exceeded, would be approximately 0.22 km² for chromium and 0.035 km² for zinc. The plumes were ellipsoid in shape, oriented north and south, as would be expected given the tidal conditions. There was no excess greater that the EQS at the seabed at the resolution of the GETM model. The interaction of the CDO discharge with the desalination intake location was considered and compared with the assessment in BEEMS TR588. It was concluded that the CDO discharges would be unlikely to have a meaningful effect on the desalination assessment due to the very low levels of excess metals at the bed. Combined effects of simultaneous CDO and desalination plumes were considered, but due to the highly localised plumes resulting from the desalination plant discharge combined effects would be negligibly different to the CDO plume alone area.

The chromium discharge plume was reviewed against the WFD assessment scoping criteria to determine if detailed impact assessments are required. None of the scoping criteria were exceeded by the chromium mixing zone and therefore detailed impact assessment is unlikely to be necessary.

References

Atkins, 2016. Data (sampling conducted from October 2014-2016).

Atkins, 2020. Sizewell C Pumping Test 2020. Wayer Quality Interpretative Report. SZC-PT-2020-ATK.

BEEMS Technical Report TR189. Sizewell Marine Water Quality Monitoring Final Summary Report. Cefas, Lowestoft.

BEEMS Technical Report TR193. SZC Discharges H1 type assessment supporting data report Edition 5. Cefas, Lowestoft.

BEEMS Technical Report TR229. Sizewell -Thermal Plume Modelling: GETM Model stage 1 Calibration and Validation. Cefas, Lowestoft.

BEEMS Technical Report TR301. Sizewell Thermal Plume Modelling: Stage 2a review. Selection of preferred SZC cooling water configuration. Cefas, Lowestoft.

BEEMS Technical Report TR302. Sizewell Thermal Plume Modelling: GETM Stage 3 results with the preferred SZC cooling water configuration. Edition 3. Cefas, Lowestoft.

BEEMS Technical Report TR306. Sizewell Marine Water and Sediment Quality Synthesis Report MSR2/5. Cefas, Lowestoft.

BEEMS Technical Report TR314. Sizewell supplementary water quality monitoring data 2014/2015. Cefas, Lowestoft.

BEEMS Technical Report TR552. Sizewell C Desalination Discharge Assessment. Cefas, Lowestoft.

Clegg S. L. and Whitfield, M. 1995. A chemical model of seawater including dissolved ammonia, and the stoichiometric dissociation constant of ammonia in estuarine water and seawater from -2° to 40 °C. *Geochim. et Cosmochim. Acta* 59, 2403 – 2421.

Doneker, R. L, and Jirka, G. H. 2007. CORMIX User Manual. A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters. EPA-823-K-07-001, Dec. 2007. Available for download at https://www.mixzon.com/downloads/

Eggleton, J., Dolphin, T., Ware, S., Bell, T., Aldridge, J., Silva, T., Forster, R., Whomersley, P., Parker, R., Rees, J. 2011. Natural variability of REA regions, their ecological significance & sensitivity. MEPF-MALSF Project 09-P114. Cefas, Lowestoft, 171 p

SZC Ltd, 2020a. The Sizewell C Project, 6.3 Volume 2 Main Development Site Chapter 21 Marine Water Quality and Sediment. PINS Reference Number EN010012 [APP-314]. NNB Generation Company (SZC) Limited.

SZC Ltd, 2020b. The Sizewell C Project, 6.3 Volume 2 Main Development Site Chapter 21 Marine Water Quality and Sediment. Appendix 21F Sizewell C H1 assessment edition 5 – supporting data report. 2020. BEEMS technical report TR193 edition 5. PINS Reference Number EN010012 [<u>APP-315</u>]. NNB Generation Company (SZC) Limited.

SZC Ltd, 2025. Sizewell C Project. Construction Water Discharge Activity Permit Application MDS/CWDA/13.

