HPC COMPANY DOCUMENT

COMPANY DOCUMENT
ENVIRONMENTAL PERMIT VARIATION APPLICATION: HINKLEY POINT C CONSTRUCTION SEWAGE TREATMENT PLANT

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APPROVAL: ENVIRONMENTAL PERMIT VARIATION APPLICATION: HINKLEY POINT C CONSTRUCTION SEWAGE TREATMENT PLANT

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01	P1 – For Implementation	First Issue	Richard Mitchener / Jessica Harris	28/06/2023

Non-Technical Summary

NNB Generation Company (HPC) Limited, is building a new nuclear power station on the northern coast of Somerset. To support the workforce required to deliver the power station, a construction-phase sewage treatment plant (CSTP) has been installed and commissioned at the site. The CSTP provides primary and secondary treatment of domestic-type sewage from the welfare facilities as well as ultraviolet disinfection of the effluent. The treated effluent is discharged from site via a discharge point towards the end of the site's jetty which minimises any potential impacts on the foreshore. The discharge is regulated under an Environmental Permit issued by the Environment Agency (EPR/XP3321GD).

The number of workers required on site is now predicted to be higher than the number for which the plant was designed. It is also possible that an extension to the workers' accommodation campus may be required, with the provision of an additional 500 beds being considered. This means that the CSTP as currently installed would not be able to manage the amount of ammonia that would be produced.

In addition, it is apparent that sewage effluent produced by Hinkley Point C is different from the best-available predictions that were used for the design; the volume produced is lower than anticipated, but ammonia concentrations are higher than anticipated and this leads to challenges for the CSTP. The nature of the working patterns on a large construction site also leads to challenges. Workforce numbers on site vary over a 24-hour period and through the week. This means that the flows and concentrations into the CSTP vary significantly; as the CSTP is primarily a biological degradation process this variability impacts the CSTP's efficiency. Due to the large variation in inputs at the site it is not feasible to design a plan that will work well under all conditions. A number of modifications have been made to improves the CSTP's performance. These are detailed in this report.

In order to address these challenges, NNB Generation Company (HPC) Limited is proposing to increase the concentration of ammonia that can be discharged from the site to 80mg/l. Detailed modelling has been undertaken which demonstrates that this concentration will not have an adverse impact on the environment.

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1 INTRODUCTION

NNB Generation Company (HPC) Limited (NNB HPC) is developing the first of new generation of nuclear power station on the north Somerset coast, approximately 13km northwest of Bridgwater. To support the construction works, welfare facilities are provided on site and a construction-phase sewage treatment plant (CSTP) has been constructed to deal with the foul waste from these facilities. This plant treats the sewage to specified criteria before the final effluent is discharge into the Bristol Channel from the site's jetty.

1.1 Purpose

The variation application, for which this report provides supporting information, seeks to amend the permitted levels of ammoniacal nitrogen that may be discharged from the Hinkley Point C (HPC) Construction Sewage Treatment Plan (CSTP).

1.2 Scope

The permit (EPR/XP3321GD/004) which NNB HPC is seeking to vary covers the discharge of domestic-type sewage after secondary treatment and ultraviolet disinfection. Other aqueous effluents arising from the construction activities at HPC are treated and discharged under the Construction Water Discharge Activity (CWDA) permit (EPR/JP3122GM/V009&010).

This application only relates to the construction phase; a separate Operational Water Discharge Activity (OWDA) permit (EPR/HP3228XT) will govern discharges from the power station once it is operational. This permit includes treated sewage effluent from the workers that will operate the plant.

1.3 Summary description of the proposed variation

NNB HPC is requesting an increase in the ammoniacal nitrogen limit to support the continued development of the project in an environmentally sustainable way. The current limit is 20 mg/l and it is requested that this be increased to 80mg/l. As detailed in Sections 2.1.1 and 2.2 of the report, this is necessary because of need for an increased workforce above that for which the CSTP was designed, the unusual working patterns at HPC and the dynamic nature of the site which precluded a fully piped sewerage network.

1.4 Contents of this report

The report includes the following sections:

- Section 2 summarises the Water Discharge Activity as currently permitted including a description of the plant and the measures that NNB HPC has taken to address the challenges at HPC;
- Section 3 sets out the proposed variation including the assessment of the potential environmental effects and further improvement measures that may be implemented.
- Section 3 summarises the conclusions.

The application forms are included in Appendix A, and the technical reports are included in Appendices B and C. Modelling files will be provided to the Environment Agency under sperate cover.

1.5 Definitions

Abbreviation	Definition
HPC	Hinkley Point C
NNB HPC	NNB Generation Company (HPC) Limited
CWDA	Construction Water Discharge Activity (Permit)
CSTP	Construction Sewage Treatment Plant
HAJ	Construction Sewage Treatment Plant
PST	Primary Settlement Tank
FST	Final Settlement Tank
RBC	Rotating Biological Contactor
MCERTS	Monitoring Certification Scheme
BOD	Biological Oxygen Demand
TSS	Total Suspended Solids
OSM	Operator Self-monitoring
MBBR	Moving Bed Bioreactor
DIN	Dissolved Inorganic Nitrogen (the sum of total ammonia, nitrate and nitrite expressed as mass of nitrogen).

2 CURRENT WATER DISCHARGE ACTIVITY

2.1 Description of designed plant

HPC is a large construction site with a variety of office-based and site-based personnel on site each day. Office and welfare space, including showers, is provided for these workers in four large buildings. Canteen facilities are provided for those staff within these buildings; food preparation is split between on-site cooking and a central production kitchen. In addition, a 510-bedroom accommodation campus is provided adjacent to the site with the sewage produced therein being pumped onto the main construction site.

The plant was designed to address the expected effluent volumes and quality from the then-predicted workforce and resident numbers using the industry-standard approach (British Water, 2013).

On the basis of the predicted flow rates and loading of key contaminants a multi-phase treatment approach was designed and installed. This was described in detail on the original application report (NNB HPC, 2018), but in summary comprises:

- An inlet pumping station that receives flows from the gravity and pumped networks as well as providing a reception point for sewage delivered by tankers. This pumping station provides flow balancing to smooth out the operational parameters.
- A primary screen to remove "rag" and other course materials; this comprised a screen and screw conveyor to move the debris to a skip from where it is taken to an appropriately permitted facility for disposal;
- A flow splitting step to distribute incoming flows between the three treatment trains;
- Primary settlement tanks (PSTs) to allow settlement of sludge including sludge pumped from the final settlement step. Sludges are removed from site by tanker to a permitted sludge reception centre.
- Rotating Biological Contactors (RBCs) where biological films are developed on rotating media; the bacteria within these films treat the liquid portion of the sewage by oxidising the ammonia to nitrate or nitrite (the nitrification process). Each treatment train contains two RBCs operating in parallel so there are six in total in the plant.
- Final settlement tanks (FSTs) take the effluent from the RBCs and settle out the remaining solids including the bacterial filmed that are sloughed off the rotating discs as part of the natural process. There is one FST per RBC and therefore there are six FSTs on site. The settled water flows over a weir and the settled sludges are pumped into the primary settlement tanks.

- Tertiary treatment by ultraviolet light to provide disinfection; three ultraviolet units, one per treatment train, were provided.
- Recirculation options for each treatment stream to allow maintenance, support the UV lamps which require cooling and to allow diversions back to the inlet tank in emergencies; and
- A final effluent pumping station to pump the combined flow to the header tank before discharge into the Bristol Channel via pipes along he HPC jetty. MCERTS flow monitoring is provided at the Final Effluent Pumping Station and a sampling tap is provided at the header tank at the landward end of the jetty.

2.1.1 Compliance challenges

Commissioning of the sewage treatment plant was undertaken over an extended period until compliant samples for the three numerical compliance values (ammoniacal nitrogen, total suspended solids (TSS) and biological oxygen demand (BOD) were received for 28 consecutive days. After achieving this condition discharge of treated effluent commenced on 16th February 2022. Although the frequency of accredited laboratory analysis was reduced to that needed under the permit at that point, site-based unaccredited analyses of ammoniacal nitrogen and "clarity" (an analogue for TSS) continues to be monitored daily. These data, together with the externally analysed Operator Self-Monitoring (OSM) samples have indicated that the plant continues to be challenged in dealing with the site's effluent of the reasons set out hereunder.

The site is operational for 24 hours per day, albeit numbers for staff overnight are much reduced from the daytime peaks. Similarly, the site is operational 7 days per week with numbers varying at the time of writing from c. 10,000 in a 24-hour period in the middle of the week to c. 2,000 on a "non-working" weekend. This "shock loading" is challenging for a biological plant to address, leading to elevated levels of ammoniacal nitrogen in the later part of the week. This challenge is exacerbated in winter when lower ambient temperatures further impinge on the efficiency of the biological treatment.

The plant was designed based on "best estimate" application of the code of practice (British Water, 2013). However, it has become apparent that these values overstated the volume produced but underestimated the concentration of ammoniacal nitrogen. Therefore, although the flow rates into the plant remain well below the design volume for the loading such that only two of the three treatment trains have been brought into full use, the ammoniacal nitrogen loading is sometimes above that that can be managed by these two modules. The BOD (a measure of the amount of organic material present) is consistent with the original calculations and the imbalance also affects the plant's efficacy. In addition, testing has indicated that the alkalinity of the influent is lower than would be expected and it is known (USEPA, 1973) that elevated acidity can significantly affect the efficiency of ammonia removal. It is likely that the lower-than-expected flow rates are, to some extent contributing to the elevated ammonia as sewage residence time within the site's network will be longer than originally anticipated allowing biological processes to develop.

A further challenge arises due to the dynamic nature of site and then need to provide welfare facilities close to the working areas. It is not practicable to plumb many of these facilities into the sewerage network and therefore for raw sewage is stored for an extended period beyond the eight-hours usually taken as the point at which septicity may develop. Septicity leads to significantly elevated ammonia levels (averaging 200mg/l) which is above what would usually be expected. This effluent is currently collected by tanker and removed from site as it is beyond the plant's current treatment capability.

2.1.2 Plant Amendments to support Compliance

During and after the commissioning of the plant a number of improvements were made to support compliance in the novel circumstances at HPC. These included:

- Installing cloth filters (known as meccana filters) which operates in duty/standby arrangement to reduce suspended solids and adsorbed ammonia;
- The provision of a single UV plant to treat the total volume which enabled duty/standby to be provided and allowed for enhanced control to ensure that the required dose is provided;
- Provision of enhanced sludge settlement via addition tanks which enhanced the efficacy of the PSTs and reduced the residence time (age) of the sludge therein;
- Utilisation of spare RBC units to provide tertiary treatment to reduce ammoniacal nitrogen levels;
- Optimisation of pumping station controls to reduce sludge aging within the network despite the lower than anticipated flow rates;
- Amendments to the sludge removal system from the FSTs to improve sludge removal and limit sludge age;
- Installation of automatic monitoring of ammoniacal nitrogen and total suspended solids to enable any compliance challenges to be identified in real time and investigations undertaken in a timely way; and
- Utilisation of a bio-stimulant to support bacterial health during the winter period.

These modifications allowed the plant to meet the commissioning criteria such that discharge could be commenced and remained compliant for several months. However, when pumping of sewage from the east office commenced in June 2022 compliance became challenging with a number of breaches recorded. These were managed by changing plant operation and the plant came back into compliance rapidly. Further compliance challenges were realised during the winter months due to cold weather and especially after the Christmas period when the very reduced site numbers impact the biofilm's health.

2.2 Further Site Development

Further increases in site workforce are being considered to support the completion of HPC and the generation of low carbon electricity as soon as possible. It is likely that the site's daily workforce peak will reach c.12,000. It is also possible that it may be necessary to expand the on-site workers' accommodation campus (Hinkley Campus) by up to 500 bed-spaces to support this effort. This will increase the load of ammoniacal nitrogen that the CSTP is required to treat significantly beyond the design loading. It is also likely that the diurnal, weekly and seasonal variations experienced by the plant will remain or increase, adding additional compliance challenges.

Consideration has been given to upgrading the CSTP to deal with the additional loading to deliver compliance with the existing permit. However, given the unusual challenges inherent in the treatment of sewage from a construction site it is unlikely that the existing limits could be met consistently.

2.2.1 Proposed Plant upgrades

It is intended to upgrade the CSTP to allow injection of magnesium hydroxide into effluent after the PST stage; this will increase the alkalinity within the system (that is the ability to buffer the acidity produced by the nitrification process. It is anticipated that this will allow the nitrification reaction to proceed at a higher rate; this will be confirmed by a trail on one of the treatment trains before wider deployment. Magnesium has been chosen as it is less corrosive than sodium hydroxide (the as-delivered pH will be 10) which reduces the health, safety and environmental challenges. Dosing rates will be set based on laboratory scale tests and a pH meter will also be used to monitor pH of effluent, stopping dosing if it rises above 9. During the trial, dosing will only be undertaken on weekdays, as the treatment of the lower inputs at the weekend is less likely to be constrained by the availability alkalinity. NNB HPC may automate this process in due course. The product used will consist of magnesium hydroxide and water only with no other chemicals. Therefore, so long as the pH is controlled as described there is no risk to the environment given that magnesium ions are ubiquitous in the sea and not hazardous.

NNB HPC is also considering providing additional treatment via the use of Moving Bed Biofilm Reactors (MBBRs), subject to successful trails. An MBBR may be used to provide a polishing step (as currently undertaken by Module 3) when site volumes are such that all three modules are needed for their original purpose. One or more MBBRs may also be used to provide some pre-treatment of the higher strength influent arising from the "deep-dig" welfare facilities.

All changes will be subject to control under the site's design change procedures and reflected in the Operation and Maintenance Manual for the plant.

3 PROPOSED VARIATION

In order to support the project and the delivery of Net Zero, it is proposed to vary the permit to allow an increased concentration of ammoniacal nitrogen in the treated effluent to 80mg/l while still ensuring a high level of environmental protection. This will also facilitate the on-site treatment of the higher-strength wastes from the "deep-dig welfare facilities removing the need for this waste to be tankered from site. This will result in a reduction in lorry movements with the concomitant reduction in carbon dioxide emissions.

3.1 Predicted flow rates

The likely flow rates from the increased population have been estimated following an analysis of the existing data. Due to the presence of the campus and the daily workforce analysis is complex however, a range of data has been used to enable realistic estimates to be derived.

Water usage at the campus is metered, and the daily occupancy is also recorded. This provides an estimate of what are use and as soon as production at the site. This data has been analysed over a period of approximately 13 weeks on the estimated flow rate per person is 110 L per head per day. This includes a margin to allow for beverages consumed on site and other external influences.

The volume produced by the workforce on site can then be estimated as the number of people on site each day is known, as is the volume of sewage produced. The volume removed from site by tanker was also included in the calculations. This calculation indicates that a reasonable estimate of the sewage produced by each worker is 50 litres per head per day.

Using these data, it was concluded that there is no requirement for an increase in flow rate to allow for the additional personnel on site required to complete the project.

3.2 Predicted composition

Biological oxygen demand and total suspended solids produced to date have remained consistently with the estimates provided within flows and loads (British Water, 2013). Therefore, it is anticipated that the loading from the increased population will remain within the parameters that the plant was designed to deal with given the lower flow rates per person observed. It is not anticipated that there were any compliance challenges related to these parameters. However, ammoniacal nitrogen levels are higher than predicted, therefore, design criteria of plant will be exceeded for this parameter. In order to allow the continued development of HPC it is proposed that limit for ammoniacal nitrogen in the treated effluent is increased to 80mg/l.

3.3 Environmental Assessment

CEFAS (2023) was engaged to assess the potential impact of a range of scenarios and the report is included in Appendix A. This was undertaken to support NNB HPC's assessment of options and was undertaken before the analysis of flow rated from the campus and workforce was completed. Following the flow rate analysis, it is apparent that no increase in the permitted flow rate is needed and therefore only the existing flow rate scenario needs to be considered.

New modelling of the mixing of the effluent with the saline waters of the Bristol Channel was not required. Previous work (CEFAS, 2019 – see Appendix B) has assessed the dispersion of, *inter alia,* sewage-derived ammoniacal nitrogen into the estuary to support the CSTP permit application and the most recent variation to the CWDA Permit. This modelling therefore included:

- Groundwater containing up to 9.5mg/l of ammoniacal nitrogen with a flow rate of up to 20l/s;
- Tunnel effluent containing up to 9.5mg/l or ammoniacal nitrogen with a flow rate of up to 30l/s;
- Cold commissioning effluent with up to 271mg/l of ammoniacal nitrogen and a flow rate of up to 70l/s for up to 5.95 hours per day; and
- Treated sewage effluent containing up to 20mg/l of ammoniacal nitrogen and a flow rate of up to 20l/s.

It should be noted that the modelling did not consider tunnel effluent and cold commissioning together as it is expected that tunnel works will be completed in advance of significant commissioning starting.

CEFAS (2023) utilised the existing modelling to consider the extent of any plume that would arise as a result of the higher concentrations of ammoniacal nitrogen within the treated sewage effluent discharge. A simple mathematical approach was considered appropriate with a scaling factor applied to the previously reported results to consider the effects of the increased flow rate. The assessment concluded that:

- The extent of the plume where concentrations are above the Environmental Quality Standard (DEFRA, 2015), remains small in the context of the receiving water; and
- The plume is not predicated to interact with the specific interest features, *Sabillaria spp*. reefs (*S. spinulosa* and *S. alveolata* and *Corallina spp.* that are recorded in the vicinity of the site.

Furthermore, although the effects of dissolved inorganic nitrogen (DIN) associated with sewage discharges have not been explicitly assessed, CEFAS (2019) has considered the effects of DIN released from site overall.

Modelling described therein, using the CPM Model (Aldridge et al, 2008) indicates that due to the high turbidity of the receiving water nitrogen is not the limiting factor for phytoplankton growth within the estuary with light levels actually being the control. Therefore, the slight local increase in DIN levels that may arise from the increased limit will not adversely affect the receiving water's ecological health.

Data regarding ammoniacal nitrogen and DIB concentration in the effluent streams discharged via Outlet 12 is presented in appendix D.

4 CONCLUSIONS

Previously undertaken complex hydrodynamic and hydro-chemical modelling has been utilised to assess the potential effects on the Bristol Channel of increasing the permitted concentration of ammoniacal nitrogen in the treated sewage effluent discharged from the HPC Construction site. These assessments have concluded that:

- The additional extent of any plume if very small with concentrations reducing to EQS within 46.04 metres of the discharge point compared to less than 7.16m under the already permitted limit;
- The area of the SAC with levels above the EQS is less than 0.002%; and
- The key species and habitats of interest are not exposed to concentrations above the EQS and therefore further assessment of any potential effects is not needed.

It is therefore concluded that the proposed variation will not have any likely significant effects on the protected site. Similarly, it is concluded that, due to the very localised effects, there will be no impact of Water Framework Directive status of either the Bridgwater Bay or River Parrett waterbodies.

It is therefore requested that the permit is varied such that:

- the limit for ammoniacal nitrogen set out in Schedule 3, Table S3.1 of the permit is increased to 80mg/l; and
- the description of the activity in Schedule1 1, Table S1.1. is modified to read “Discharge treated sewage effluent after secondary treatment (including addition of approved chemicals) and subject to disinfection by ultraviolet irradiation via outlet 12”.

5 REFERENCES

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CEFAS (Centre for Ecology, Fisheries and Aquaculture Science), 2023. Assessment of ammonia discharges associated with treated sewage and commissioning at HPC. BEEMS Technical Report TR581, Revision 2.

CEFAS (Centre for Ecology, Fisheries and Aquaculture Science), 2021. Hinkley Point C construction discharge modelling assessment at the temporary jetty location. CEEMS Technical Report TR428. Revision 14

DEFRA, 2015. Water Framework Directive (Standards and Classification) Direction (England and Wales) 2015.

NNB Generation Company (HPC) Limited. 2018. Application for an Environmental Permit for The Hinkley Point C Construction Sewage Treatment Plant (CSTP). Version 2.0. Report Reference: NNB-209-REP-001003

US Environmental Protection Agency, 1973. Revised Nitrification and Denitrification Facilities: Wastewater Treatment. Report Reference: EPA/A-73-004a

APPENDIX A ASSESSMENT OF AMMONIA DISCHARGES ASSOCIATED WITH TREATED SEWAGE AND COMMISSIONING AT HPC (TR581)

CEFAS REPORT TR581 ASSESSMENT OF AMMONIA DISCHARGES ASSOCIATED WITH TREATED SEWAGE AND COMMISSIONING OF HPC

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02	19/04/2023	A. Griffith	Principle Scientist	D. Haverson	BEEMS Modelling Lead	H. Buckley	Nuclear Programme Site Lead (Hinkley Point)
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BEEMS Technical Report TR581

Assessment of Ammonia Discharges Associated with Treated Sewage and Commissioning of HPC

Dr David Haverson, Andrew Griffith

Version and Quality Control

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Executive summary

The Hinkley Point C (HPC) Development Consent Order (DCO) was granted by the UK Secretary of State for Energy and Climate Change in March 2013. HPC environmental permit for the Construction Sewage Treatment System (Environment Agency's Permit number EPR/XP3321GD/V004) permits NNB GenCo to discharge a maximum of 20 mg/l of ammoniacal nitrogen from the sewage treatment system. The cold commissioning discharge permit (EPR/JP3122GM/V009&010) also allows for additional discharges of ammonia associated with the commissioning phase, tunnelling, and groundwater. Notably these two discharges will overlap during commissioning and therefore need to be considered together for assessment purposes. To support the delivery of HPC, NNB GenCo is considering varying the Construction Sewage Treatment System environmental permit (EPR/XP3321GD/V004) to allow an increased concentration of ammoniacal nitrogen within the permitted discharge. The aim of this assessment is to provide the evidence to support the decision to vary the discharge.

Presently, the discharge of ammoniacal nitrogen from the sewage treatment works was assessed, as 20 mg/l at an average flow rate of 13.3 l/s. To investigate the impact of varying the sewage treatment discharge, three different concentrations have been considered; 40, 60 and 80 mg/l of sewage. Additionally, an alternative flow rate mix has been considered, based on the current dewatering during construction, whereby the sewage flow rate is increased by 10 l/s and the groundwater decreased by 10 l/s, maintaining the overall average 38.3 l/s flow.