Environment Agency, 2022. Guidance: Surface water pollution risk assessment for your environmental permit. Updated February 2022. <u>https://www.gov.uk/guidance/surface-water-pollution-risk-assessment-for-your-environmental-permit.</u>

NOT PROTECTIVELY MARKED

Environment Agency, 2023. Guidance: Water Framework Directive assessment: estuarine and coastal waters. Clearing the Waters for All. Updated 9 October 2023. <u>https://www.gov.uk/guidance/water-framework-directive-assessment-estuarine-and-coastal-waters</u>

Appendix A 2014 Groundwater data

Table A.1: 2014 Groundwater data for substances of relevance to the discharge assessment. Note values less than the LoD are shown as the LoD value.

Sample		Arsenic (Dissolved)	Cadmium (Dissolved)	Chromium* (Dissolved)	Copper (Dissolved)	Nickel (Dissolved)	Lead (Dissolved)	Zinc (Dissolved)	Mercury	lron (Dissolved)	Total Ammonia as N
	Units	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
	LoD	1	0.08	1	1	1	1	1	0.01	20	10
G6a	10-Nov-14	1	0.2	1	2.3	2.1	1	14	0.01	200	708
G1	10-Nov-14	1	0.13	1	2.7	1.5	1	46	0.01	130	443
G3	11-Nov-14	1	0.08	1	2.1	1.3	1	12	0.01	30	856
G4	11-Nov-14	1.2	0.08	1	1.9	1.2	1	14	0.01	30	459
G5	11-Nov-14	1	0.08	1	2.2	1.6	1	17	0.01	30	467
C3S	12-Nov-14	2.3	0.08	2.5	1.5	3.7	1	8.6	0.01	50	109
C3D	12-Nov-14	2.9	0.08	6.6	1	6.2	1	2.3	0.01	20	163
GW12	12-Nov-14	12	0.08	35	10	1.5	1	4	0.01	40	10111
G7	13-Nov-14	5.4	0.08	68	3.9	1.4	1	6.9	0.01	150	241
P12	13-Nov-14	5.4	0.08	67	1	1.2	1	4.3	0.01	1500	4978
C1S	17-Nov-14	1	0.08	3.3	1	1	1	1	0.01	20	42
C1D	17-Nov-14	1.5	0.08	1	1	1.5	1	2.6	0.01	1100	86
BP12	17-Nov-14	1	0.08	1.7	1	1	1	3.3	0.01	20	38
C2D	18-Nov-14	7.1	0.08	1	1	3	1	2.3	0.01	130	700
C2S	18-Nov-14	2.5	0.08	1	1	3.1	1	6.6	0.01	610	280
BP23	19-Nov-14	1	0.08	1	1	1	1	7.6	0.01	20	4511
C4S	19-Nov-14	1	0.08	1	1	1.2	1	3.4	0.01	20	5522
C4D	19-Nov-14	12	0.08	1	1	6.6	1	5	0.01	20	7156
BP27	19-Nov-14	1	0.08	1	1	1	1	5.3	0.024	20	7156