The assessments considered the release from the sewage treatment works as both a construction only discharge, plus a combined construction and commissioning discharge.

Applying the Environment Agency's Screening tests, the results of 'test 5' (allowable effective volume flux) showed that when considering construction alone, each scenario tested was within permissible limits. However, the partitioning of un-ionised ammonia is influenced by the physical conditions and this partitioning is not factored into the basic screening tests. Therefore, while the screening test was passed, further assessment of the discharges in terms of mixing calculations and nearfield modelling was conducted. When considering the combined construction and commissioning discharges, due to the considerable increase in ammonia from the commissioning phase, the screening tests were not passed. However, this is consistent with previous assessments (BEEMS Technical Report TR428) which required modelling to fully assess the potential implications of the commissioning discharges.

For the construction discharge alone, nearfield modelling using CORMIX showed that concentrations of un-ionised ammonia fall below the environmental quality standard (EQS) (21 µg/l) within <7.16 m of the discharge point for the original scenario (i.e., 20 mg/l total ammonia). This distance required to mix the discharge down to the EQS increased to a maximum of 46.04 m for the 80 mg/l discharge scenario, with the original flows, and to 82.08 m for 80 mg/l discharge with the alternative flow rates. While the estimated mixing zone was considerably larger under the new scenarios compared to the baseline scenario (increasing from ~7m to over 80 m), the mixing zone was still very small in respect to the scale of the receiving environment and therefore would not be expected to cause any significant environmental effects.

Reanalysis of the General Estuarine Transport Model (GETM) modelling results showed that during the period where the construction and commissioning discharges overlap, the discharge scenarios led to an estimated additional 0.11 to 0.31 µg/l of un-ionised ammonia with the original flow rates and 0.06 to 0.61 µg/l of un-ionised ammonia with the alternative flow rates at the locations of the sensitive biological receptors. From the time series of instantaneous un-ionised ammonia concentrations at the eight *Corallina* locations and seven *Sabellaria* locations, the maximum instantaneous value (10.4 µg/l) was below the EQS of 21 µg/l. For all scenarios, the area of exceedance of un-ionised ammonia, as a 95th percentile, had a maximum value of 0.2 ha at the surface and was not exceeded at the bed. For context the receiving water body (Bridgwater Bay) has a surface area of 9,224.5 ha, and therefore the area of exceedance would represent 0.002% of the water body.

For construction and commissioning the maximum allowable concentration for total ammonia, (8 mg/l as a 95th percentile) was not exceeded at the surface or bed in any scenario, but the PNEC (1.1 mg/l as a mean) was exceeded at the surface only, however only for a maximum of 0.04 ha (equivalent to 1 grid cell in the model and the point of immediate discharge).

The overall conclusion was that all of the scenarios considered would not lead to significant environmental effects.

1 Background

The Hinkley Point C (HPC) Development Consent Order (DCO) was granted by the UK Secretary of State for Energy and Climate Change in March 2013. The DCO and associated Licences and Permits detail NNB Gen Co's (HPC) environmental monitoring requirements with respect to the construction and operation of the new station.

HPC environmental permit (Environment Agency's Permit number EPR/XP3321GD/V004) for the Construction Sewage Treatment System consents NNB GenCo to discharge a maximum of 20 mg/l of ammoniacal nitrogen from the HPC Sewage Treatment plant during construction. Additionally, during commissioning, NNB GenCo are permitted to release 271 mg/l of ammoniacal nitrogen (EPR/JP3122GM/V009&010) and to discharge groundwater during the construction period. To support the delivery of HPC, NNB GenCo is considering varying the site's Construction Sewage Treatment System environmental permit (EPR/XP3321GD/V004) to allow an increased concentration of ammoniacal nitrogen within the permitted discharge. NNB GenCo has commissioned Cefas under the BEEMS programme to undertake appropriate additional modelling studies to support the discharge control strategy.

1.1 Scenarios

The currently permitted discharge of ammoniacal nitrogen from the sewage treatment works was assessed as 20 mg/l at a flow rate of 13.3 l/s, see Case D of BEEMS TR428. The flow from the sewage treatment works represents only a partial flow of the total contribution of ammoniacal nitrogen to the total 38.3 l/s flow of Case D. During the construction period the total flow of Case D is comprised of 13.3 l/s coming from the sewage treatment works and 25 l/s from general groundwater and tunnelling effluent flow.

To investigate the impact of varying the sewage treatment discharge, three different concentrations of ammoniacal nitrogen in the treated sewage flow were considered; 40, 60 and 80 mg/l. Additionally, an alternative flow rate mix has been considered, based on the current dewatering during construction, whereby the treated sewage flow rate is increased by 10 l/s and the groundwater decreased by 10 l/s, maintaining the overall 38.3 l/s flow. Table 1 summaries the different scenarios being tested and their respective ammonia concentrations.

As discussed further in Section 2.3 ammoniacal nitrogen will be discharged during commissioning as well as during the construction phase and while the commissioning discharge will not be varied the implications of altered construction discharges when combined with the commissioning discharges must be considered and are therefore factored into the assessment.

Table 1: Summary of the discharge scenarios and their ammoniacal nitrogen concentrations.

Flow	Scenario (ammoniacal nitrogen in treated sewage)	Total flow (m^3/s)[1]	Total ammonia (µg/l)[2]	Un-ionised ammonia (µg/l)[3]
Original	20 mg/l	0.038	10,034	44.8
	40 mg/l	0.038	16,979	75.7
	60 mg/l	0.038	23,924	106.7
	80 mg/l	0.038	30,869	137.7
Alternative	20 mg/l	0.038	14,020	62.5
	40 mg/l	0.038	26,187	116.8
	60 mg/l	0.038	38,355	171.1
	80 mg/l	0.038	50,522	225.3

[1]: Comprised of 25 l/s groundwater and tunnelling effluent plus 13.3 l/s treated sewage or the original case, or 15 l/s groundwater plus 23.3 l/s treated sewage for the alternative case.

[2]: Derived from the mixing of the sewage ammonia scenario plus groundwater at 4,732 µg/l total ammonia (refer to BEEMS Technical Report TR428).

[3]: Derived using the Environment Agency un-ionised ammonia calculator based on discharge with salinity of 1, pH of 7.3 and temperature of 12.5°C (refer to BEEMS Technical Report TR428).

2 Assessment Methodology

2.1 Screening and un-ionised ammonia mixing

The first step in assessing the alternative treated sewage discharges was to apply the Environment Agency screening tests (Environment Agency and Department for Environment Food and Rural Affairs, 2022). The concentration of substances present in the discharge were assessed against lists of specific pollutants and priority hazardous substances and compared to environmental quality standards (EQS). There are several different 'tests' depending on the nature of the discharge and surrounding conditions. For the construction and commissioning discharges, and in line with previous assessments in BEEMS Technical Report TR428, test 1 and test 5 for 'estuaries and coastal waters' are applicable.

Test 1 is a comparison of the concentration of each assessment substance to the representative EQS. If concentrations of substances are below their EQS levels in the discharges the test is passed and the substance is screened out of further assessment.

Test 5 compares the discharge to calculated Effective Volume Flux (EVF) levels. The EVF is determined based on the discharge rate, the concentration of the substance and the EQS of that substance. The calculation applied is as follows:

EVF = (Discharge Rate (m^3/s) * Concentration (µg/l)) / (EQS – background concentration)

The result is compared to the Allowable EVF (AEVF), which is determined by the water depth at the point of discharge. The water depth at the discharge point is at least 3 m. Consistent with previous assessments (BEEMS Technical Report TR428) an AEVF of 3 has been applied. Background concentrations applied are consistent with BEEMS Technical Report TR428 and follow either baseline measurements from the area (Amec, 2009) or concentrations recommended by the environment Agency.

Ammonia is a key consideration in treated sewage discharges and is considered as both total ammonia (ammoniacal nitrogen $NH_3 + NH_4^+$) and un-ionised ammonia (NH_3) alone. Un-ionised ammonia is a specific pollutant with a EQS (at 21 µg/l annual average). All measures of ammonia are expressed 'as N' referring to the mass of nitrogen in the compound.

In general, the un-ionised form of ammonia is more toxic than the ionised form. The partitioning between ammonium (NH_4^+) and un-ionised ammonia 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. Mixing curves have been calculated to determine the proportion of un-ionised ammonia at different levels of mixing. Interpolation of these curves at the EQS level provides to amount of mixing required to reach the EQS. Parameters used in the mixing calculations are given in Section 4.

2.2 Construction only discharges

The seven additional discharge scenarios described in Section 1.1 were assessed alone to consider the period of construction discharges before the commissioning discharges are added.

Initial screening was based on the characteristics of the discharge, with a salinity of 1, pH of 7.3 and background temperature of 12.5°C (BEEMS Technical Report TR428). While initial screening showed that construction only discharges are below the AEVF (see Section 3) the partitioning of ammonium and un-ionised ammonia varies with significantly with pH. The ground water pH (7.3) is lower than the background seawater pH (7.86) so as the discharge mixes the proportion of un-ionised ammonia will increase (although notably while being diluted). Therefore, mixing calculations and nearfield modelling were applied to determine the range at which the EQS level would be reached. Whilst the total flow rate considered during the construction only scenario is 38.3 l/s, the flow rate modelled in CORMIX was conservatively increased to 45 l/s, mirroring what was previously modelled using CORMIX in BEEMS Technical Report TR428.

Mixing calculations are described in Section 4 and were used to determine the extent of mixing required to reach the EQS for un-ionised ammonia. Notably these calculations are independent of the volumes of the discharge. Initial mixing was therefore further investigated with the nearfield CORMIX model to determine the range at which the EQS would be met under the different scenarios. The construction discharge was modelled using CORMIX US EPA supported mixing zone model (CORMIX Version 12.0GT HYDRO1 Version 12.0.1.0 January 2023), using the same hydrodynamic model parameters as used in BEEMS Technical Report TR428 which has been previously agreed with the Environment Agency [1].

To investigate how the discharge evolves over the state of the tide, multiple stages of the tide were considered: peak flood, peak ebb, high water, and low water. Whilst the plume is buoyant[2], the water depth at the discharge is only 3 m at low water, there is a risk of slack water pooling at low water, where the depths and low velocities will inhibit mixing. Therefore, an additional scenario was also modelled in BEEMS Technical Report TR428 and replicated here, of low tide +1 hour.

2.3 Construction and commissioning discharges

High levels of ammonia will be discharge during commissioning overlapping with the construction discharge. Previous modelling of ammonia discharges during construction and commissioning were presented in BEEMS Technical Report TR428. The release and mixing of ammonia was modelled using the validated Hinkley Point 25 m resolution GETM model. This is a 3D hydrodynamic model with an inbuilt passive tracer to represent ammonia. The model setup, calibration and validation are described in BEEMS Technical Report TR267 Edition 2. As with the 100 m resolution Hinkley Point GETM model (BEEMS Technical Report TR177) the surface is forced with reanalysed data from a meteorological model (ERA40 interim from ECMWF). The boundary conditions were forced by a broader 3D GETM domain, described in BEEMS Technical Report TR177.

The discharge outfall is attached to a jetty pile and located approximately 1 m above the seabed (approximately 2 m below lowest astronomical tide (LAT)). CORMIX modelling (shown in Appendix D of TR428) indicates that the plume will be buoyant and form a surface pool (or pond) at slack water which will become increasingly elongated as the tidal flow increases, forming a long thin streak at peak tidal flow.

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[1] Comments from the Environment Agency noted that CORMIX was run with a temperature of 12°C for both the discharge and the receiving environment, however this differs from the 12.5°C used in the calculation of unionised ammonia. Both represent mean background conditions and the difference is a function of rounding. Notably, as the mixing is driven by the density difference between the fresh and saline waters, the rounding error has no significant effect on the results. Re-running the CORMIX model using 12.5°C results in the distance before EQS is reached increasing by 3cm for results discussed in section 5.1..

[2] The plume is buoyant because it is a freshwater discharge into a saline environment. The discharge is not considered to be heated and has been modelled at ambient temperature (i.e. there is no thermal uplift).

CORMIX is unable to replicate many of the features simulated by the GETM model, and GETM is therefore a better model to use away from the near field (further than 10s of metres from the outfall). Specifically, GETM can replicate wind driven behaviour and has precise bathymetry so that interactions with the tidal flow (e.g. eddies) are well replicated. Whilst CORMIX can include winds, they are applied omnidirectionally and are used for determining heat loss fluxes at the surface. As the discharges considered in this report are released at ambient sea temperature and are not considered to be heated, wind has not been included in the CORMIX model. Neither the CORMIX nor the GETM model includes the effects of waves which enhance vertical mixing and increase dilution. The modelling predictions of plume areas above the EQS are therefore conservative: the actual discharge will be subject to more mixing and dilution (caused by wave action) than the models are able to replicate and so the actual concentrations in the environment will be lower than those predicted.

As the scenarios considered here maintain the same total flow rate as previously modelled, no new GETM modelling was undertaken, but instead the results were scaled according to the change in the concentrations. BEEMS Technical Report TR428 considered two discharge scenarios during the construction + commissioning assessment: 38.3 l/s construction discharge at 10 mg/l ammoniacal nitrogen plus commissioning discharge at either 37 l/s or 70 /ls discharge at 271 mg/l ammoniacal nitrogen, depending on the release from one or two treatment tanks. For the assessment here, the worst case scenario of two treatment tanks has been assessed, due to the higher total ammonia content in the combined discharges. To determine the predicted effect of the treated sewage variation, the previous GETM results are scaled by determining the percentage increase in total mass of ammonia from the various waste streams. This percentage increase was then also applied to un-ionised ammonia results.

To assess the impact of varying the treated sewage discharge, the spatial extent of the total ammonia was assessed at the surface and bed against the (non-statutory) Predicted No Effect Concentration (PNEC) of 1.1 mg/l as a mean and the Maximum Allowable Concentration (MAC) of 8 mg/l as a 95th percentile. Likewise, for the un-ionised ammonia, the spatial extent was assessed against the (statutory) EQS of 21 µg/l at the surface and bed as a mean and 95th percentile.

In addition to the spatial extents, the exposure of un-ionised ammonia to sensitive biological receptors was also considered, specifically *Sabellaria* and *Corallina* (see Section 2.4 for more details on the biological receptors). Figure 1 shows a time series of un-ionised ammonia at the locations of *Corallina*[3] for the 38 l/s at 10 mg/l +70 l/s at 271 mg/l scenario, as shown in BEEMS Technical Report TR428. From the time series, the average concentration of un-ionised ammonia at the eight stations of *Corallina* is approximately 2 µg/l with periodic spikes in concentration. This is due to the discharge strategy during construction and commissioning. The construction discharge is a small continuous discharge, whereas the commissioning discharge is a pulsed discharge with a higher flow rate and concentration. The spikes in concentration, seen in Figure 1, at the locations of the *Corallina* previously assessed in BEEMS TR428 (see Figure 2) correspond to the time of the pulse discharge, whereas the 2 µg/l mean baseline is made up of both the construction discharge and the dispersion of the commissioning discharges. Therefore, when applying the percentage increase to the un-ionised ammonia, due to the variation in the treated sewage discharge, it was applied to the 2 µg/l mean baseline, rather than applied as a constant to the whole time series.

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[3] Note: location C4 was omitted in the original version of this figure however baseline for C4 is similar to other locations and results for C4 are shown on Figure 13. This omission does not influence the illustration of the 2µg/L baseline, which is the purpose of this figure.

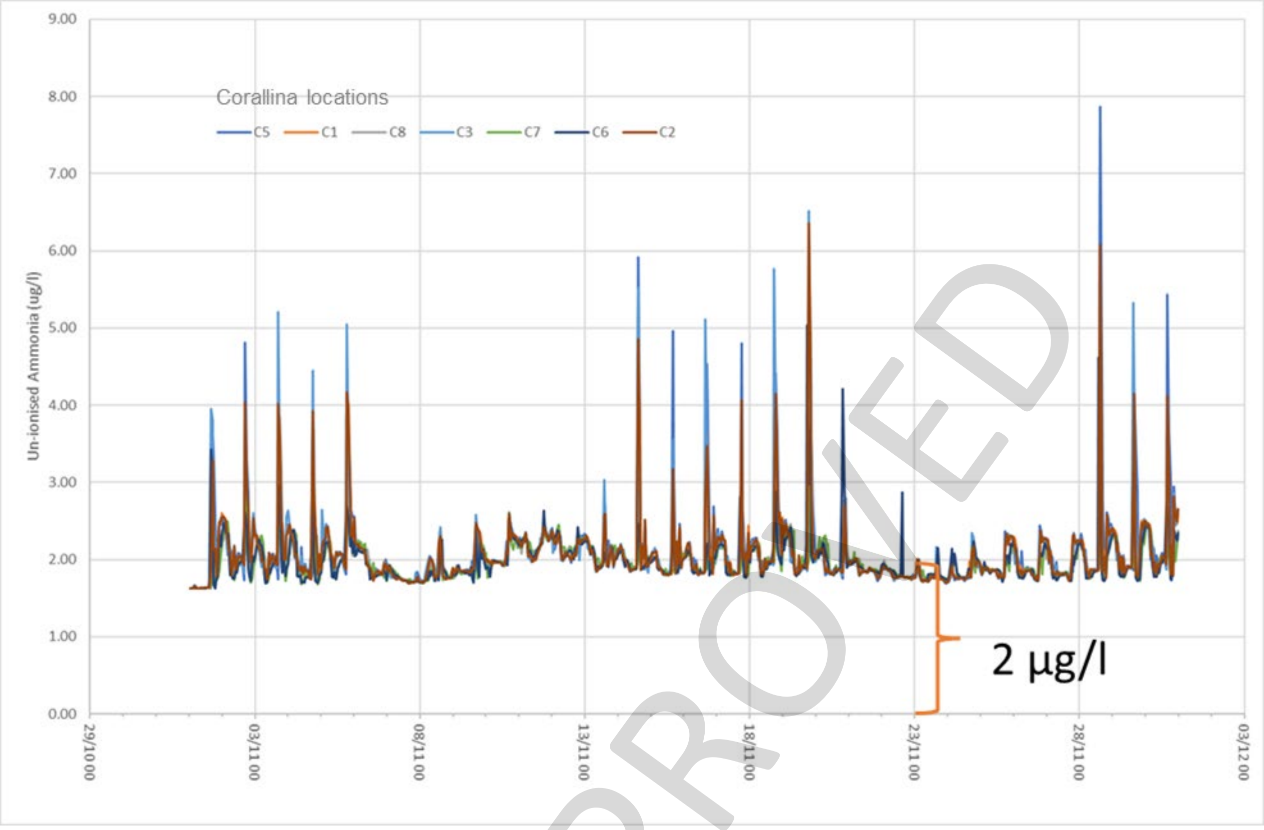

Figure 1: The original time series of un-ionised ammonia at the locations of Corallina (C1 to C8, see Figure 2) for the 38 l/s at 10 mg/l +70 l/s at 271 mg/l scenario, as shown in BEEMS Technical Report TR428.

2.4 Biological receptors

There are two biological receptors that the un-ionised ammonia was assessed against to determine the acceptable discharge concentration. These are; *Corallina* spp. and *Sabellaria* spp. This report has investigated the potential exposure of these species to un-ionised ammonia with respect to the EQS (21 µg/l annual average).

2.4.1 Corallina spp.

Corallina spp. or coral weed is a calcareous, branching red seaweed (Rhodophyta). Fronds can be up to 4 – 20 cm in length rising from a calcareous crustose holdfast. *Corallina* spp. is an intertidal species typically found inhabiting littoral wave-exposed rocky shores and shallow sublittoral habitats forming turfs in pools and gullies, sometimes extending into the sublittoral fringe (Tyler-Walters, 2008). Dense, sometimes monospecific, swards of *Corallina* are a characteristic feature of the mid to low shore rocky ledges to the west of Hinkley Point (Bamber & Irving, 1992). It is found all around the UK extending its range north to Norway and Greenland and south to Morocco and Argentina (Tyler-Walters, 2008). *Corallina* spp. are of national importance although official conservation status is uncertain (BEEMS Technical Report TR029).

An unusual geological formation at Hinkley Point has caused conditions which favour the development of lush red algal turfs composed mainly of *Corallina* spp. The topography is such that a series of scarps and slopes run parallel to the shore and retain water as the tide retreats, creating a series of narrow pools or streams along the shore. In places where the scarps are breached, water can spill down to the lower shore, thus creating a permanently wet environment suitable for growth of algal species which would otherwise exist only fully submerged in rock pools (BEEMS Technical Report TR029).

Until recently two species of *Corallina* were recognised for the British flora: *Corallina elongata* and *Corallina officinalis* (Irvine and Johansen, 1994). The *Corallina* species found at Hinkley Point has provisionally been described as '*officinalis'*, but the taxonomy of the Corallinales has recently been revised (Walker *et al*., 2009) and a new species *Corallina caespitosa* sp. nov. has been added. Hence, there are three possible species which may exist at Hinkley Point (BEEMS Technical Report TR068B).

Figure 2 shows the location of *Corallina* spp. habitat in relation to the Hinkley Point site. There are eight patches of *Corallina* spp. indicated on the map, as defined in BEEMS Technical Report TR428. Concentrations of un-ionised ammonia were assessed at these locations. As the *Corallina* is intertidal the un-ionised ammonia concentrations at the eight stations will be assessed using the surface concentrations, as in BEEMS Technical Report TR428.