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Sample		Arsenic (Dissolved)	Cadmium (Dissolved)	Chromium* (Dissolved)	Copper (Dissolved)	Nickel (Dissolved)	Lead (Dissolved)	Zinc (Dissolved)	Mercury	lron (Dissolved)	Total Ammonia as N
Campio	Units	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
	LoD	1	0.08	1	1	1	1	1	0.01	20	10
GW3	20-Nov-14	1	0.08	2.4	1	1.1	1	9.3	0.01	20	6844
GW2	20-Nov-14	1	0.08	1.3	1	9.3	1	13	0.01	60	10889
GW20	20-Nov-14	1	0.08	1	1.3	1	1	7.9	0.01	20	5056
GW16D	20-Nov-14	1.1	0.08	1.3	1	1	1	6	0.01	20	3578
PZ21	20-Nov-14	1.1	0.08	2.1	1.6	1	1	18	0.01	20	3578
P1	16-Oct-14	1	0.08	1	1	1	1	1	0.01	1500	<mark>614</mark>
P14	16-Oct-14	1	0.08	1	1.5	1.1	1	1	0.01	1100	498
P12	16-Oct-14	1	0.08	1	1	1	1	1	0.01	1700	1167
PZ16	20-Oct-14	57	0.08	45	30	1	1	40	0.01	20	4044
P13	21-Oct-14	1	0.08	1	1	1	1	2.7	0.01	20	17
P10	21-Oct-14	10	0.08	7.8	1.8	1	1	5.8	0.01	2900	117
P8	21-Oct-14	1.4	0.08	1	1	1	1	1	0.01	330	1322
P9	21-Oct-14	1	0.08	1	1	1	1	2.5	0.01	20	179
P15	22-Oct-14	1	0.08	8.5	1	1	1	6.1	0.01	70	428
P3	22-Oct-14	7.9	0.08	6.3	3.3	1	1	10	0.01	5600	2178
GW9S	22-Oct-14	37	0.08	12	4	1	1	4.8	0.01	30	5678
GW9D	22-Oct-14	3	0.08	9.3	3.3	1	1	3.9	0.013	20	5211
DUP 1	22-Oct-14	40	0.08	11	4.2	1	1	5.7	0.01	20	5600
C35	23-Oct-14	1	0.08	1	1	1	1	11	0.01	290	210
C3D	23-Oct-14	3.6	0.08	2.1	1.3	1	1	5.9	0.01	220	288
C4D	23-Oct-14	3.4	0.08	3.7	1.3	3.1	1	5.8	0.01	1100	171
C45	23-Oct-14	1	0.08	1	1	1.6	1	2.8	0.01	1000	474
C2D	23-Oct-14	1	0.08	1	1	1	1	3.5	0.01	3600	599
BP6	22-Jan-15	1	0.08	2.5	1	1	1	4.4	0.01	20	<mark>6</mark> 5

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Sample		Arsenic (Dissolved)	Cadmium (Dissolved)	Chromium* (Dissolved)	Copper (Dissolved)	Nickel (Dissolved)	Lead (Dissolved)	Zinc (Dissolved)	Mercury	lron (Dissolved)	Total Ammonia as N
Campio	Units	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
	LoD	1	0.08	1	1	1	1	1	0.01	20	10
BP7	22-Jan-15	1	0.08	2.3	1	1	1	3.5	0.01	20	54
BP9	22-Jan-15	1.3	0.08	2.8	1	1	1	6.7	0.01	20	60
BP27	21-Jan-15	1	0.08	1.7	1	1	1	3.4	0.01	20	52
BP28	21-Jan-15	1	0.57	2.7	1	18	1	15	0.01	20	163
BP6	23-Apr-15	2	0.08	8.8	1.2	1	1	7.1	0.01	20	249
BP7	23-Apr-15	1.6	0.08	8.6	4.7	1	1	1.9	0.01	20	311
BP9	23-Apr-15	3.4	0.08	7.9	1	1	1	5.2	0.01	20	140
BP27	23-Apr-15	1.2	0.08	6	1	1	1	3.1	0.01	20	109
BP28	23-Apr-15	1.1	0.6	5.3	1	16	1	14	0.01	20	156
C7	23-Apr-15	1.1	0.08	6.8	1	1	1	4	0.01	20	124
G3	09-Jun-15	1.5	0.08	2	1	1.1	1	7.8	0.01	440	218
G4	09-Jun-15	1.3	0.08	2.6	2.2	2.1	1	15	0.01	430	482
G5	09-Jun-15	1.3	0.087	3.1	3.1	5.1	1	18	0.01	430	272
G8	09-Jun-15	2.1	0.08	4.1	2.9	1.5	1	12	0.01	440	163
SW1	09-Jun-15	1.4	0.08	4.1	2.7	1.7	1	16	0.01	460	156
SW4	09-Jun-15	1.3	0.08	3.2	1	1	1	5.3	0.01	420	101
P9	10-Jun-15	1	0.08	6.8	1	1	1	6.6	0.01	480	622
P12	10-Jun-15	1	0.08	5.9	1	1	1	5.3	0.01	250	<mark>856</mark>
P13	10-Jun-15	7.3	0.08	3.9	1	5.8	1	2.2	0.01	18000	334
C3D	10-Jun-15	3.4	0.08	5.1	1	1	1	4	0.01	900	381
C3S	10-Jun-15	1.3	0.11	12	2.2	6.8	1	14	0.01	100	412
G1	10-Jun-15	1.9	0.08	14	1.9	1.6	1	8.9	0.01	520	350
SW2	10-Jun-15	1.8	0.088	10	2.2	1.3	1	14	0.01	530	264
P8	11-Jun-15	1.6	0.08	4.8	1	1	1	1	0.01	590	1944

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Sample		Arsenic (Dissolved)	Cadmium (Dissolved)	Chromium* (Dissolved)	Copper (Dissolved)	Nickel (Dissolved)	Lead (Dissolved)	Zinc (Dissolved)	Mercury	lron (Dissolved)	Total Ammonia as N
Campio	Units	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
	LoD	1	0.08	1	1	1	1	1	0.01	20	10
BP23	11-Jun-15	1	0.08	1.3	1	1	1	1	0.01	170	428
BP27	11-Jun-15	1	0.08	1.9	1	1	1	1.2	0.01	380	303
BP28	11-Jun-15	1	0.49	1.2	1	17	1	9.8	0.01	170	428
C7	11-Jun-15	1	0.08	2.5	1	1.4	1	2.7	0.01	400	576
PZ18	16-Jun-15	21	0.08	34	5.5	9.3	1	27	0.01	20	76
C2D	16-Jun-15	2.8	0.08	7.9	1	1.4	1	4.5	0.01	20	26
C2S	16-Jun-15	1.5	0.08	4.4	1	2.1	1	5.9	0.01	40	78
GW9D	16-Jun-15	11	0.08	14	5.4	3.7	1	3.3	0.01	20	5056
GW9S	16-Jun-15	17	0.08	9.1	2.9	1.2	1	2.4	0.01	40	3733
C4S	17-Jun-15	1	0.08	1.4	1	2.1	1	4.1	0.01	20	30
C4D	17-Jun-15	67	0.08	64	14	30	1	10	0.01	20	93
BP12	17-Jun-15	2.5	0.08	17	1	1.4	1	4.3	0.01	20	19
P10	17-Jun-15	11	0.08	31	2.3	1.7	1	4.8	0.01	20	86
G6A	17-Jun-15	2.9	0.08	16	2.1	1.7	1	13	0.01	20	78
G7A	17-Jun-15	3.5	0.08	13	1	1	1	8.5	0.01	20	280
SW3	17-Jun-15	2.2	0.08	10	1.9	1.8	1	14	0.01	20	61
SW8	17-Jun-15	3.4	0.08	11	1	1	1	4	0.01	20	272
P15	18-Jun-15	1.5	0.08	15	1	1	1	6.1	0.01	20	20
P3	18-Jun-15	2	0.08	8.1	1	2.7	1	6.4	0.01	20	43
C1S	18-Jun-15	3.4	0.08	7.1	1	2.8	1	5.2	0.016	60	778
C1D	18-Jun-15	1.1	0.08	7.7	1	3.1	1	3.7	0.01	20	249
C1D	14-Jul-15	1	0.08	2.1	1	1	1	2.1	0.01	1 1 0	72
C1S	14-Jul-15	1	0.08	3.4	1	1	1	1	0.01	20	93
BP6	14-Jul-15	1	0.08	3.5	1	1	1	1.9	0.01	20	109