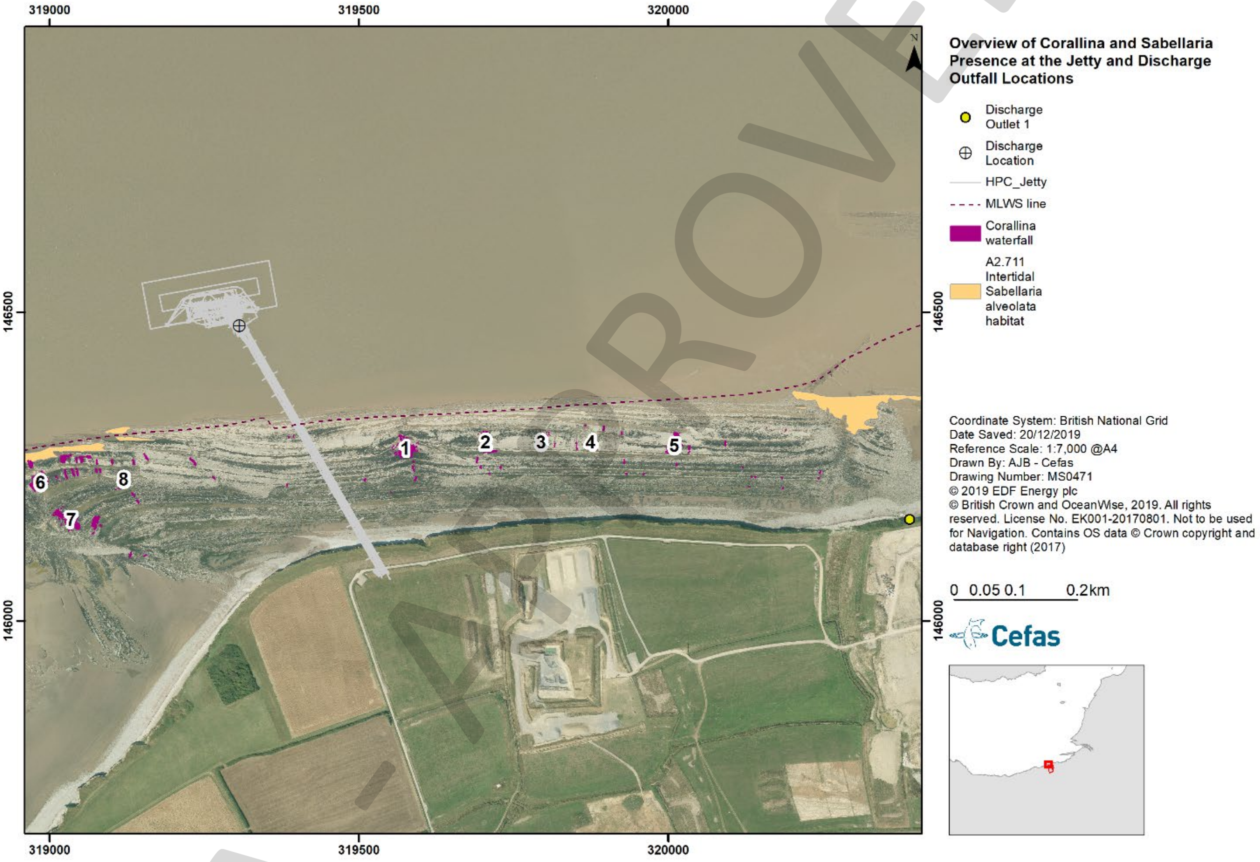

Figure 2: Location of the intertidal *Corallina* spp. around Hinkley Point.

2.4.2 Sabellaria spp.

As part of the Severn Estuary Special Area of Conservation (SAC), *Sabellaria* spp. reefs are a key ecological feature of the site and are included, as biogenic reef habitat, under the SAC designation. The two species of *Sabellaria* spp. that are of interest are *Sabellaria spinulosa* and *Sabellaria alveolata.* As well as a qualifying interest feature of the Severn Estuary SAC, both *S. alveolata* and *S. spinulosa* also have their own UK Biodiversity Action Plans and reef structures are listed under Annex I of the EC Habitats Directive (see BEEMS Technical Report TR068 Version 2).

Both species are sabellariid polychaetes which form reef structures through the aggregation of growth tubes. *S. spinulosa* is a predominantly subtidal species that is relatively widespread around the UK and is found either individually or as crusts or reefs; settling directly on the seabed, on tubes of the same species or on hard body parts of other benthic species (such as large bivalves). *S. alveolata* is a predominantly intertidal species that is found mainly around the west and south-west of the UK, settling on exposed bedrock and hard substrates from boulders to pebbles (BEEMS Technical Report TR039). *Sabellaria* reefs are common around Hinkley Point and elsewhere in the Severn Estuary and Bristol Channel but is unusual in that *S. alveolata* occurs in the subtidal, as well as the intertidal which is not commonly observed in other areas.

Figure 3 shows the location of *S. alveolata* habitat in relation to the Hinkley Point site. There are seven patches of *S. alveolata* indicated on the map, as defined in BEEMS Technical Report TR428. Concentrations of un-ionised ammonia will be assessed at these locations. For stations A and E, the *Sabellaria* is subtidal. For stations B, C, D, F and G, the *Sabellaria* is intertidal. As such, for the subtidal *Sabellaria* the un-ionised ammonia concentrations haven been assessed against the EQS using the seabed concentrations, whereas the intertidal have been assessed using the surface concentrations. This is as done in BEEMS Technical Report TR428.

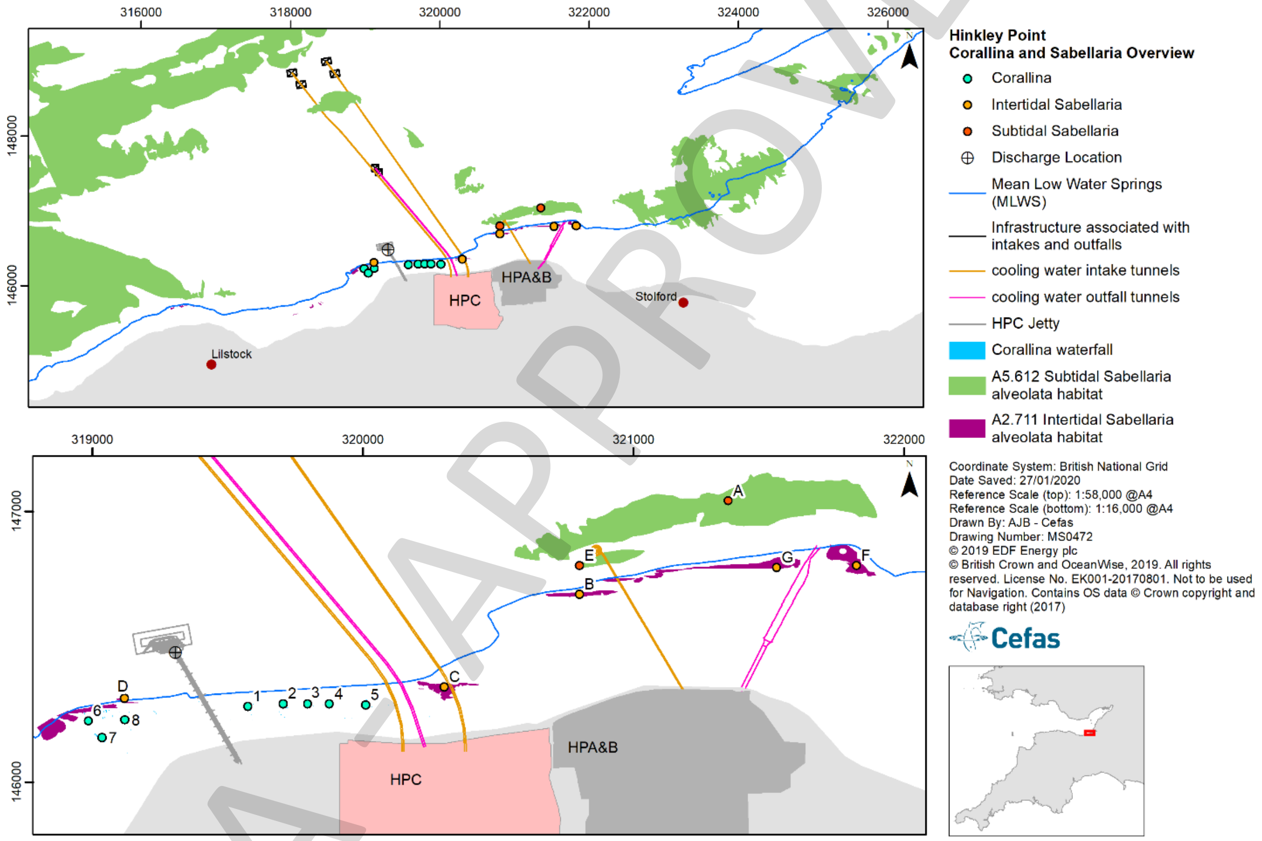

Figure 3: Location of subtidal and intertidal *Sabellaria alveolata* around Hinkley Point.

3 Screening Results

Screening of the seven possible discharge scenarios considering the construction discharge alone showed that all, including the current permitted 20 mg/l ammonia scenario failed test 1 (i.e. are above EQS at the point of discharge). Comparison against the AEVF (test 5) showed that all scenarios were below the threshold. The results of test 5 suggest that when considering construction alone each scenario tested is within permissible limits. The results of the screening tests are shown in Table 2.

As described in Section 2.2, the partitioning of un-ionised ammonia is influenced by the physical conditions and this partitioning is not factored into the basic screening tests. Therefore, while the screening test was passed, further assessment of the discharges in terms of mixing calculations and nearfield modelling is provided in Section 4 and Section 5.1.

Screening of the construction plus commissioning discharges is shown in Table 3. An additional 271,206 µg/l of ammoniacal nitrogen from commissioning was added to construction discharges for these scenarios with the discharge concentration calculated based on a commissioning discharge rate of 70 l/s (refer BEEMS Technical Report TR428, Appendix C for detail of commissioning discharges). Due to the considerable increase in ammonia from the commissioning phase, the screening tests were not passed, however this is consistent with previous assessments (BEEMS Technical Report TR428) which required modelling to fully assess the potential implications of the commissioning discharges. Detailed assessment of the alternative scenarios including the commissioning phase discharges is provided in Section 5.

Table 2: Screening tests for construction phase alternative treated sewage discharge scenarios.

Scenario (ammoniacal nitrogen in treated sewage)	**Flow m^3/s**	**Total ammonia µg/l**	**Un-ionised ammonia µg/l**	**Saltwater AA EQS µg/l**	**Background concentration µg/l**	**Test 1**	**Test 5 Effective volume flux**	**TraC Water test 5 EVF < 3.0 (Pass/Fail)**
BASELINE (20 mg/l)	0.038	10,034	44.8	21	4.6	2.1	0.1	Pass
40 mg/l	0.038	16,979	75.7	21	4.6	3.6	0.2	Pass
60 mg/l	0.038	23,924	106.7	21	4.6	5.1	0.2	Pass
80 mg/l	0.038	30,869	137.7	21	4.6	6.6	0.3	Pass
BASELINE (20 mg/l) - alt. flow	0.038	14,020	62.5	21	4.6	3.0	0.1	Pass
40 mg/l - alt. flow	0.038	26,187	116.8	21	4.6	5.6	0.3	Pass
60 mg/l - alt. flow	0.038	38,355	171.1	21	4.6	8.1	0.4	Pass
80 mg/l . alt flow	0.038	50,522	225.3	21	4.6	10.7	0.5	Pass

Notes: Un-ionised ammonia calculated based on discharge with salinity of 1, pH of 7.3 and temperature of 12.5°C.

Table 3: Screening tests for construction and commissioning phase alternative sewage discharge scenarios.

Scenario (ammoniacal nitrogen in treated sewage)	**Flow m^3/s**	**Total ammonia µg/l**	**Un-ionised ammonia µg/l**	**Saltwater AA EQS µg/l**	**Background concentration µg/l**	**Test 1**	**Test 5 Effective volume flux**	**TraC Water test 5 EVF < 3.0 (Pass/Fail)**
BASELINE (20 mg/l) + commissioning	0.108	178,878	32,799	21.00	4.60	1,562	216.6	Fail
40 mg/l + commissioning	0.108	181,334	33,249	21.00	4.60	1,583	219.6	Fail
60 mg/l + commissioning	0.108	183,790	33,700	21.00	4.60	1,605	222.5	Fail
80 mg/l + commissioning	0.108	186,247	34,150	21.00	4.60	1,626	225.5	Fail
BASELINE (20 mg/l) - alt. flow + commissioning	0.108	180,288	33,058	21.00	4.60	1,574	218.3	Fail
40 mg/l - alt flow + commissioning	0.108	184,591	33,847	21.00	4.60	1,612	223.5	Fail
60 mg/l - alt. flow + commissioning	0.108	188,894	34,636	21.00	4.60	1,649	228.7	Fail
80 mg/l alt. flow + commissioning	0.108	193,196	35,425	21.00	4.60	1,687	233.9	Fail

Notes: Un-ionised ammonia calculated based on discharge with salinity of 1, pH of 9 (pH 9 represents the expected pH of the commissioning wastewater as per permit EPR/JP3122GM/V009&010) and temperature of 12.5°C. Commissioning flow of 70 l/s added with a concentration of ammoniacal nitrogen of 271,260 µg/l (see Section 1.1 for volume and concentration calculations).

4 Un-ionised Ammonia Mixing Calculations

The mixing of the construction discharges with seawater influences the partitioning of un-ionised ammonia as described in Section 2. Mixing of the discharge was calculated based on the progressive dilution from the source concentration of ammoniacal nitrogen with the discharge characteristics of pH 7.3 and salinity of 1, through to complete mixing down to background ammoniacal nitrogen levels and average ambient seawater conditions (salinity of 31.5 and pH of 7.86). The components of the mixing calculations are consistent with the previous assessment in BEEMS Technical Report TR428. Mixing curves are shown in Figure 4 and Figure 5 and the level of mixing and dilution required to reach the EQS for un-ionised ammonia is summarised in Table 4. These calculations are independent of the volume of the discharge and therefore must be considered in combination with modelling dilution rates from CORMIX modelling (Section 5.1).

Table 4: Nearfield mixing of un-ionised ammonia under the construction phase alternative scenarios.

Scenario (ammoniacal nitrogen in treated sewage)	Un-ionised ammonia (µg/l)	Mixing % required to EQS (21 µg/l)	Dilution factor required to EQS (21 µg/l)
BASELINE (20 mg/l)	44.8	81	4.4
40 mg/l	75.7	90	9.1
60 mg/l	106.7	93	13.3
80 mg/l	137.7	95	17.6
BASELINE (20 mg/l) - alt. flow	62.5	86	7.0
40 mg/l – alt. flow	116.8	94	14.7
60 mg/l - alt. flow	171.1	96	22.1
80 mg/l – alt. flow	225.3	97	29.5

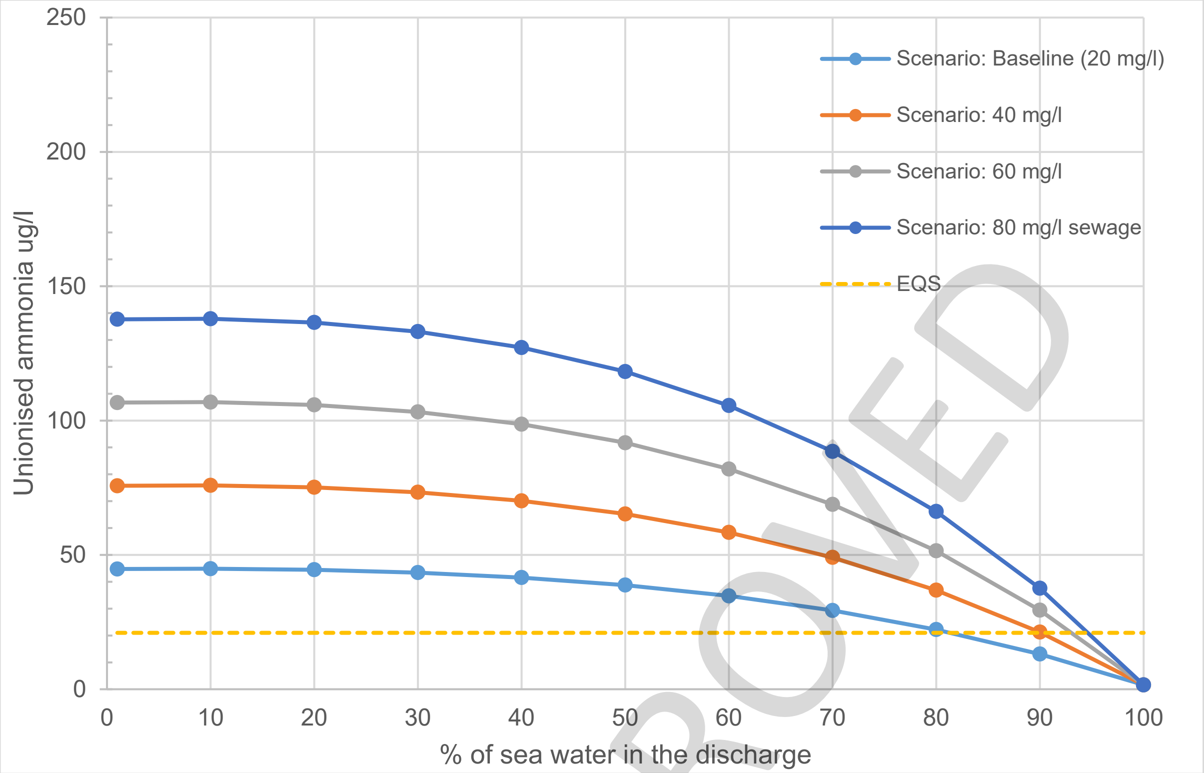

Figure 4: Mixing of the construction discharge and un-ionised ammonia partitioning with baseline flows (treated sewage at 13.3 l/s and groundwater at 25 l/s).

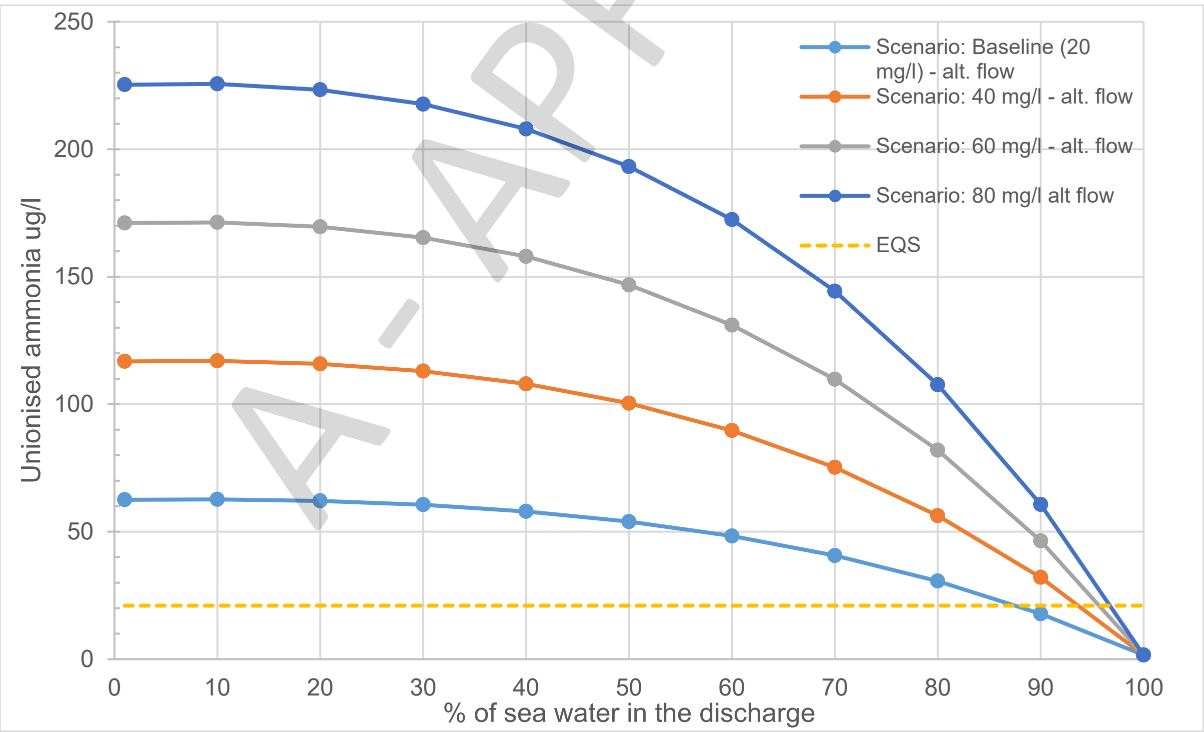

Figure 5: Mixing of the construction discharge and un-ionised ammonia partitioning with alternative flows (treated sewage at 23.3 l/s and groundwater at 15 l/s).

5 Modelling Results

5.1 CORMIX

Figure 6 and Figure 7 show the shape of the plume, from the CORMIX results with a 45 l/s discharge, for the rising tide and low water, respectively. As was seen in BEEMS Technical Report TR428, due to the strong tidal currents, the resulting plume from the construction discharge forms a long elongated shore parallel shape. At low water, this elongated plume expands and pools at slack water. Due to the freshwater nature of the plume, the plume remains buoyant and rises to the surface at all states of the tide. Figure 8 to Figure 12 show the dilution curves for the five states of the tide investigated for the 45 l/s discharge. From these curves, the distance the plume extends before mixing to the required level of dilution can be determined, as summarised in Table 4, in order to fall below the EQS.