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SIZEWELL C CONSTRUCTION WATER DISCHARGE ASSESSMENT: GROUNDWATER

NOT PROTECTIVELY MARKED

Sample		Arsenic (Dissolved)	Cadmium (Dissolved)	Chromium* (Dissolved)	Copper (Dissolved)	Nickel (Dissolved)	Lead (Dissolved)	Zinc (Dissolved)	Mercury	lron (Dissolved)	Total Ammonia as N
Campie	Units	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
	LoD	1	0.08	1	1	1	1	1	0.01	20	10
BP7	14-Jul-15	1	0.08	2.7	1	1	1	2.2	0.01	20	117
BP9	14-Jul-15	1	0.08	2.9	1	1	1	2.5	0.01	20	101
G3	15-Jul-15	1.7	0.08	4.3	1	1.1	1	6.1	0.01	20	436
SW1	15-Jul-15	2	0.08	3.5	1.6	2.4	1	6.1	0.01	20	<mark>6</mark> 61
SW4	15-Jul-15	1.5	0.08	3.3	1	1	1	4.2	0.01	20	443
G4	15-Jul-15	1.6	0.08	4.5	1.7	3.9	1	8.9	0.01	20	280
G8	15-Jul-15	3.4	0.08	10	2.3	4	1	13	0.01	20	194
P14	15-Jul-15	2.4	0.08	11	1.1	6	1	9.3	0.01	60	148
GW2	21-Jul-15	1	0.08	2.3	1	8.2	1	7.5	0.01	20	124
GW3	21-Jul-15	1	0.08	2.8	1	1.1	1	6.7	0.01	20	78
C3S	21-Jul-15	1	0.08	3.8	1	4.6	1	7.6	0.037	20	171
C3D	21-Jul-15	4.6	0.08	19	1.2	1.6	1	5.3	0.044	20	187
P13	21-Jul-15	3.4	0.09	18	3.3	10	7.1	33	0.01	1700	381
Duplicate	22-Jul-15	1	0.08	5.8	1	1	1	11	0.014	20	233
G6A	22-Jul-15	1.5	0.08	8.6	1.9	1	1	8.8	0.19	20	443
SW8	22-Jul-15	3.9	0.16	5.6	1.6	1	1	5.3	0.019	20	342
SW10	22-Jul-15	2.3	0.08	6.8	1.2	1	1	6	0.011	20	74
C2D	22-Jul-15	4.7	0.08	2.7	1	1	1	2.9	0.017	20	264
C2S	22-Jul-15	1	0.08	1.8	1.6	1	1.4	25	0.013	20	194
GW20	22-Jul-15	1	0.08	8.1	1.1	1	1	6.1	0.022	20	117
PZ_21	23-Jul-15	1.2	0.08	3.7	1.5	1	1	12	0.01	20	<mark>6</mark> 1
GW16D	23-Jul-15	1	0.08	1.4	1	1	1	8.8	0.01	20	117
GW12	23-Jul-15	3	0.08	2.7	1	1	1	9.3	0.01	4200	2878
G7a	23-Jul-15	3.2	0.08	3.7	1	1	1	5.3	0.01	80	646

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SIZEWELL C CONSTRUCTION WATER DISCHARGE ASSESSMENT: GROUNDWATER

NOT PROTECTIVELY MARKED

Sample		Arsenic (Dissolved)	Cadmium (Dissolved)	Chromium* (Dissolved)	Copper (Dissolved)	Nickel (Dissolved)	Lead (Dissolved)	Zinc (Dissolved)	Mercury	lron (Dissolved)	Total Ammonia as N
Campie	Units	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
	LoD	1	0.08	1	1	1	1	1	0.01	20	10
SW2	23-Jul-15	1.1	0.08	2.3	1.6	1	1	9.9	0.01	20	233
CPB11	17-Sep-15	1	0.08	1	1	1.5	1	2.5	0.01	50	<mark>6</mark> 1
CPB13	17-Sep-15	2	0.08	1	1	1.2	1	5.3	0.011	20	163
CPB14	17-Sep-15	1	0.08	1	1	1	1	3.3	0.011	20	716
SD7	17-Sep-15	3.1	0.08	1	1	1	1	6.9	0.011	20	202
SD3	14-Oct-2015	2.4	0.15	8.2	4.3	9.7	4.8	53	0.01	1100	311
SD6	14-Oct-2015	2.1	0.08	2.1	1	1.6	1	4.7	0.01	360	1011
SD8	14-Oct-2015	1	0.08	2.6	4.0	2.6	1	11	0.01	20	54
BP6	13-Oct-2015	1	0.08	9.0	1	1	1	4.5	0.01	20	8
BP7	14-Oct-2015	1	0.08	2.4	1	1	1	9.4	0.01	20	8
BP9	13-Oct-2015	1.3	0.08	2.4	1.0	1	1	6.3	0.01	20	8
BP27	13-Oct-2015	1	0.14	8.9	1.2	2.6	1	2.7	0.01	20	9
BP28	13-Oct-2015	1	0.58	7.8	2.0	16	1	9.4	0.01	20	8
C7	13-Oct-2015	1	0.08	2.8	3.7	1	1	12	0.01	20	19
BP9	20-Jan-2016	1.2	0.08	2.7	1	1	1	3.4	0.010	20	117
C7	20-Jan-2016	1	0.08	3.3	1	1.1	1	4.9	0.01	20	77
BP27	20-Jan-2016	1	0.08	2.4	1	1	1	3.4	0.010	20	58
BP28	20-Jan-2016	1	0.56	2.0	1.1	15	1	9.6	0.010	20	52
BP6	21-Jan-2016	1	0.08	3.8	1	1	1	4.3	0.010	20	72
BP7	21-Jan-2016	1	0.08	4.7	1	1	1	2.7	0.010	20	86
BP27	20-Apr-2016	1	0.08	1	1	1	1	1	0.01	20	156
BP28	20-Apr-2016	1	0.32	1	1	8.4	1	3.6	0.01	20	171
C7	20-Apr-2016	1	0.08	1	1	1.1	1	10	0.01	20	218
BP6	20-Apr-2016	1	0.08	1	1	1	1	6.0	0.01	20	218

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SIZEWELL C CONSTRUCTION WATER DISCHARGE ASSESSMENT: GROUNDWATER

NOT PROTECTIVELY MARKED

Sample		Arsenic (Dissolved)	Cadmium (Dissolved)	Chromium* (Dissolved)	Copper (Dissolved)	Nickel (Dissolved)	Lead (Dissolved)	Zinc (Dissolved)	Mercury	lron (Dissolved)	Total Ammonia as N
	Units	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
	LoD	1	0.08	1	1	1	1	1	0.01	20	10
BP7	20-Apr-2016	1	0.08	1	1	1	1	3.2	0.01	20	202
BP9	20-Apr-2016	1	0.08	1.0	1	1	1	1	0.01	20	5600
BP7	13-Jul-2016	1	0.08	1	1	1	1	1	0.024	290	93
BP9	13-Jul-2016	1	0.08	1	1	1	1	1	0.015	230	93
C7	13-Jul-2016	1	0.08	1	1	1	1	1	0.063	240	117
BP6	13-Jul-2016	1	0.08	1	1	1	1	1	0.01	290	148
BP27	13-Jul-2016	1	0.08	1	1	1	1	1	0.046	310	86
BP28	13-Jul-2016	1	0.47	1	1	12	1	2.3	0.019	96	93
	95th Percentile	11.7	0.19	18.7	4.1	9.9	1.0	17.7	0.021	1500	5577
	Mean	3.6	0.10	6.6	1.8	2.7	1.1	7.4	0.013	405	972

* Cr includes both Cr(III) and Cr(VI).

Appendix B 2020 Groundwater data

Table A.2: 2020 Groundwater data for substances of relevance to the discharge assessment. Note values less than the LoD are shown as the LoD value, several samples did not achieve the target LoD. Where reported values are below detection they are highlighted pink.