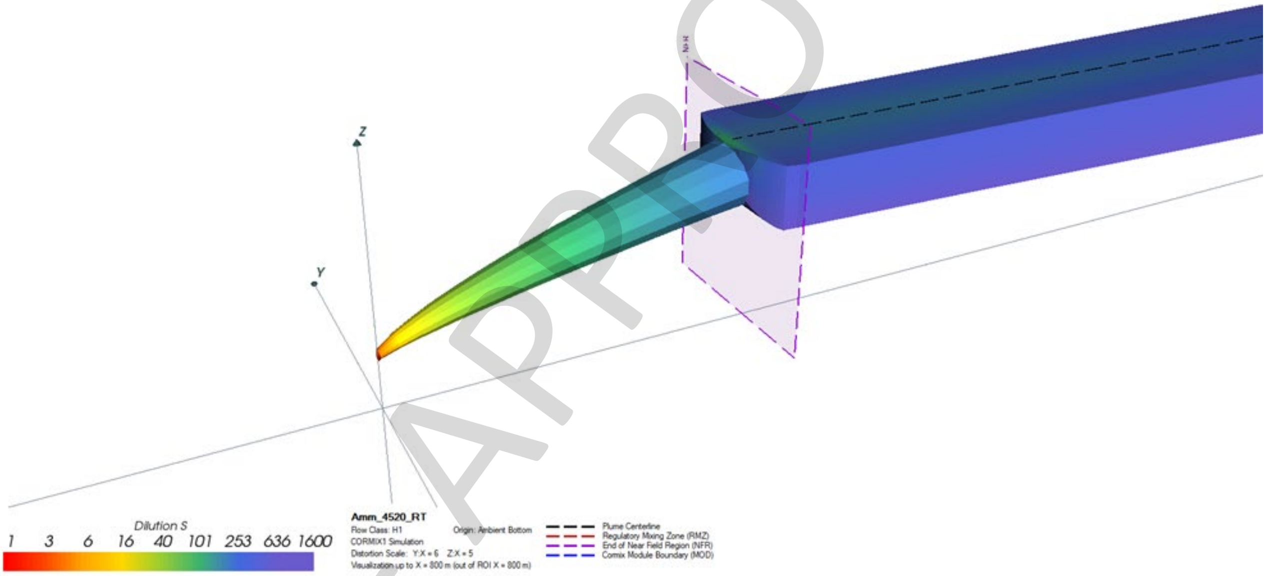

Figure 6: CORMIX output at rising mid tide, showing the long elongated plume due to peak tidal currents.

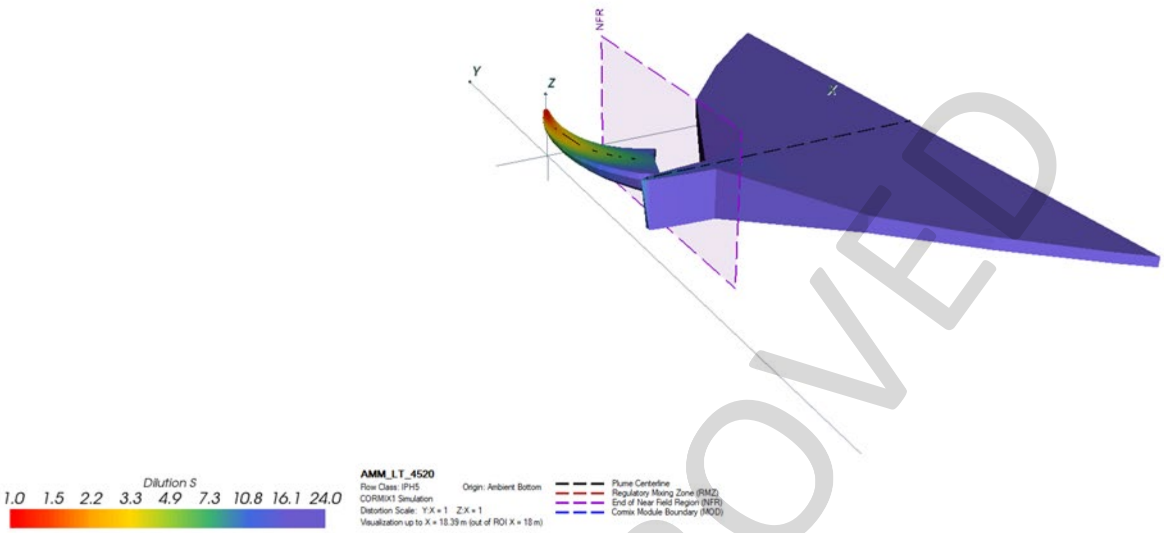

Figure 7: CORMIX output at low tide, showing the buoyant slack water plume.

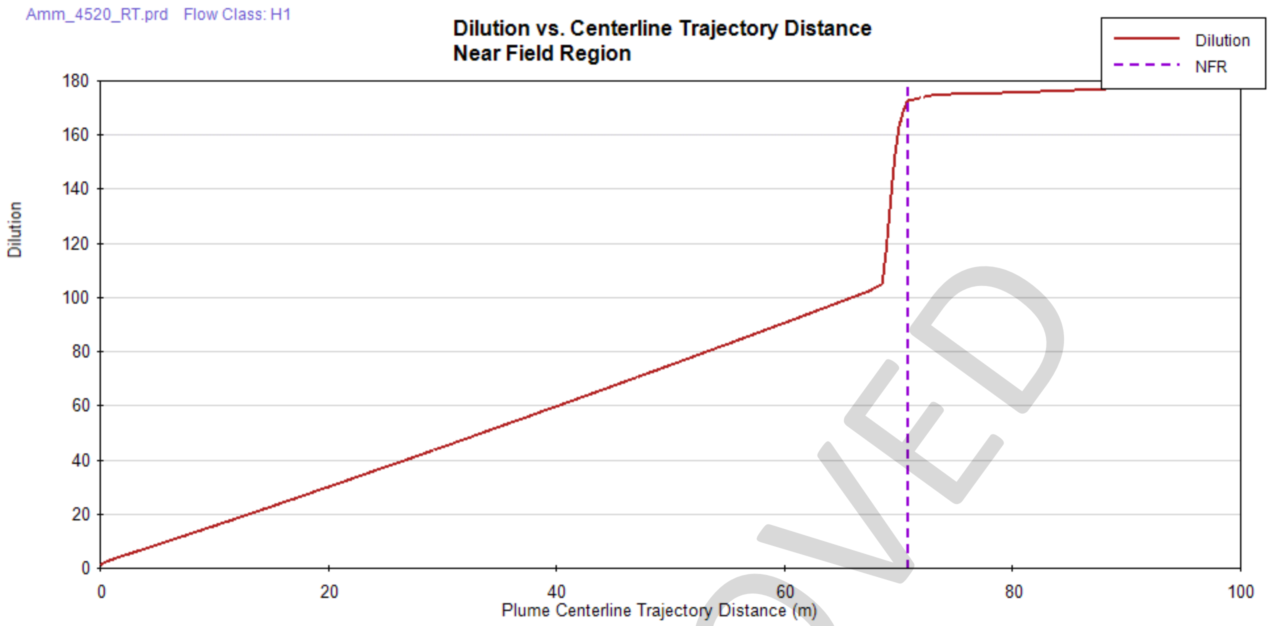

Figure 8: CORMIX outputs showing the dilution of the plume along the centreline for the 45 l/s simulation at rising mid tide.

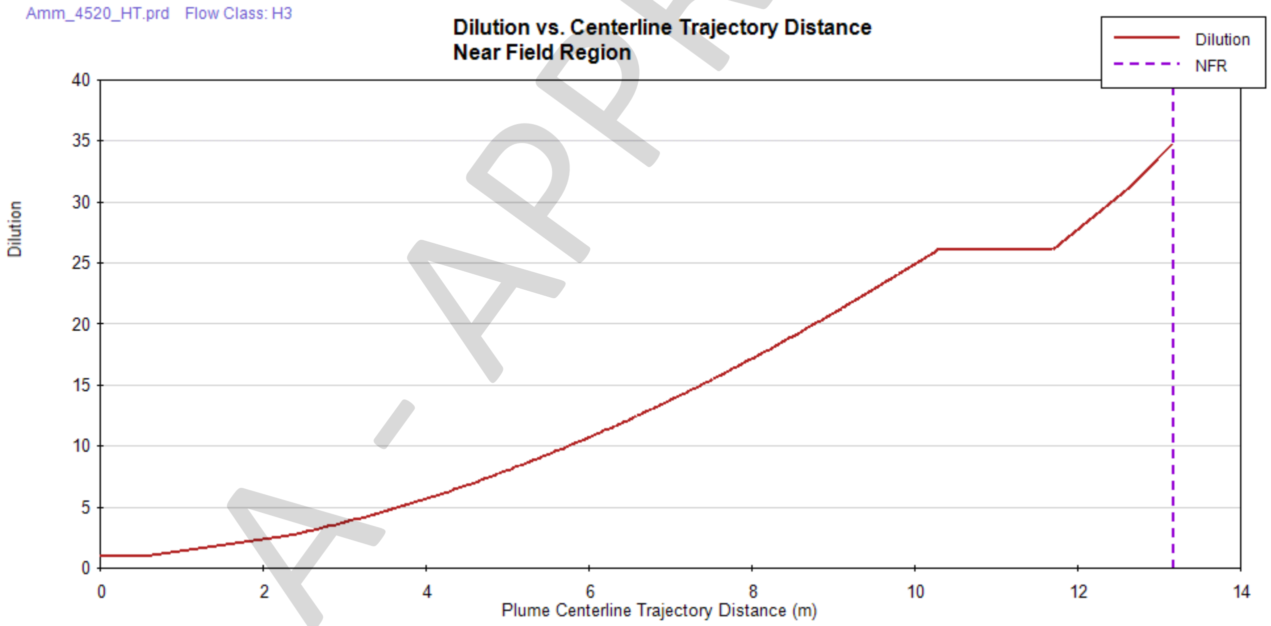

Figure 9: CORMIX outputs showing the dilution of the plume along the centreline for the 45 l/s simulation at high tide.

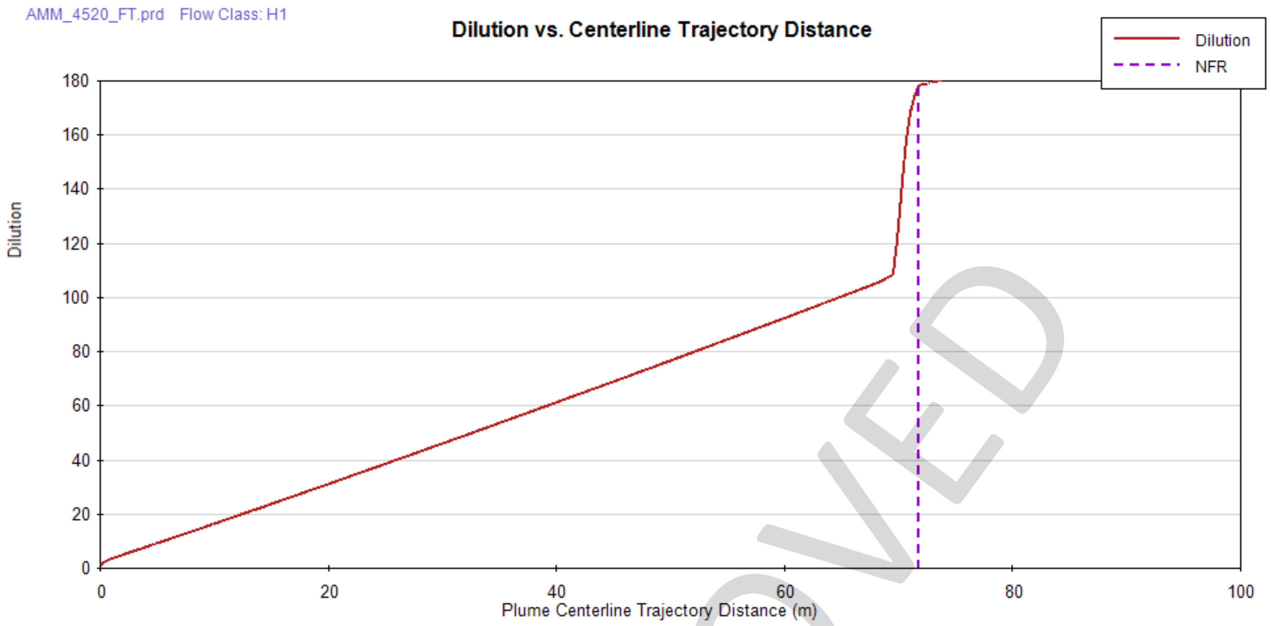

Figure 10: CORMIX outputs showing the dilution of the plume along the centreline for the 45 l/s simulation at falling mid tide.

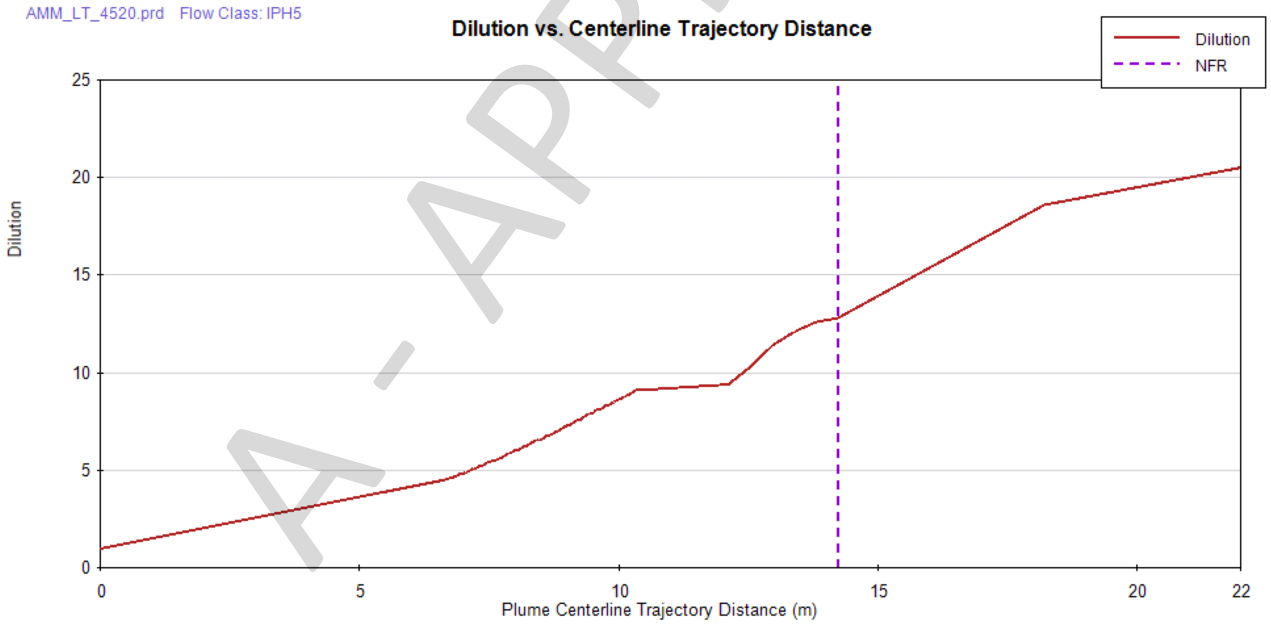

Figure 11: CORMIX outputs showing the dilution of the plume along the centreline for the 45 l/s simulation at low tide.

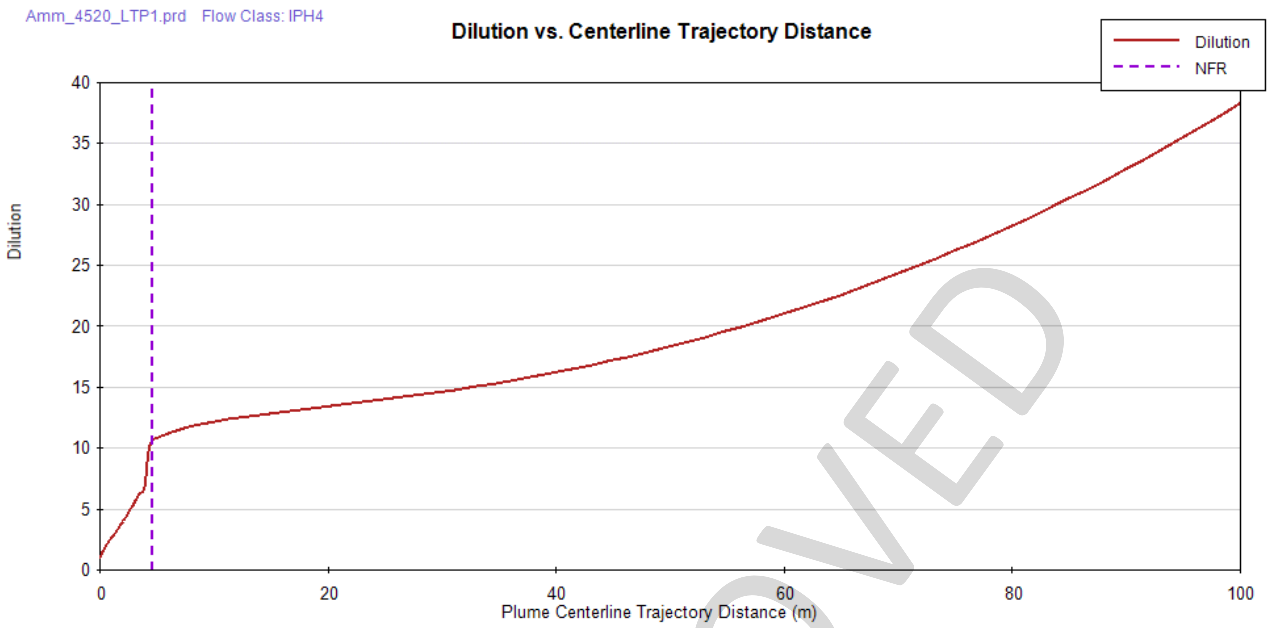

Figure 12: CORMIX outputs showing the dilution of the plume along the centreline for the 45 l/s simulation at low tide +1 hour.

Using the mixing calculations and required dilution to reach the EQS, summarised in Table 4, the CORMIX modelling shows the concentrations of un-ionised ammonia fell below the EQS (21 µg/l) within <7.16 m for the original scenario (i.e. 20 mg/l total ammonia). This distance to the EQS increased to a maximum of 46.04 m for the 80 mg/l discharge scenario, with the original flows, and to 82.08 m for 80 mg/l discharge with the alternative flow rates. The results are summarised in Table 5.

Initial screening of the construction only discharge scenarios shows that while discharges failed test 1 (they are above the EQS), they passed test 5 (the effective volume flux is below 3). This suggests that the construction only discharge should be acceptable at the higher concentrations tested. While the estimated mixing zone is considerably larger under the new scenarios compared to the baseline scenario (increasing from ~7m to over 80m), the mixing zone was still very small in respect to the scale of the receiving environment and therefore is not expected to cause any significant impacts.

Table 5: Summary of CORMIX results showing the distances whereby the discharge of un-ionised ammonia falls below the EQS.

Ammonia Scenario	**EQS (µg/l)**	**Required mixing %**	**Dilution**	**Distance to required mixing (m)**				
				Rising tide	**High tide**	**Falling tide**	**Low tide**	**Low tide +1 hr**
Baseline flows – 45 l/s (treated sewage 13 l/s)								
20 mg/l	21	81.3	4.36	2.75	4.58	2.57	7.16	3.52
40 mg/l	21	90.1	9.13	5.80	6.47	5.33	11.74	4.96
60 mg/l	21	93.0	13.34	8.66	7.76	8.21	12.68	18.77
80 mg/l	21	94.6	17.55	11.63	8.88	11.01	14.16	46.04
Alternate flows – 45 l/s (treated sewage 23 l/s)								
20 mg/l	21	87.5	7.00	4.35	5.73	4.02	8.99	4.8
40 mg/l	21	93.6	14.72	9.61	8.14	9.11	13.17	30.12
60 mg/l	21	95.7	22.09	14.71	9.97	14.13	20.78	62.82
80 mg/l	21	96.7	29.47	19.77	12.44	19.05	21.68	82.08
				Limiting distance (lmax) due to TIDAL REVERSAL has been reached[1].				

[1] lmax is the maximum distance CORMIX can determine in one direction before the direction of the tidal currents reverses due to the state of the tide and the plume travels back on itself.

5.2 GETM reanalysis

5.2.1 Un-ionised ammonia

High levels of ammonia will be discharge during commissioning overlapping with the construction discharge (38 l/s at 10 mg/l + 70 l/s at 271 mg/l). These discharges have been modelled based on the original flows and concentrations in BEEMS Technical Report TR428. This modelling was then extrapolated to determine the mixing zones for un-ionised ammonia (and total ammonia) by determining the additional total mass as a percentage of the original flows. Table 6 and Table 7 summarise the total mass of each source of ammonia and their contribution to the total mass of ammonia, for the baseline flows and the alternative flows (treated sewage is increased by 10 l/s and groundwater decreased by 10 l/s). From the additional percentage increases for the different flow scenarios, the additional un-ionised ammonia concentration at the location of the *Corallina* and *Sabellaria*, has been calculated and is summarised in Table 8.

During the period where the construction and commissioning discharges overlap, the discharge scenarios led to an estimated additional 0.11 to 0.31 µg/l of un-ionised ammonia with the original flow rates and 0.06 to 0.61 µg/l of un-ionised ammonia with the alternative flow rates at the locations of the sensitive biological receptors (*Sabellaria* and *Corallina*). These values are based on the original un-ionised ammonia time series, shown in BEEMS Technical Report TR428[4], and apply the additional percentage increase based on the total ammonia which, under the original (baseline) scenario, had an average exposure of 2 µg/l over the length of the combined construction and commissioning discharges.

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[4] The calculation of un-ionised ammonia from total ammonia used the conditions of the receiving ambient seawater with a salinity of 31.5, pH of 7.86 and temperature of 12.5°C (refer to BEEMS Technical Report TR428)

Table 6: Summary of the contributions to the total mass of ammonia from the different sources, for the different treated sewage scenarios using the baseline flows.

Scenario	Source	Flow (l/s)	Concentration (mg/l)	Duration (hrs)	Mass (kg/day)
Baseline - 20 mg/l	Treated sewage	13.3	20	24	22.982
	Groundwater	25	4.732	24	10.221
	Commissioning	70	271	5.95	406.34
	Total mass				**439.54**
Baseline - 40 mg/l	Treated sewage	13.3	40	24	45.965
	Groundwater	25	4.732	24	10.221
	Commissioning	70	271	5.95	406.34
	Total mass (percentage increase)				**462.52 (4.97%)**
Baseline - 60 mg/l	Treated sewage	13.3	60	24	68.947
	Groundwater	25	4.732	24	10.221
	Commissioning	70	271	5.95	406.34
	Total mass (percentage increase)				**485.51 (9.47%)**
Baseline - 80 mg/l	Treated sewage	13.3	80	24	91.930
	Groundwater	25	4.732	24	10.221
	Commissioning	70	271	5.95	406.34
	Total mass (percentage increase)				**508.49 (13.56%)**

Table 7: Summary of the contributions to the total mass of ammonia from the different sources, for the different sewage scenarios using the alternative flows.

Scenario	Source	Flow	Concentration	Duration	Mass
		(l/s)	(mg/l)	(hrs)	(kg/day)
Alternative - 20 mg/l	Treated sewage	23.3	20	24	40.262
	Groundwater	15	4.732	24	6.133
	Commissioning	70	271	5.95	406.34
				Total mass (percentage increase)	**452.73 (2.91%)**
Alternative - 40 mg/l	Treated sewage	23.3	40	24	80.525
	Groundwater	15	4.732	24	6.133
	Commissioning	70	271	5.95	406.34
				Total mass (percentage increase)	**492.99 (10.84%)**
Alternative - 60 mg/l	Treated sewage	23.3	60	24	120.787
	Groundwater	15	4.732	24	6.133
	Commissioning	70	271	5.95	406.34
				Total mass (percentage increase)	**533.26 (17.57%)**
Alternative - 80 mg/l	Treated sewage	23.3	80	24	161.050
	Groundwater	15	4.732	24	6.133
	Commissioning	70	271	5.95	406.34
				Total mass (percentage increase)	**573.52 (23.36%)**

Table 8: Summary of the additional un-ionised ammonia concentration at the location of the *Corallina* and *Sabellaria*, with the baseline construction and commissioning discharges.

Flow	**Source**	**Un-ionised ammonia (ug/l)**	**Difference from baseline (ug/l)**	**Un-ionised ammonia (ug/l)**	**Difference from baseline (ug/l)**	**Un-ionised ammonia (ug/l)**	**Difference from baseline (ug/l)**	**Un-ionised ammonia (ug/l)**	**Difference from baseline (ug/l)**
		20 mg/l		40 mg/l		60 mg/l		80 mg/l	
Baseline	Treated sewage	0.105	0.000	0.209	0.105	0.314	0.209	0.418	0.314
	Groundwater	0.047	0.000	0.047	0.000	0.047	0.000	0.047	0.000
	Commissioning	1.849	0.000	1.849	0.000	1.849	0.000	1.849	0.000
	Total	2.000	0.000	2.105	0.105	2.209	0.209	2.314	0.314
Alternative	Treated sewage	0.183	0.079	0.366	0.262	0.550	0.445	0.733	0.628
	Groundwater	0.028	-0.019	0.028	-0.019	0.028	-0.019	0.028	-0.019
	Commissioning	1.849	0.000	1.849	0.000	1.849	0.000	1.849	0.000
	Total	2.060	0.060	2.243	0.243	2.426	0.426	2.610	0.610

To assess the exposure of un-ionised ammonia at the locations of the *Corallina* and *Sabellaria*, the additional un-ionised ammonia, summarised in Table 8, have been added to the instantaneous time series of un-ionised ammonia concentrations at the eight *Corallina* locations (Figure 13) and seven *Sabellaria* locations (Figure 14). Figure 14 shows that for the 80 mg/l scenario with the alternative flow rates, the maximum instantaneous value (10.4 µg/l) was below the EQS of 21 µg/l. Plots of the individual time series for each *Corallina* and *Sabellaria* stations are shown in Appendix A. The mean and 95th percentile concentrations of un-ionised ammonia at the *Corallina* and *Sabellaria* features for the 20, 40, 60 and 80 mg/l scenarios with the baseline and alternative flows are summarised in Table 9 to Table 12.

Figure 15 show the spatial plots of the surface 95th percentile un-ionised ammonia for the construction and commissioning discharges for the 80 mg/l scenario with alternative flows. Table 13 summarises the area of exceedance above the EQS for un-ionised ammonia for all scenarios.

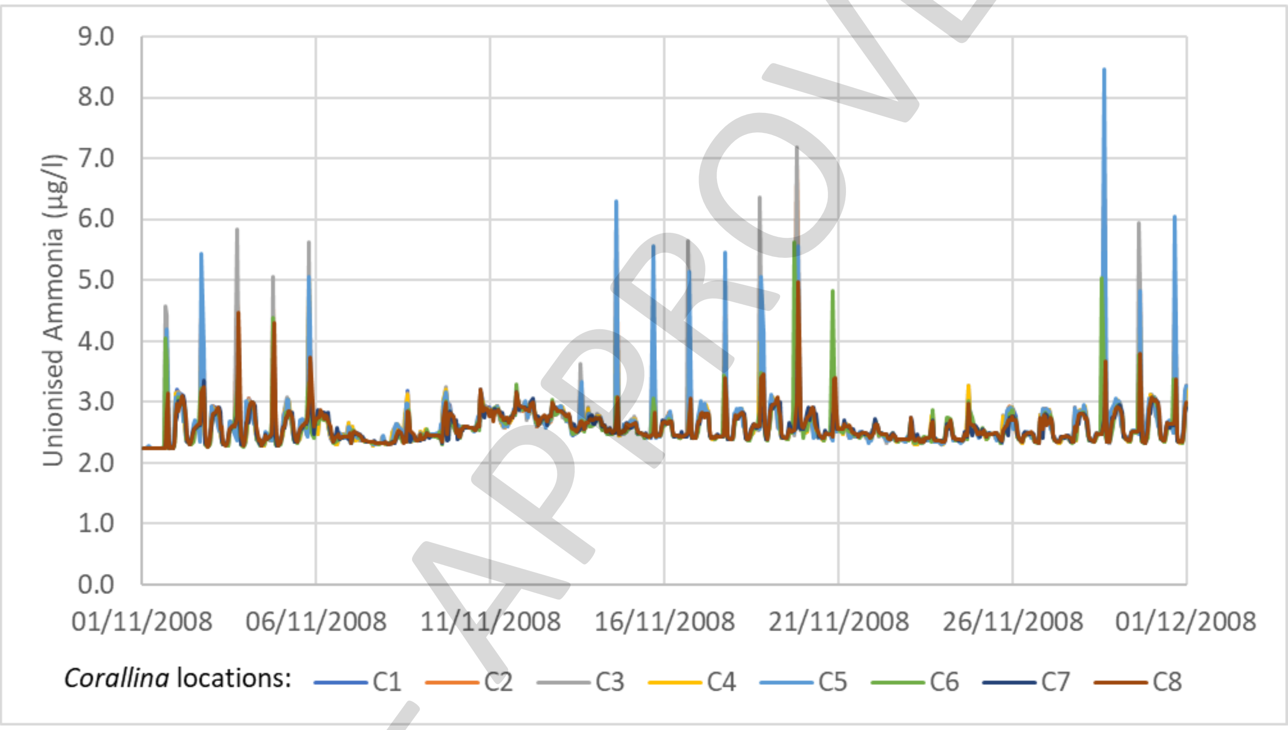

Figure 13: Time series of un-ionised ammonia at the locations of Corallina for the alternative 38 l/s at 80 mg/l+70 l/s at 271 mg/l scenario using mean conditions of temperature, salinity, and pH.

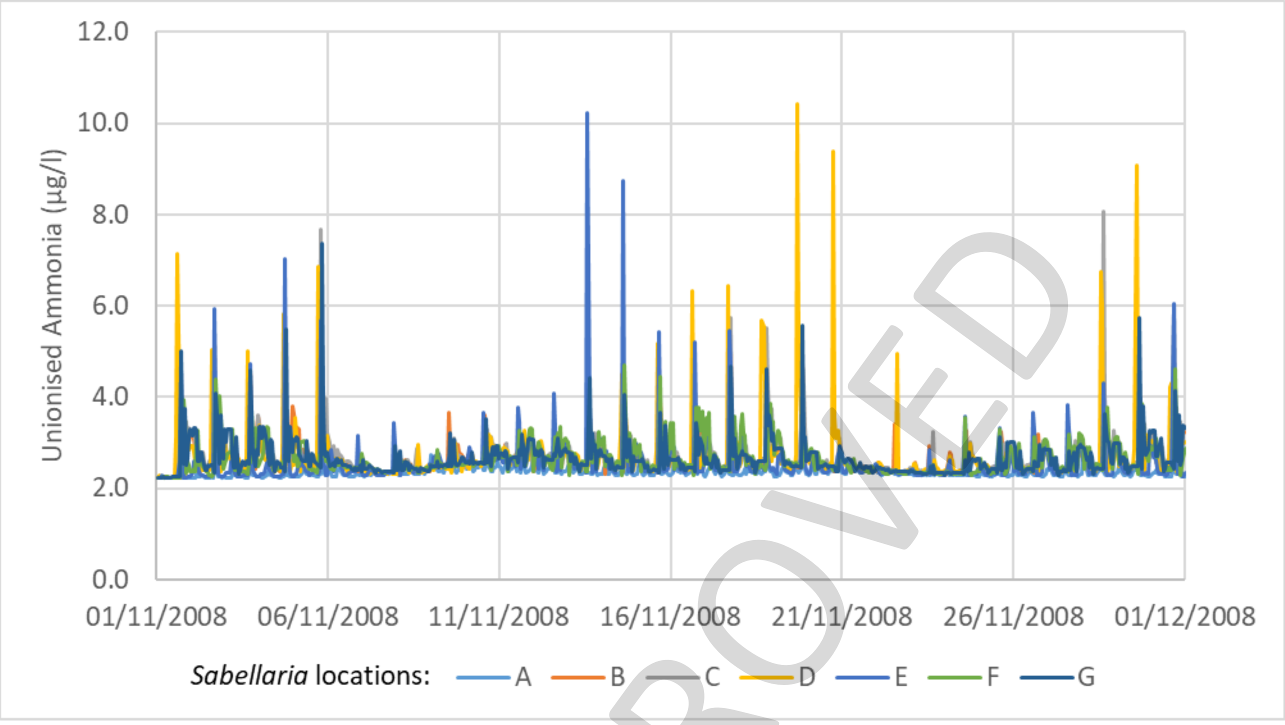

Figure 14: Time series of un-ionised ammonia at the locations of Sabellaria for the alternative 38 l/s at 80 mg/l +70 l/s at 271 mg/l scenario using mean conditions of temperature, salinity, and pH.

Table 9: Summary of un-ionised ammonia (μg/l) at *Sabellaria* features (A – G) for mean temperatures, with the baseline flows.

Scenario	**20 mg/l**		**40 mg/l**		**60 mg/l**		**80 mg/l**	
Location	Mean	95th percentile	Mean	95th percentile	Mean	95th percentile	Mean	95th percentile
A	1.74	1.90	1.84	2.01	1.95	2.11	2.05	2.22
B	2.01	2.60	2.11	2.71	2.22	2.81	2.32	2.91
C	2.08	2.68	2.19	2.79	2.29	2.89	2.40	3.00
D	2.07	2.56	2.18	2.67	2.28	2.77	2.38	2.88
E	1.95	2.54	2.06	2.65	2.16	2.75	2.27	2.86
F	2.03	2.72	2.13	2.82	2.24	2.93	2.34	3.03
G	2.05	2.71	2.15	2.82	2.26	2.92	2.36	3.03

Table 10: Summary of un-ionised ammonia (µg/l) at *Sabellaria* features (A – G) for mean temperatures, with the alternative flows.

Scenario	**20 mg/l**		**40 mg/l**		**60 mg/l**		**80 mg/l**	
Location	Mean	95th percentile	Mean	95th percentile	Mean	95th percentile	Mean	95th percentile
A	1.80	1.96	1.98	2.15	2.16	2.33	2.35	2.51
B	2.07	2.66	2.25	2.84	2.43	3.03	2.62	3.21
C	2.14	2.74	2.33	2.92	2.51	3.11	2.69	3.29
D	2.13	2.62	2.31	2.81	2.50	2.99	2.68	3.17
E	2.01	2.60	2.19	2.79	2.38	2.97	2.56	3.15
F	2.09	2.78	2.27	2.96	2.45	3.15	2.64	3.33
G	2.11	2.77	2.29	2.96	2.47	3.14	2.66	3.32

Table 11: Summary of un-ionised ammonia (µg/l) at *Corallina* features (1 – 8) for mean temperatures, with the baseline flows.

Scenario	**20 mg/l**		**40 mg/l**		**60 mg/l**		**80 mg/l**	
Location	Mean	95th percentile	Mean	95th percentile	Mean	95th percentile	Mean	95th percentile
C1	1.97	2.41	2.07	2.52	2.18	2.62	2.28	2.73
C2	2.01	2.50	2.12	2.60	2.22	2.71	2.33	2.81
C3	2.01	2.48	2.12	2.58	2.22	2.69	2.33	2.79
C4	1.98	2.44	2.09	2.54	2.19	2.65	2.30	2.75
C5	2.03	2.48	2.13	2.58	2.24	2.69	2.34	2.79
C6	1.97	2.43	2.08	2.54	2.18	2.64	2.29	2.75
C7	1.96	2.32	2.06	2.43	2.17	2.53	2.27	2.64
C8	1.98	2.39	2.09	2.49	2.19	2.60	2.30	2.70

Table 12: Summary of un-ionised ammonia (µg/l) at *Corallina* features (1 – 8) for mean temperatures, with the alternative flows.

Scenario	**20 mg/l**		**40 mg/l**		**60 mg/l**		**80 mg/l**	
Location	Mean	95th percentile	Mean	95th percentile	Mean	95th percentile	Mean	95th percentile
C1	2.03	2.47	2.21	2.66	2.40	2.84	2.58	3.02
C2	2.07	2.56	2.26	2.74	2.44	2.93	2.62	3.11
C3	2.07	2.54	2.26	2.72	2.44	2.90	2.62	3.09
C4	2.04	2.50	2.23	2.68	2.41	2.86	2.59	3.05
C5	2.09	2.54	2.27	2.72	2.46	2.91	2.64	3.09
C6	2.03	2.49	2.22	2.68	2.40	2.86	2.58	3.04
C7	2.02	2.38	2.20	2.57	2.38	2.75	2.57	2.93
C8	2.04	2.45	2.23	2.63	2.41	2.81	2.59	3.00

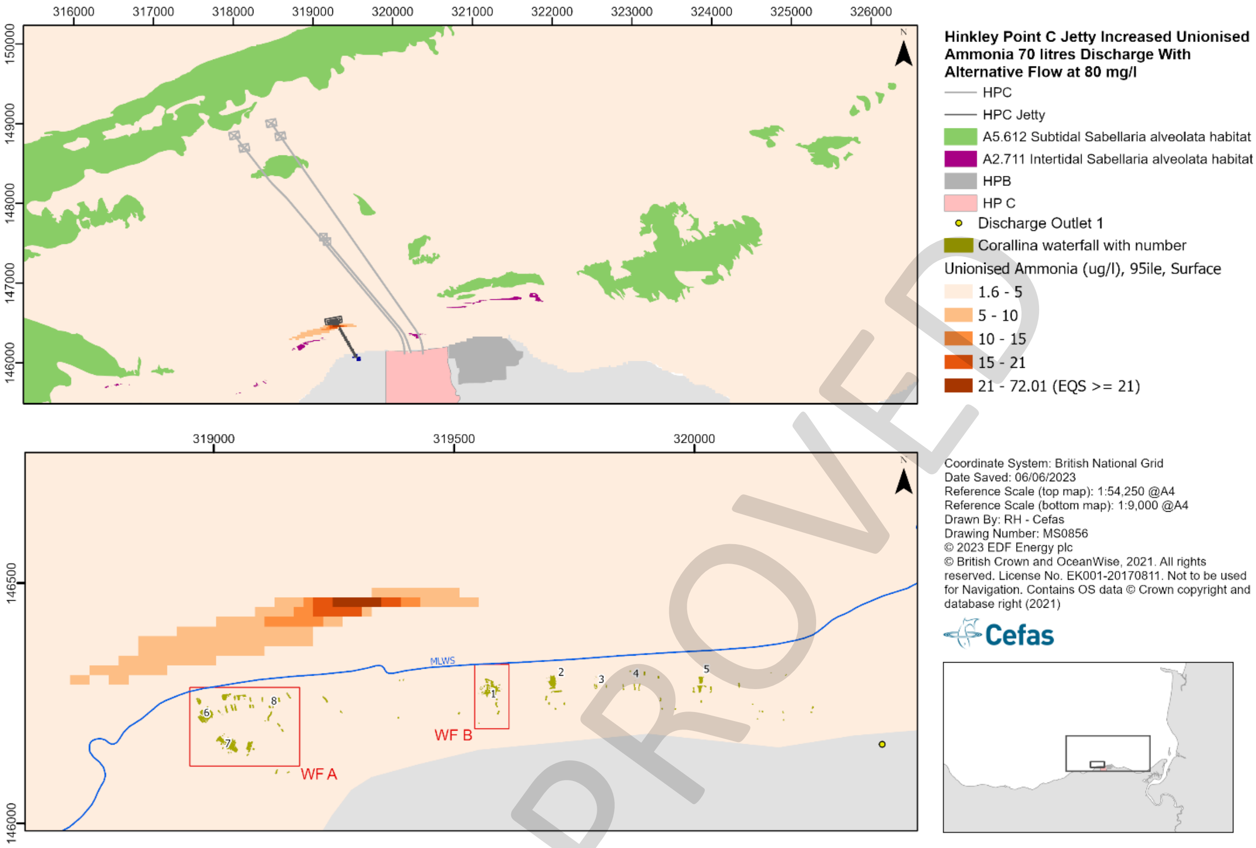

Figure 15: Surface 95th percentile un-ionised ammonia (38 l/s at 80 mg/l+ 70 l/s at 271 mg/l). The upper panel includes the intertidal and subtidal *Sabellaria*. The closest *Sabellaria* to the discharge is in the intertidal near station 8.The lower panel includes *Corallina* waterfalls.

Table 13: Area of exceedance for un-ionised ammonia from GETM model.

Flows	Scenario	20 mg/l		40 mg/l		60 mg/l		80 mg/l	
		Area > 21 µg/l Bed	Area > 21 µg/l Surface	Area > 21 µg/l Bed	Area > 21 µg/l Surface	Area > 21 µg/l Bed	Area > 21 µg/l Surface	Area > 21 µg/l Bed	Area > 21 µg/l Surface
Baseline	Construction (38 l/s) + Commissioning (70 l/s) Mean	No exceedance	No exceedance	No exceedance	No exceedance	No exceedance	No exceedance	No exceedance	No exceedance
	Construction (38 l/s) + Commissioning (70 l/s) 95th percentile	No exceedance	0.20 ha	No exceedance	0.20 ha	No exceedance	0.20 ha	No exceedance	0.20 ha
Alternative	Construction (38 l/s) + Commissioning (70 l/s) Mean	No exceedance	No exceedance	No exceedance	No exceedance	No exceedance	No exceedance	No exceedance	No exceedance
	Construction (38 l/s) + Commissioning (70 l/s) 95th percentile	No exceedance	0.20 ha	No exceedance	0.20 ha	No exceedance	0.20 ha	No exceedance	0.20 ha

5.2.2 Total ammonia

For total ammonia, the PNEC based on the mean value is 1.1 mg/l, whilst the MAC based on the 95th percentile is 8 mg/l. The MAC was not exceeded at the surface or bed in any scenario, but the PNEC was exceeded at the surface but only for a maximum of 0.04 ha (equivalent to 1 grid cell in the model and the point of immediate discharge). In reality both the PNEC and MAC will be exceeded immediately at the point of discharge, but as the mixing would occur at a sub grid cell level, this is not seen in the GETM model. Figure 16 and Figure 17 show the spatial plots of the surface mean and 95th percentile total ammonia for the construction and commissioning discharges for the 80 mg/l scenario with alternative flows. Table 14 summarises the area of exceedance above the PNEC and MAC for total ammonia for all scenarios.

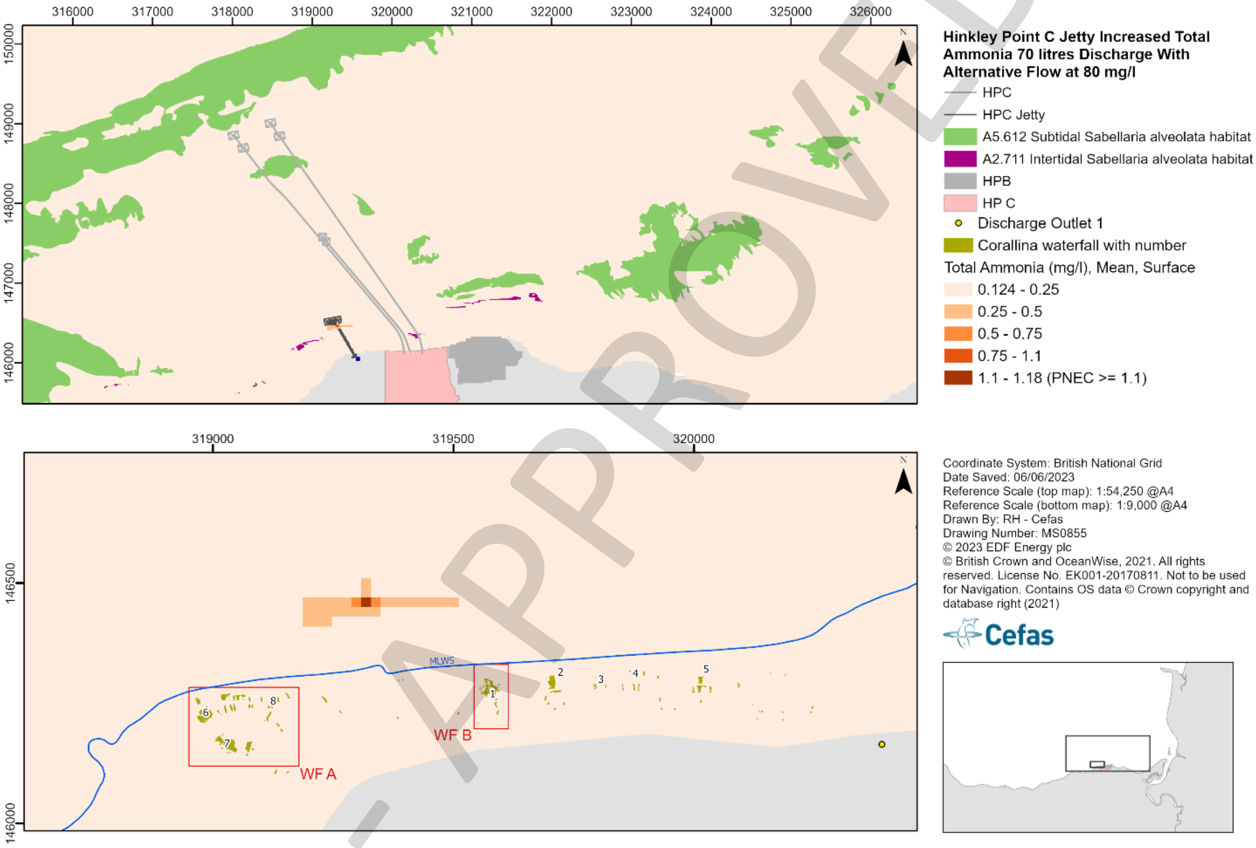

Figure 16: Surface mean ammonia concentration (mg/l) for the 80 mg/l at 70 l/s discharge simulation. The upper panel includes the intertidal and subtidal *Sabellaria*. The closest *Sabellaria* to the discharge is in the intertidal near station 8.The lower panel includes *Corallina* waterfalls.