	Substance	Arsenic	Cadmium	Copper	Chromium	Iron	Lead	Mercury	Nickel	Zinc	Total
		(total)	(total)	(total)	(total)*	(total)	(total)	(dissolved)	(total)	(total)	ammonia as N
	Units	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Sample	LoD	1	0.2	1	1	10	1	0.05	1	1	20
20-01431-1	12/02/2020	11	0.2	3	1	9120	1	0.05	2	17	700
20-01431-2	12/02/2020										
20-02741-1	18/03/2020	1	0.2	38	1	15700	15	0.05	1	98	1120
20-02809-1	18/03/2020	10	2	23	10	16200	10	0.5	10	53	1840
20-02809-2	18/03/2020	10	2	23	10	15900	10	0.5	10	56	1840
20-02809-3	18/03/2020	10	2	10	10	16300	10	0.5	10	33	1110
20-02809-4	18/03/2020	10	2	10	10	16900	10	0.5	10	34	1990
20-02741-2	18/03/2020										
20-02741-3	18/03/2020	1	0.2	1	1	15600	1	0.05	1	11	1910
20-02810-1	19/03/2020	10	2	10	10	15900	10	0.25	10	13	1040
20-02899-1	19/03/2020	10	2	10	10	16400	10	0.5	10	10	1740
20-02899-2	20/03/2020	10	2	10	10	16600	10	0.5	10	10	1760
20-02904-1	20/03/2020	10	2	10	10	17000	10	0.5	10	10	1710
20-02904-2	21/03/2020	10	2	10	10	17100	10	0.5	10	55	1760
20-02904-3	21/03/2020	10	2	10	10	17600	10	0.5	10	10	1750
20-02909-1	22/03/2020	10	2	10	10	17300	10	0.5	10	10	1790
20-02909-2	22/03/2020	10	2	10	10	17400	10	0.5	10	10	1780
20-02909-3	23/03/2020	10	2	10	10	17800	10	0.5	10	10	1820
20-02971-1	23/03/2020	10	2	10	10	17200	10	0.05	10	10	1180
20-02971-2	24/03/2020	10	2	10	10	17500	10	0.05	10	10	1930
20-02973-1	24/03/2020	10	2	10	10	17000	10	0.05	10	10	1950
20-02973-2	25/03/2020	10	2	10	10	17500	10	0.05	10	10	1190
20-03029-1	25/03/2020	10	2	10	10	17800	10	0.5	10	10	1330
20-02975-1	25/03/2020										
20-02973-3	25/03/2020	10	2	10	10	17700	10	0.05	10	14	1160
20-03029-2	26/03/2020	10	2	10	10	17500	10	0.5	10	10	1180
20-03084-1	26/03/2020	10	2	10	10	18300	10	0.5	10	10	1380
20-03084-2	27/03/2020	10	2	10	10	19200	10	0.5	10	10	1180
20-03084-3	27/03/2020	10	2	10	10	18800	10	0.5	10	10	1190

SIZEWELL C CONSTRUCTION WATER DISCHARGE ASSESSMENT: GROUNDWATER

NOT PROTECTIVELY MARKED

	Substance	Arsenic	Cadmium	Copper	Chromium	Iron	Lead	Mercury	Nickel	Zinc	Total
		(total)	(total)	(total)	(total)*	(total)	(total)	(dissolved)	(total)	(total)	ammonia as N
	Units	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Sample	LoD	1	0.2	1	1	10	1	0.05	1	1	20
20-03084-4	28/03/2020	10	2	10	10	19700	10	0.5	10	10	1150
20-03084-5	28/03/2020	10	2	10	10	17200	10	0.5	10	10	1140
20-03084-6	29/03/2020	10	2	10	10	18500	10	0.5	10	10	1150
20-03084-7	30/03/2020	10	2	10	10	17600	10	0.5	10	10	1180
20-03135-1	30/03/2020	10	2	10	10	14300	10	0.5	10	10	1550
20-03135-2	31/03/2020	10	2	10	10	15500	10	0.5	10	10	1260
20-03135-3	31/03/2020	10	2	10	10	14300	10	0.5	10	10	1260
	95th Percentile	10	2	23	10	18960	10	0.5	10	55	1938
	Mean	9	2	11	9	16801	10	0.4	9	19	1455

* Cr includes both Cr(III) and Cr(VI).

Appendix C Cormix model outputs



Figure 10. CORMIX output at rising mid tide, showing the plume of 250 L/s discharge.



Figure 11. CORMIX output at high tide, showing the plume of 250 L/s discharge.











Figure 14. Dilution curve for a 250 L/s discharge at the CDO; rising tide.







Figure 16. Dilution curve for a 250 L/s discharge at the CDO; falling tide.



Figure 17. Dilution curve for a 250 L/s discharge at the CDO; low tide.