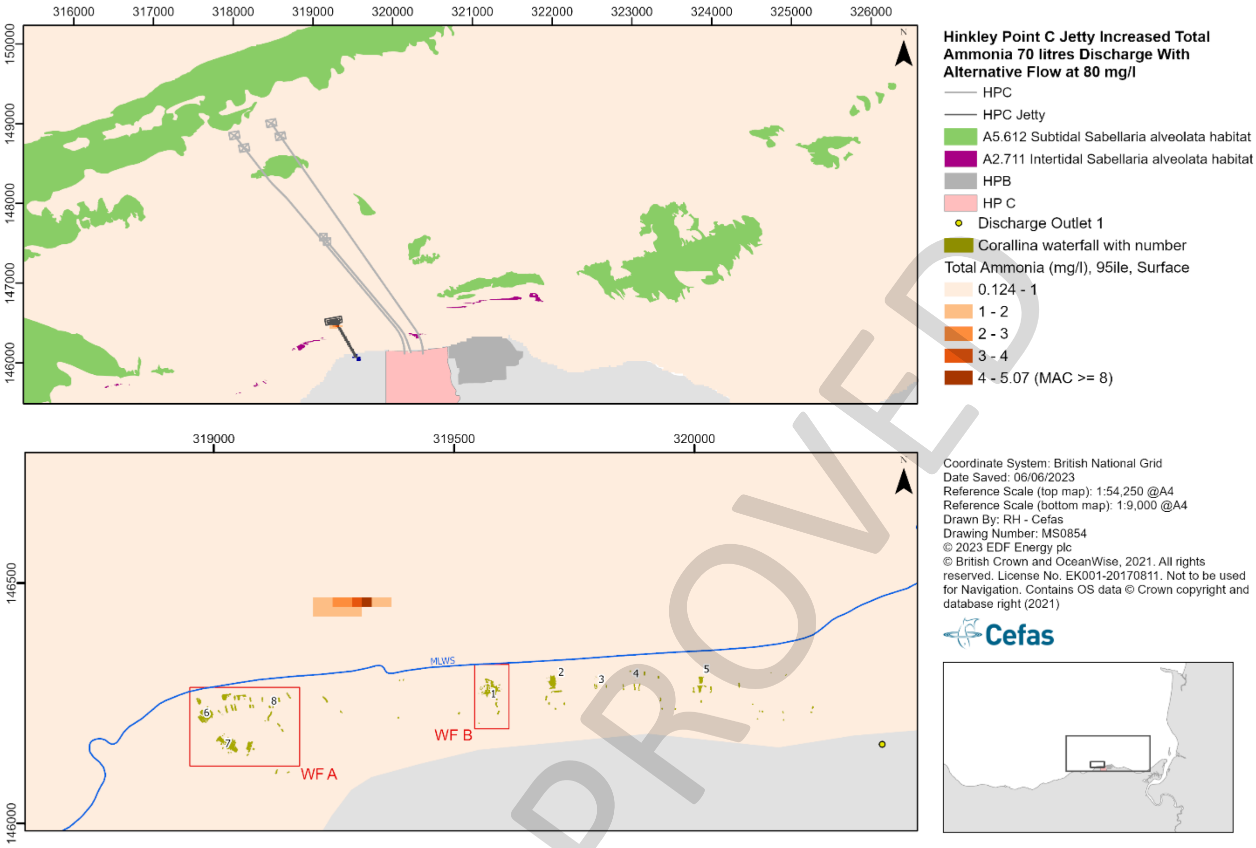

Figure 17: 95th percentile surface concentration (mg/l) of ammonia for 80 mg/l at 70 l/s. No value exceeds > 8000 µg/l MAC. The upper panel includes the intertidal and subtidal *Sabellaria*. The closest *Sabellaria* to the discharge is in the intertidal near station 8.The lower panel includes *Corallina* waterfalls.

Table 14: Area of exceedance for total ammonia, above the PNEC (1.1 mg/l) and MAC (8 mg/l) from GETM model.

Flows	Scenario	20 mg/l		40 mg/l		60 mg/l		80 mg/l	
		Area > 1.1 mg/l Bed	Area > 1.1 mg/l Surface	Area > 1.1 mg/l Bed	Area > 1.1 mg/l Surface	Area > 1.1 mg/l Bed	Area > 1.1 mg/l Surface	Area > 1.1 mg/l Bed	Area > 1.1 mg/l Surface
Baseline	Construction (38 l/s) + Commissioning (70 l/s) Mean	No exceedance	No exceedance	No exceedance	No exceedance	No exceedance	0.04 ha	No exceedance	0.04 ha
Alternative	Construction (38 l/s) + Commissioning (70 l/s) Mean	No exceedance	No exceedance	No exceedance	0.04 ha	No exceedance	0.04 ha	No exceedance	0.04 ha
Flows	Scenario	20 mg/l		40 mg/l		60 mg/l		80 mg/l	
		Area > 8 mg/l Bed	Area > 8 mg/l Surface	Area > 8 mg/l Bed	Area > 8 mg/l Surface	Area > 8 mg/l Bed	Area > 8 mg/l Surface	Area > 8 mg/l Bed	Area > 8 mg/l Surface
Baseline	Construction (38 l/s) + Commissioning (70 l/s) 95th percentile	No exceedance	No exceedance	No exceedance	No exceedance	No exceedance	No exceedance	No exceedance	No exceedance
Alternative	Construction (38 l/s) + Commissioning (70 l/s) 95th percentile	No exceedance	No exceedance	No exceedance	No exceedance	No exceedance	No exceedance	No exceedance	No exceedance

6 Conclusion

Seven alternative discharge scenarios, from the HPC sewage treatment works, have been tested and compared to the original construction discharge scenario (treated sewage ammoniacal nitrogen at 20 mg/l at 13.3 l/s + ground water 4.7 mg/l at 25 l/s). The additional scenarios included increasing the treated sewage ammoniacal nitrogen concentration to 40, 60 and 80 mg/l, plus alternative flows by increasing the treated sewage flowrate by 10 l/s and decreasing the groundwater flow by 10 l/s. The assessments considered both the construction only discharge, plus the combined construction and commissioning discharges.

Applying the Environment Agency's Screening tests, the results of 'test 5' shows that when considering construction alone each scenario tested was within permissible limits. However, the partitioning of un-ionised ammonia is influenced by the physical conditions and this partitioning is not factored into the basic screening tests. Therefore, while the screening test was passed, further assessment of the discharges in terms of mixing calculations and nearfield modelling was conducted. When considering the combined construction and commissioning discharges, due to the considerable increase in ammonia from the commissioning phase, the screening tests were not passed. However, this is consistent with previous assessments (BEEMS Technical Report TR428) which required modelling to fully assess the potential implications of the commissioning discharges.

For the construction only discharge, nearfield modelling using CORMIX shows the concentrations of un-ionised ammonia fall below the EQS (21 µg/l) within <7.16 m for the original scenario (i.e. treated sewage at 20 mg/l ammoniacal nitrogen). This distance to the EQS increased to a maximum of 46.04 m for the 80 mg/l discharge scenario, with the original flows, and to 82.08 m for 80 mg/l discharge with the alternative flow rates. While the estimated mixing zone was considerably larger under the new scenarios compared to the baseline scenario (increasing from ~7m to over 80m), the mixing zone was still very small in respect to the scale of the receiving environment and therefore is not expected to cause any significant environmental effects.

Reanalysis of the GETM modelling results show that during the period where the construction and commissioning discharges overlap, the discharge scenarios will lead to an estimated additional 0.11 to 0.31 µg/l of un-ionised ammonia with the original flow rates and 0.06 to 0.61 µg/l of un-ionised ammonia with the alternative flow rates at the locations of the sensitive biological receptors. From the time series of instantaneous un-ionised ammonia concentrations at the eight *Corallina* locations and seven *Sabellaria* locations, the maximum instantaneous value (10.4 µg/l) was below the EQS of 21 µg/l. For all scenarios, the area of exceedance of un-ionised ammonia as a 95th percentile has a maximum value of 0.2 ha at the surface and was not exceeded at the bed. For context the receiving water body (Bridgwater Bay) has a surface area of 9,224.5 ha, and therefore the area of exceedance represents 0.002% of the water body.

For total ammonia, the MAC (8 mg/l as a 95th percentile) was not exceeded at the surface or bed in any scenario, but the PNEC (1.1 mg/l as a mean) was exceeded at the surface only, however only for a maximum of 0.04 ha (equivalent to 1 grid cell in the model and the point of immediate discharge).

The overall conclusion was that all of the scenarios considered would not lead to significant environmental effects.

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Appendix A Additional Plots

A.1 Time series of ammonia discharge

Figure 18 to Figure 25 show the individual time series of un-ionised ammonia at the *Corallina* locations C1-C8, as originally shown grouped in Figure 13. Figure 26 to Figure 32 show the individual time series of un-ionised ammonia at the *Sabellaria* locations A – G, as originally shown grouped in Figure 14.

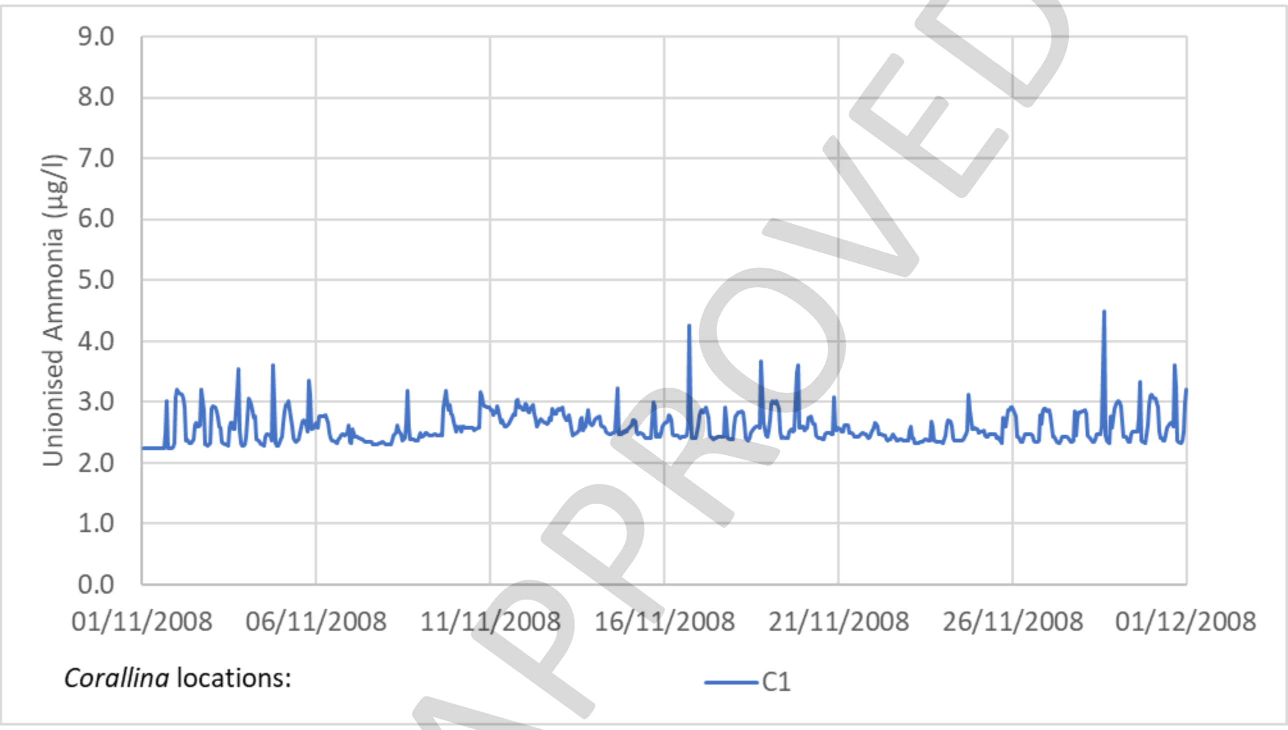

Figure 18: Time series of un-ionised ammonia at the *Corallina* location C1 for the alternative 38 l/s at 80 mg/l+70 l/s at 271 mg/l scenario using mean conditions of temperature, salinity, and pH.

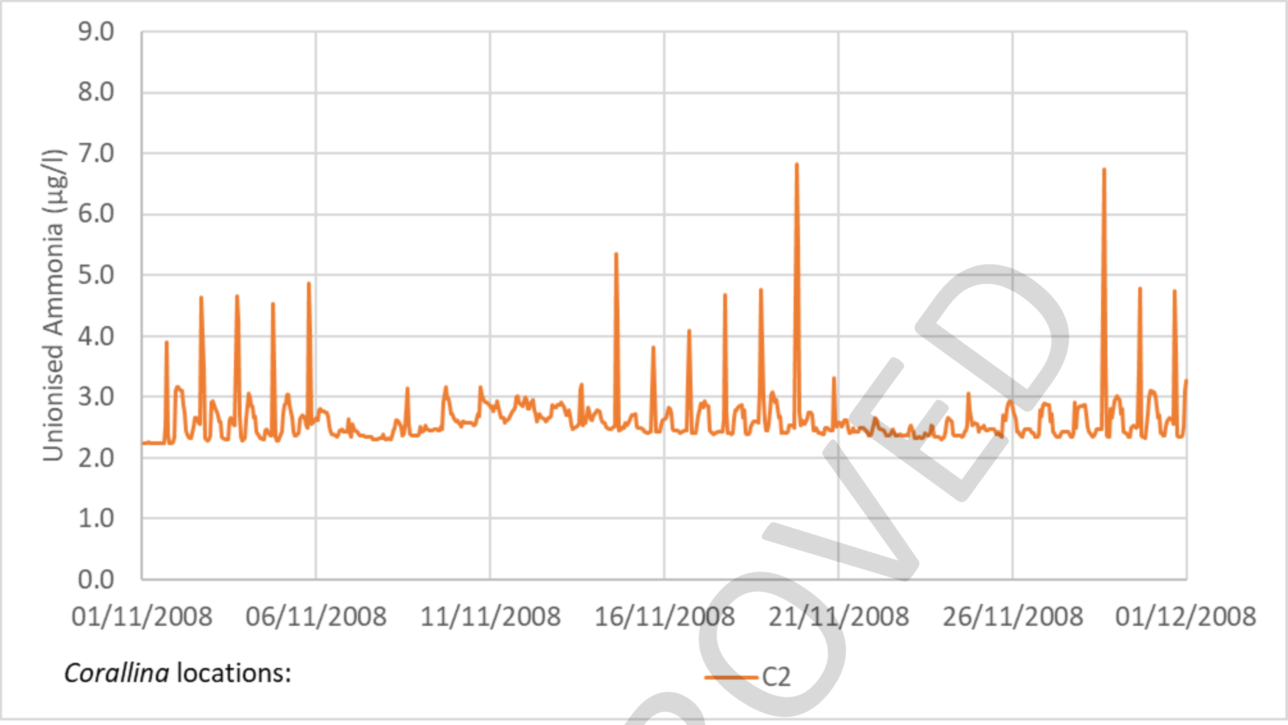

Figure 19: Time series of un-ionised ammonia at the *Corallina* location C2 for the alternative 38 l/s at 80 mg/l+70 l/s at 271 mg/l scenario using mean conditions of temperature, salinity, and pH.

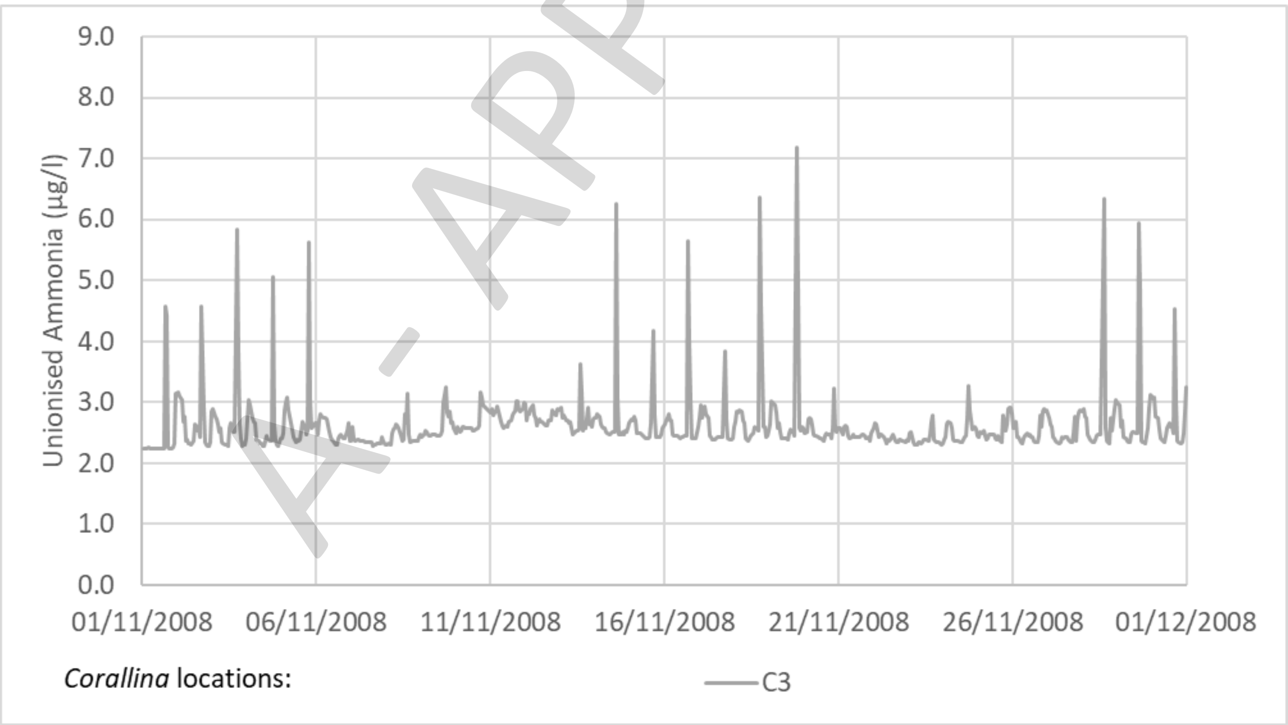

Figure 20: Time series of un-ionised ammonia at the *Corallina* location C3 for the alternative 38 l/s at 80 mg/l+70 l/s at 271 mg/l scenario using mean conditions of temperature, salinity, and pH.

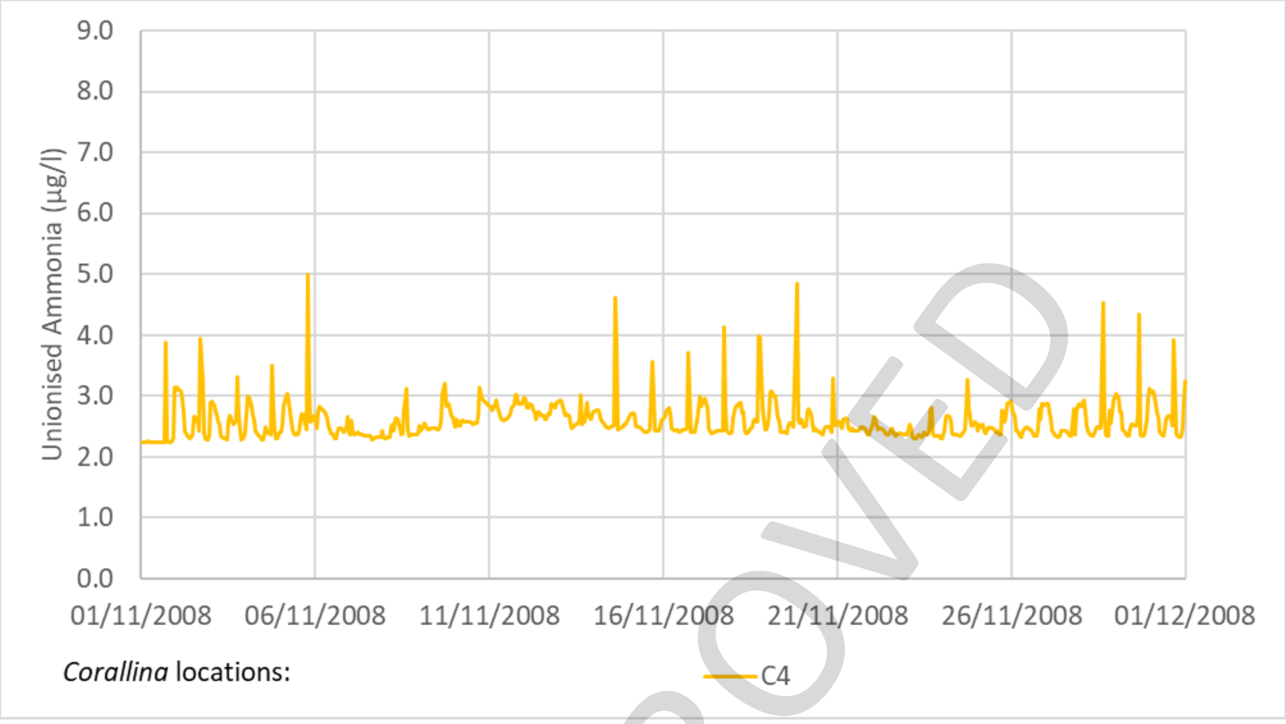

Figure 21: Time series of un-ionised ammonia at the *Corallina* location C4 for the alternative 38 l/s at 80 mg/l+70 l/s at 271 mg/l scenario using mean conditions of temperature, salinity, and pH.

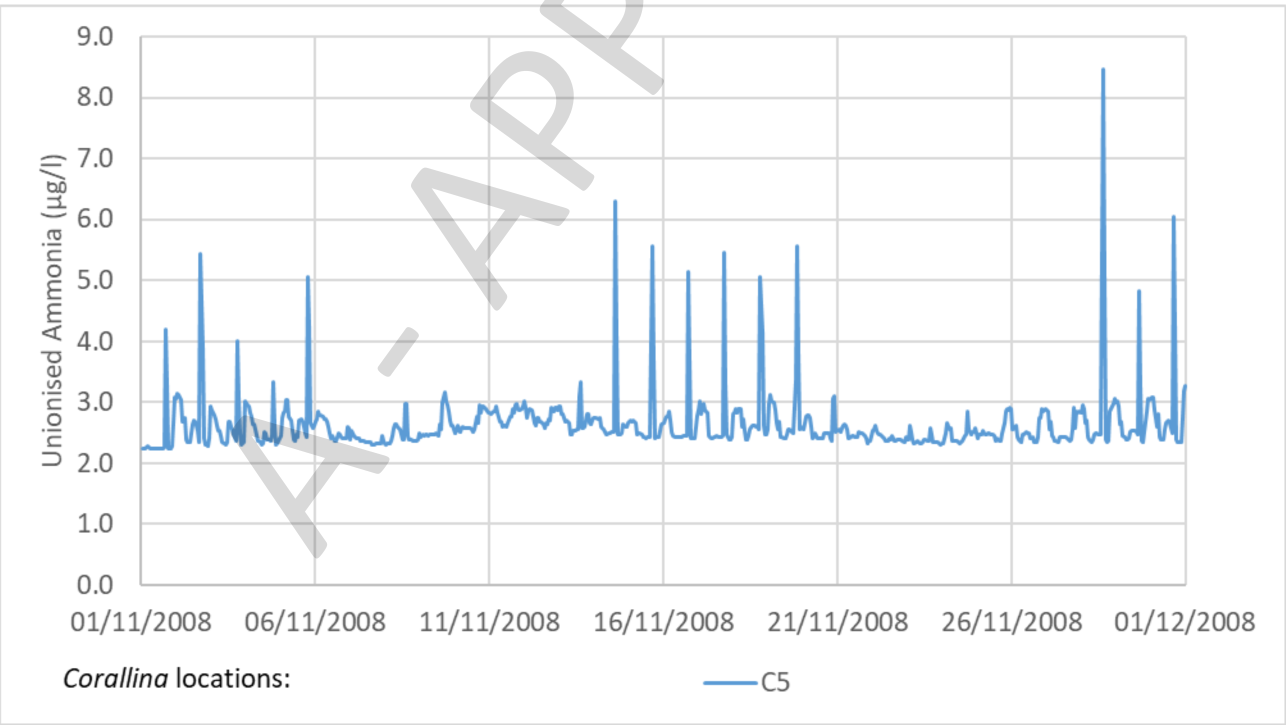

Figure 22: Time series of un-ionised ammonia at the *Corallina* location C5 for the alternative 38 l/s at 80 mg/l+70 l/s at 271 mg/l scenario using mean conditions of temperature, salinity, and pH.

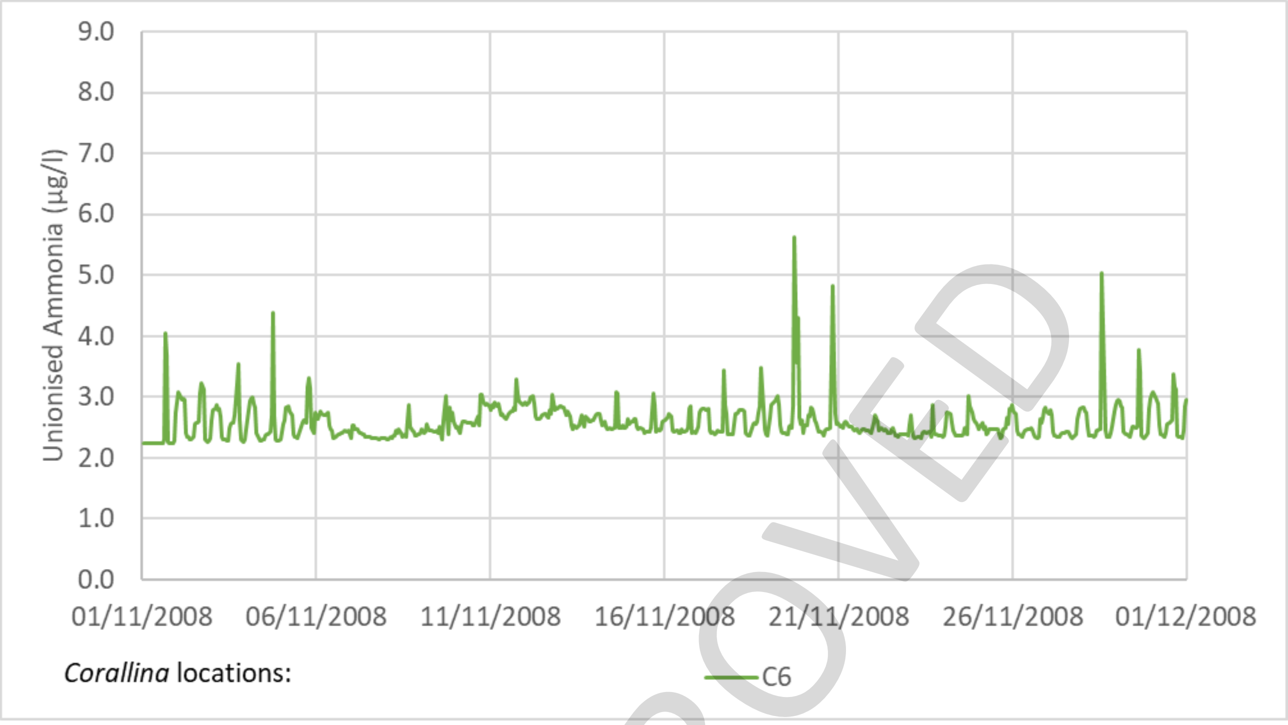

Figure 23: Time series of un-ionised ammonia at the *Corallina* location C6 for the alternative 38 l/s at 80 mg/l+70 l/s at 271 mg/l scenario using mean conditions of temperature, salinity, and pH.

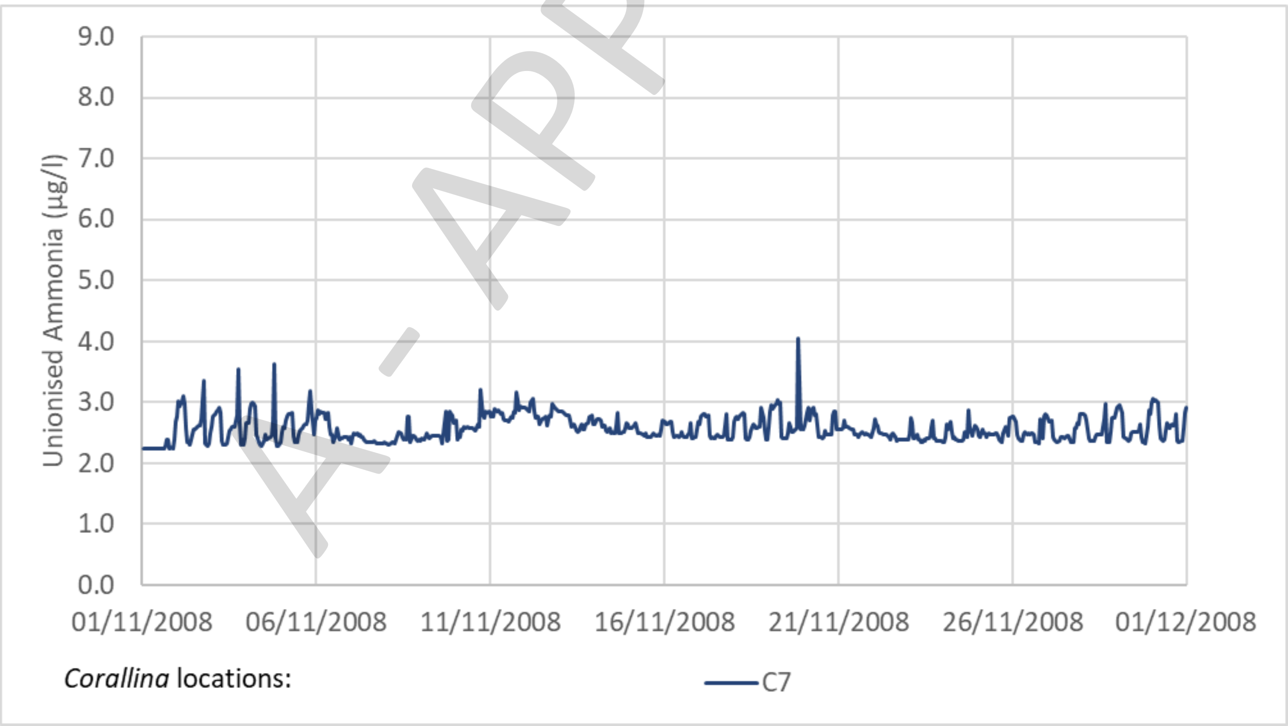

Figure 24: Time series of un-ionised ammonia at the *Corallina* location C7 for the alternative 38 l/s at 80 mg/l+70 l/s at 271 mg/l scenario using mean conditions of temperature, salinity, and pH.

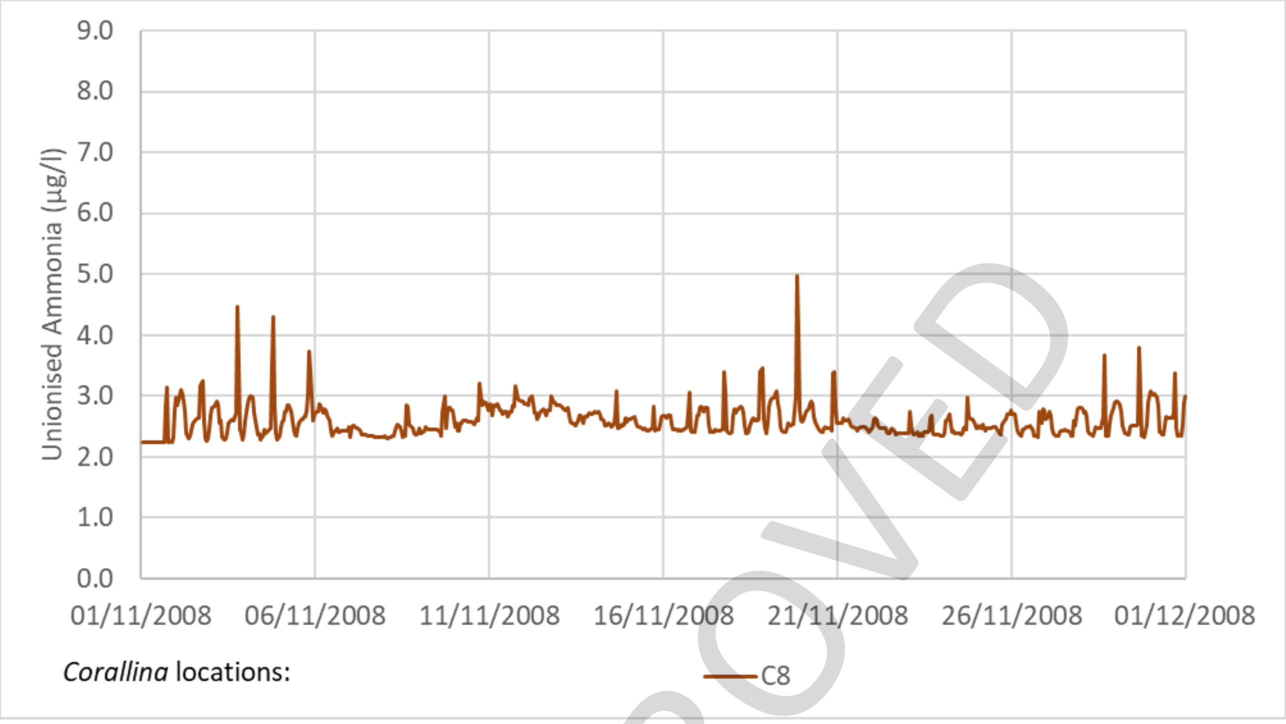

Figure 25: Time series of un-ionised ammonia at the *Corallina* location C8 for the alternative 38 l/s at 80 mg/l+70 l/s at 271 mg/l scenario using mean conditions of temperature, salinity, and pH.

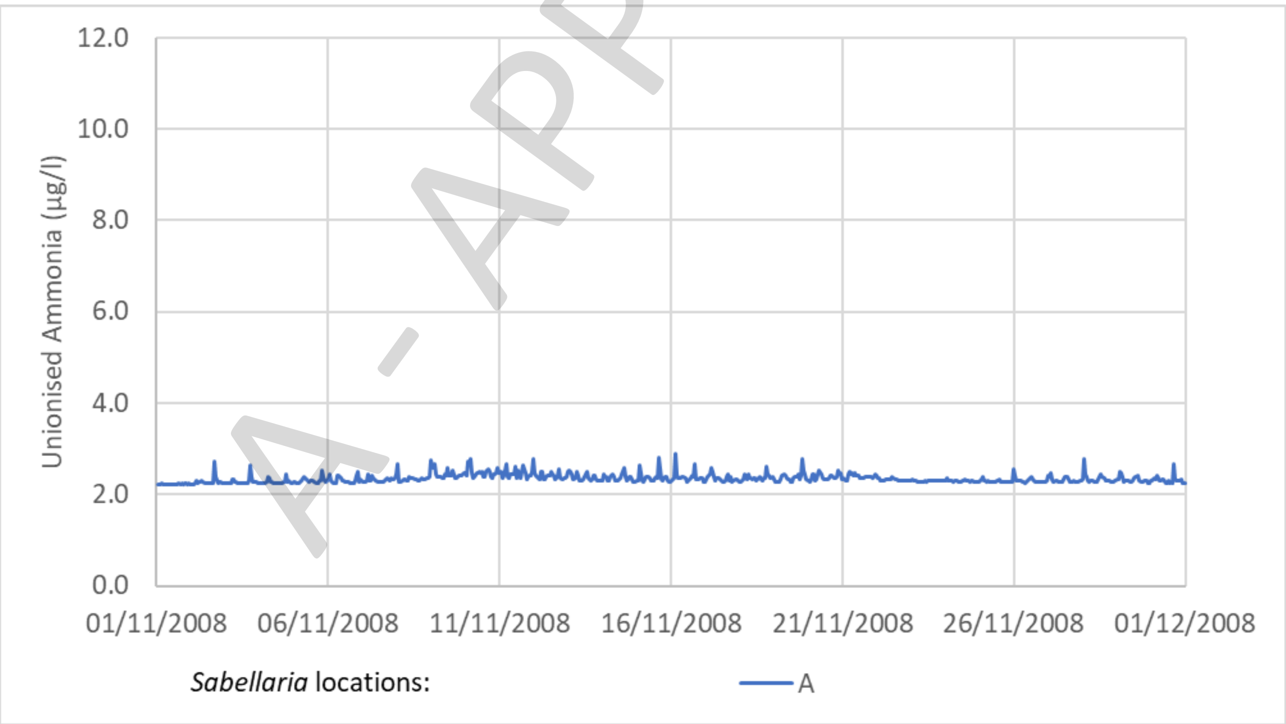

Figure 26: Time series of un-ionised ammonia at the *Sabellaria* location A for the alternative 38 l/s at 80 mg/l +70 l/s at 271 mg/l scenario using mean conditions of temperature, salinity, and pH.

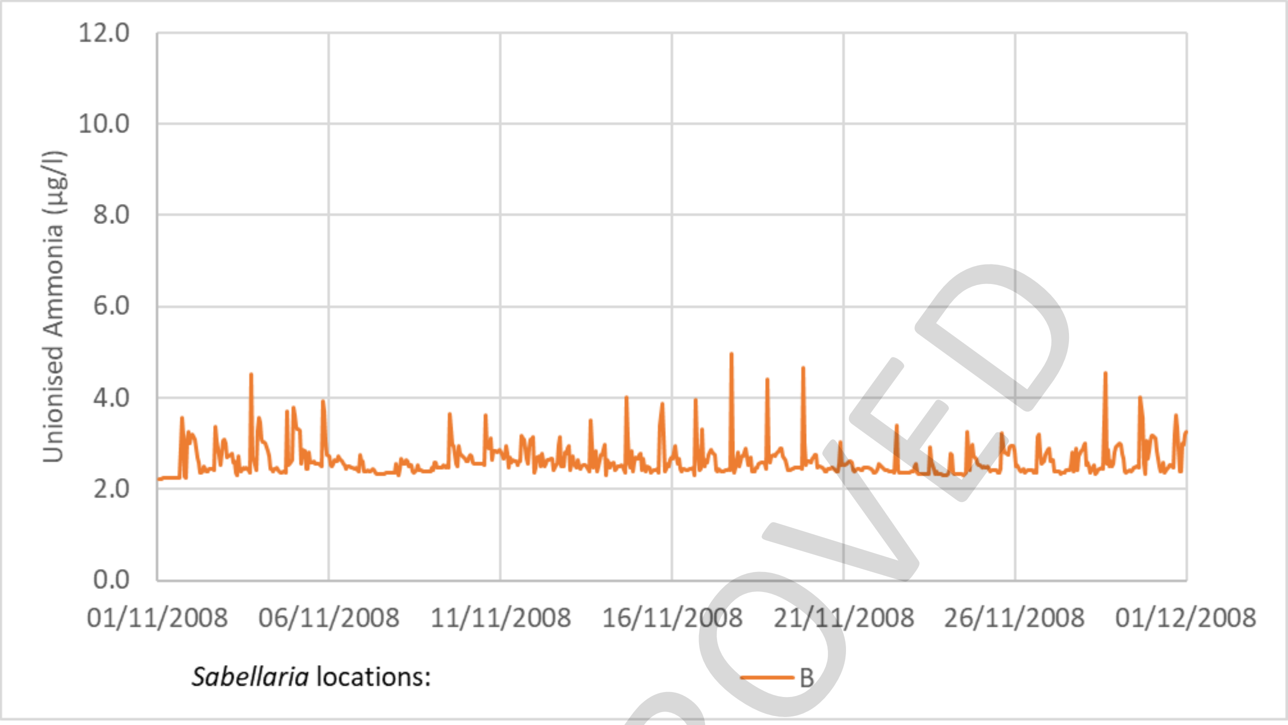

Figure 27: Time series of un-ionised ammonia at the *Sabellaria* location B for the alternative 38 l/s at 80 mg/l +70 l/s at 271 mg/l scenario using mean conditions of temperature, salinity, and pH.

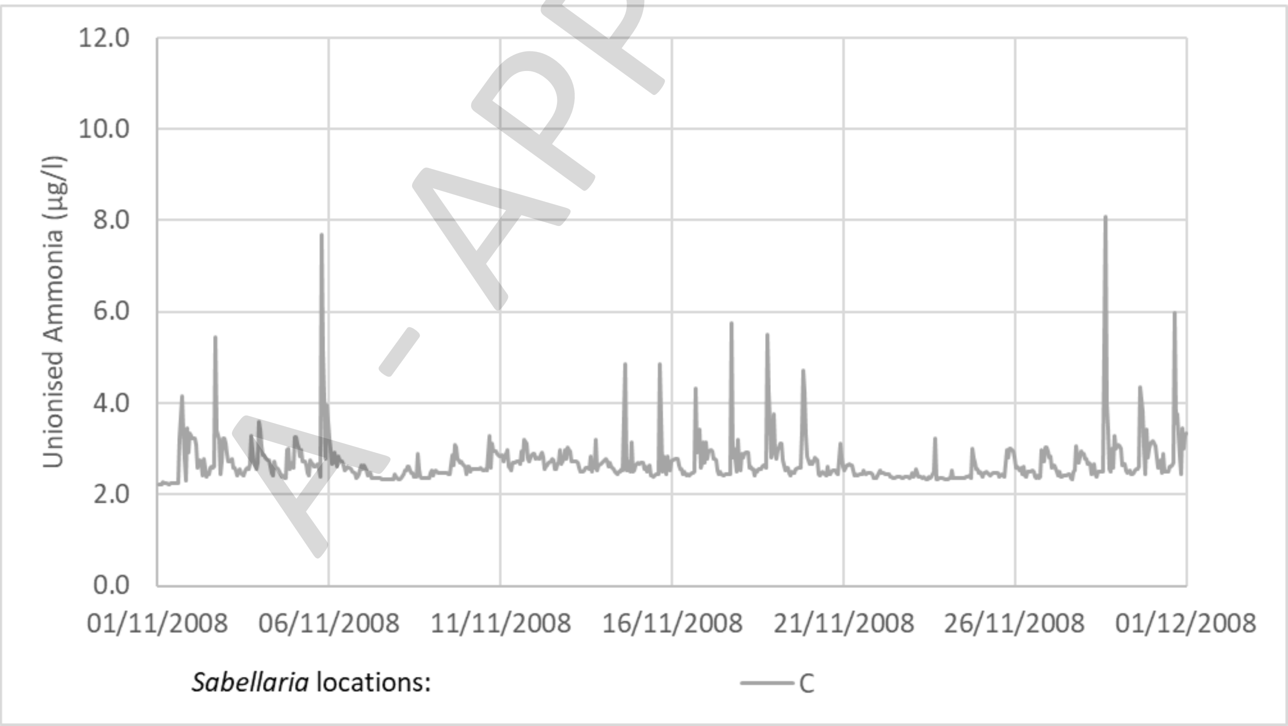

Figure 28: Time series of un-ionised ammonia at the *Sabellaria* location C for the alternative 38 l/s at 80 mg/l +70 l/s at 271 mg/l scenario using mean conditions of temperature, salinity, and pH.

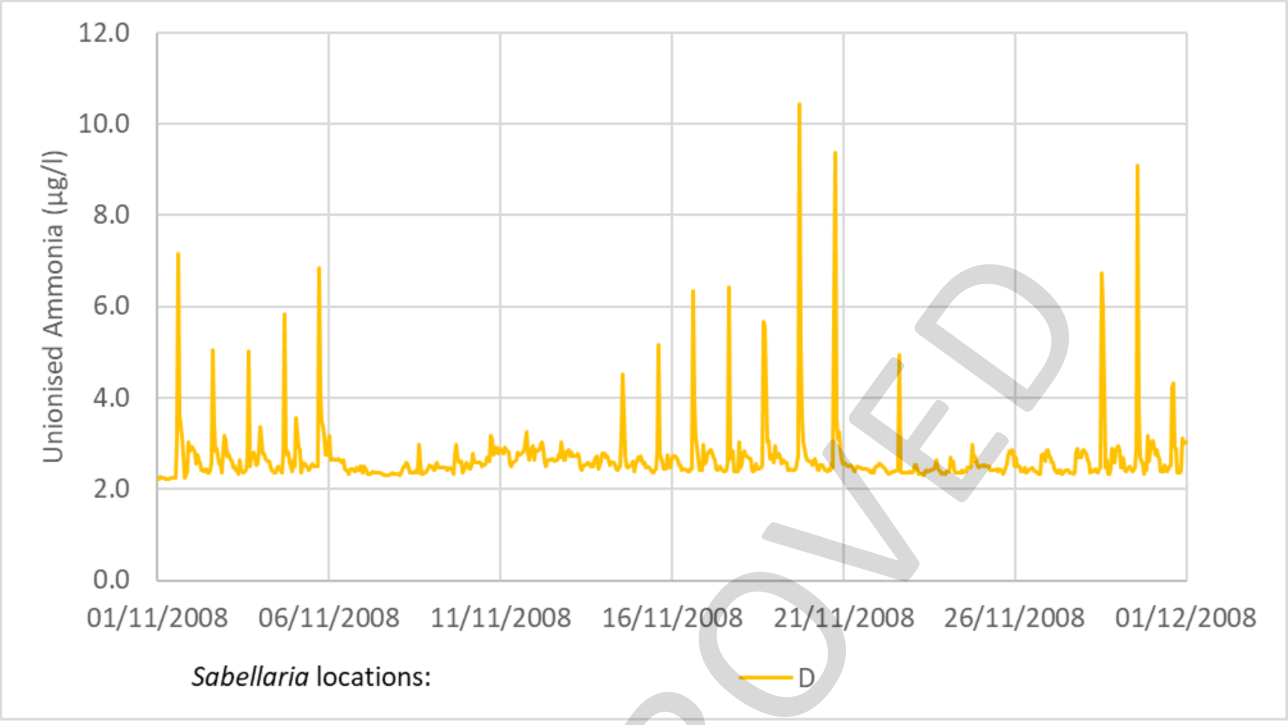

Figure 29: Time series of un-ionised ammonia at the *Sabellaria* location D for the alternative 38 l/s at 80 mg/l +70 l/s at 271 mg/l scenario using mean conditions of temperature, salinity, and pH.

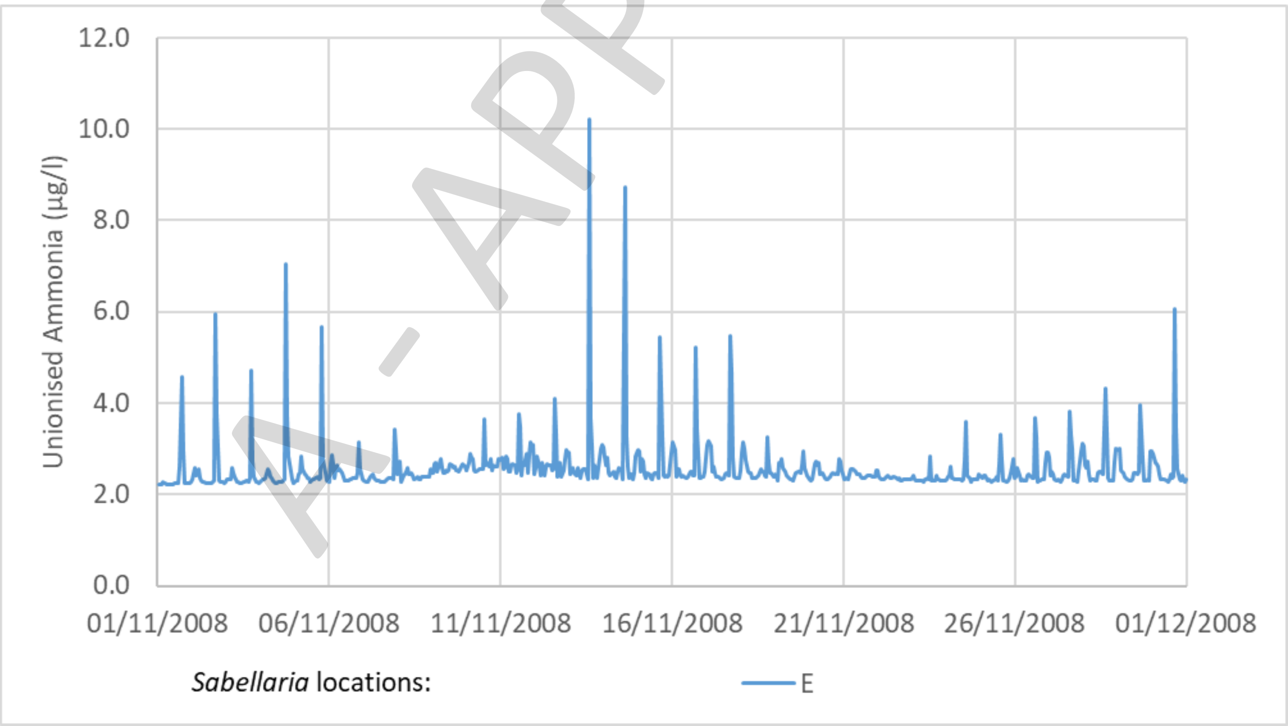

Figure 30: Time series of un-ionised ammonia at the *Sabellaria* location E for the alternative 38 l/s at 80 mg/l +70 l/s at 271 mg/l scenario using mean conditions of temperature, salinity, and pH.

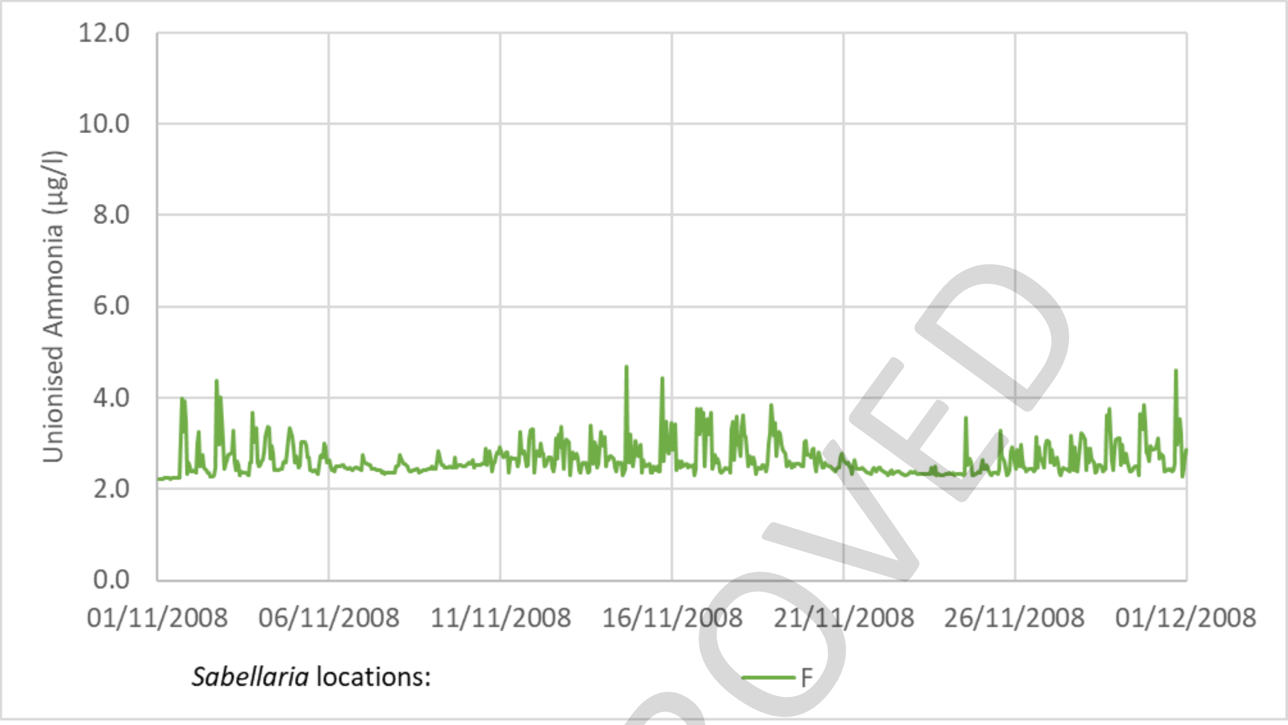

Figure 31: Time series of un-ionised ammonia at the *Sabellaria* location F for the alternative 38 l/s at 80 mg/l +70 l/s at 271 mg/l scenario using mean conditions of temperature, salinity, and pH.

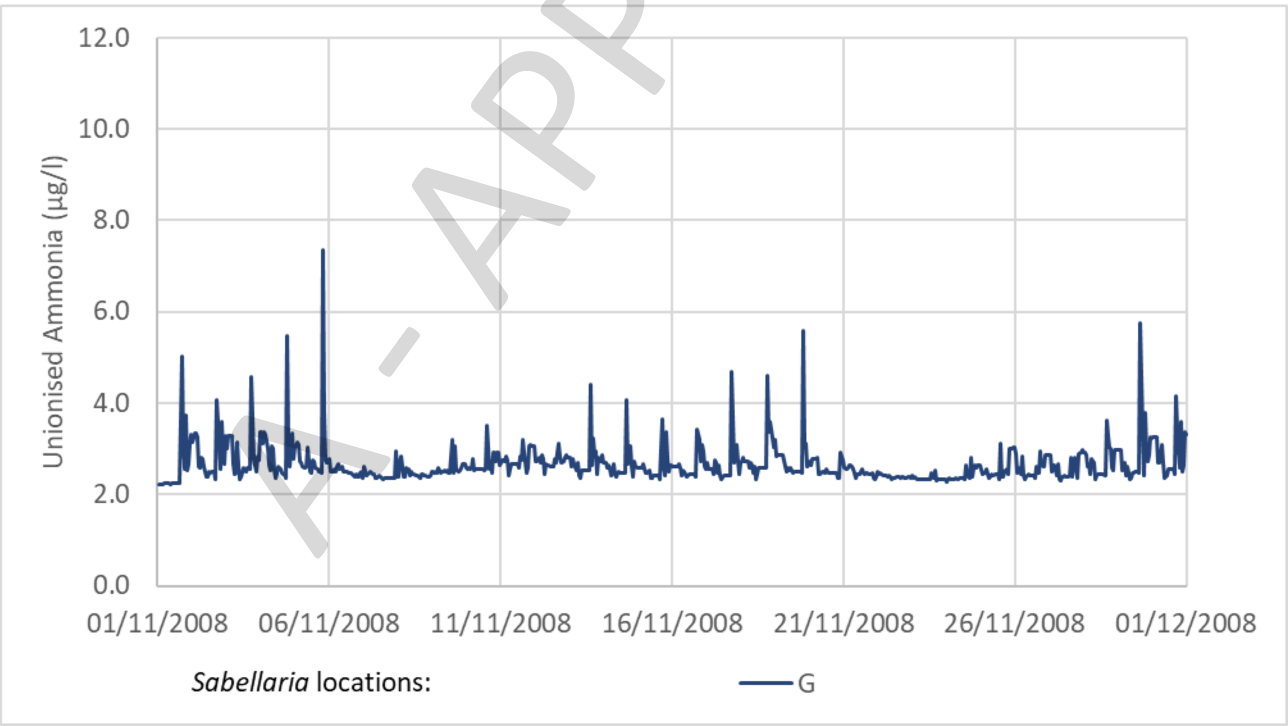

Figure 32: Time series of un-ionised ammonia at the *Sabellaria* location G for the alternative 38 l/s at 80 mg/l +70 l/s at 271 mg/l scenario using mean conditions of temperature, salinity, and pH.

Glossary

Term / acronym	Definition
AEVF	Allowable Effective Volume Flux
DCO	Development Consent Order
EQS	Environmental Quality Standard
EVF	Effective Volume Flux
HPC	Hinkley Point C
MAC	Maximum Allowable Concentration
PNEC	Predicted No Effect Concentration
WDA	Water Discharge Activity

APPENDIX B HINKLEY POINT C CONSTRUCTION DISCHARGE MODELLING ASSESSMENT AT THE TEMPORARY JETTY LOCATION

Cefas BEEMS Technical Report TR428; Hinkley Point C construction discharge modelling assessment at the temporary jetty location

NOT PROTECTIVELY MARKED

DOCUMENT TITLE	Cefas BEEMS Technical Report TR428; Hinkley Point C construction discharge modelling assessment at the temporary jetty location.

ISSUE REASON	P6 - For Construction

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CONTRACTOR NAME	Cefas		
CONTRACTOR DOCUMENT NUMBER	BEEMS Technical Report TR428	**CONTRACTOR REVISION**	14

ECS CODES

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01	14/08/2017	Liam Fernand	Principal Physical Oceanographer	Dave Sheahan	Principal Scientist	Dean Foden	Hinkley Point lead
02	13/09/2017	Liam Fernand	Principal Physical Oceanographer	Dave Sheahan	Principal Scientist	Brain Robinson	Programme director
03	15/09/2017	Liam Fernand	Principal Physical Oceanographer	Dave Sheahan	Principal Scientist	Dean Foden	Hinkley Point Lead
04	19/10/2017	Dave Sheahan	Principal Scientist	Liam Fernand	Principal Physical Oceanographer	Liam Fernand	Principal Physical Oceanographer
05	25/10/2017	Dave Sheahan	Principal Scientist	Liam Fernand	Principal Physical Oceanographer	Brian Robinson	Programme Director
06	09/04/2018	Liam Fernand	Principal Physical Oceanographer	Dave Sheahan	Principal Scientist	Dean Foden	Hinkley Point Lead
07	20/04/2018	Dean Foden	Hinkley Point Lead	Dave Sheahan	Principal Scientist	Dave Sheahan	Principal Scientist
08	08/06/2018	Liam Fernand	Principal Physical Oceanographer	Dave Sheahan	Principal Scientist	Dean Foden	Hinkley Point Lead
09	26/01/2021	Liam Fernand	Principal Physical Oceanographer	Dave Sheahan	Principal Scientist	Dean Foden	Hinkley Point Lead
10	23/03/2021	Dave Sheahan	Principal Scientist	David Haverson	Modelling Lead	Dean Foden	Hinkley Point Lead
11	24/03/2021	Dave Sheahan	Principal Scientist	David Haverson	Modelling Lead	Dean Foden	Hinkley Point Lead
12	10/06/2021	Dave Sheahan	Principal Scientist	David Haverson	Modelling Lead	Dean Foden	Hinkley Point Lead
13	25/06/2021	Dave Sheahan	Principal Scientist	David Haverson	Modelling Lead	Andrew Griffith	Principle Investigator
14	24/11/2021	Dave Sheahan	Principal Scientist	David Haverson	Modelling Lead	Andrew Griffith	Principle Investigator

REVISION STATUS/SUMMARY OF CHANGES

Revision	Purpose	Amendment	By	Date
01	Initial release		LF	14/08/2017
02	Update	Revision following client comments	LF	13/09/2017
03	Update	Revised TBM chemicals source terms	LF	15/09/2017
04	Update	Revision following client comments	DS	19/10/2017
05	Update	Revision following regulator comments	DS	25/10/2017
06	Update	Revision following addition of sections on sewage discharge and coliforms	LF	9/04/2018
07	Update	Minor update in response to EDFE comments	DF	20/04/2018
08	Update	Update in response to comments from the Environment Agency	LF	08/06/2018
09	Update	Update to include cold commissioning	LF	26/01/2021
10	Update	Revision following client comments	DS	23/03/2021
11	Update	Revision following client comments	DS	24/03/2021
12	Update	Revision following EA and client comment	DS	10/06/2021
13	Update	Revision following EA and client comment	DS	25/06/2021
13	Update	Table correction following EA and client comment	DS	24/11/2021

Hinkley Point C construction discharge modelling assessment at the location of the temporary jetty Revision 14

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Hinkley Point C construction discharge modelling assessment at the location of the temporary jetty Revision 14

Dave Sheahan, Liam Fernand, Amelia Araujo, Tiago Silva, Berrit Bredemeier, Lenka Fronkova, Jonathon Beecham, Mark Breckels, Gemma Kiff, Richard Harrod.

Version and Quality Control

	Version	Author	Date
Draft with source terms updated from Edition 1 and the inclusion of tunnel boring and sewage discharges	0.01	Liam Fernand	09/08/2016
Executive QC	0.02	Dean Foden	10/08/2017
Revision	0.03	Liam Fernand & Dave Sheahan	11/08/2017
Executive QC & Final Draft	0.04	Dean Foden	14/08/2017
Submission to EDFE as Edition 2 Prel A	1.00		
Revision following client comments	1.01	Dave Sheahan	25/08/2017
Executive QC	1.02	Dean Foden	31/08/2017
Submission to EDFE as Edition 2 Prel B	2.00		31/08/2017
Revised TBM chemicals source terms	2.01	Liam Fernand	12/09/2017
Executive QC & Final Draft	2.02	Brian Robinson	13/09/2017
Submission to EDFE as Ed 3 Prel A	3.00		13/09/2017
Revision following client comments	3.01	Liam Fernand	14/09/2017
Executive QC & Final Draft	3.02	Dean Foden	15/09/2017
Submission to EDFE as Ed 3 BPE	4.00		15/09/2017
Revision following client comments	4.01	Liam Fernand	14/09/2017
Executive QC & Final Draft	4.02	Dean Foden	15/09/2017
Revision following regulator comments	4.03	Liam Fernand	16/10/2017
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Submission to EDFE as Ed 5 BPE	5.00		19/10/2017
Revision following addition of sections on sewage discharge and coliforms	5.01	Liam Fernand	28/03/2018
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Submission to EDFE as Ed 6	6.00		09/04/2018
Minor update in response to EDFE comments	6.01	Dean Foden	20/04/2018
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Submission to EDFE as Ed 6	8.00		08/06/2018

Update to include cold commissioning	8.01	Liam Fernand and Dave Sheahan	20/01/2021
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Executive QC & Final Draft	10.02	Dean Foden	23/03/2021
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Submission to EDFE as Revision 12	13.00		25/06/2021
Correction in response to client comment	13.01	David Sheahan	23/11/2021
Executive QC & Final Draft	13.02	Andrew Griffith	24/11/2021
Submission to EDFE as Revision 12	14.00		24/11/2021

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Abbreviations and Glossary

Abbreviation / Term	Definition
AEVF	Allowable Effective Volume Flux
BOD	Biological oxygen demand
CETP	Commissioning Effluent Treatment Plant
CPM	Combined Phytoplankton and Macroalgal Model
CWDA	Construction Water Discharge Activity
CWW	Cementitious Washwater Water
DIN	Dissolved inorganic nitrogen
EQS	Environmental Quality Standard
EVF	Effective Volume Flux
CWW	Cementitious wastewater
GETM	General Estuarine Transport Model
HXA	KER, TER, SEK Tanks
KER	Liquid Radwaste Monitoring and Discharge System
MAC	Maximum Allowable Concentration
MSFD	Marine Strategy Framework Directive
NTU	Nephelometric Turbidity Units
PNEC	Predicted No Effect Concentration
PSU	Principal Salinity Units
SCL	Spray Concrete Lined
SEK	Conventional Island Liquid Waste Discharge System Tanks
TBM	Tunnel Boring Machine
TER	Additional holding tanks for return to liquid waste treatment
TraC	Transitional and Coastal
UV	Ultraviolet
WDA	Water Discharge Activity
WFD	Water Framework Directive

Executive summary

Cefas has been commissioned by NNB Generation Company (HPC) Ltd (NNB GenCo) to assess the priority substances and specific pollutants present in various discharges, to be made under a proposed Construction Water Discharge Activity (CWDA) permit application, at the location of the temporary jetty at Hinkley Point C (HPC). Dilution and dispersion of the substances in the marine environment have been investigated using a validated GETM (General Estuarine Transport Model) model of Hinkley Point (see BEEMS Technical Report TR267 Edition 2).

The contaminants of concern at the jetty discharge are:

1. Groundwater from the dewatering system which contains metals and dissolved inorganic nitrogen (DIN) and ammoniacal nitrogen.
2. Treated sewage discharge which contains DIN and ammoniacal nitrogen from three permanent treatment units.
3. Effluent from tunnel excavations containing small amounts of Tunnel Boring Machine (TBM) soil conditioning chemicals and variable quantities of groundwater containing metals and DIN and ammoniacal nitrogen.
4. Addition of nutrients, ammoniacal nitrogen and other process chemicals resulting from cold commissioning of the turbines and associated pipework.
5. Cementitious washwater (CWW)
6. Commissioning discharge of hydrazine.
7. Commissioning discharge considering hydrazine, ethanolamine contribution to ammoniacal nitrogen,
8. Commissioning discharge considering hydrazine, ethanolamine contribution to nitrogen and trisodium phosphate contribution to phosphorus.

Version History

In Edition 2, analysis of the treated sewage discharge and the discharge from the tunnelling operations was added. Of all the groundwater chemicals released, zinc is released in the highest concentrations compared to the Environmental Quality Standard (EQS). Edition 2 used values for background concentrations supplied by the Environment Agency (EA) which are statistically more robust than previously used concentrations, and which were also lower than in Edition 1 of this report. As modelling was performed above the background concentration of the contaminant of interest, the difference between the EQS for zinc and the background concentration increased from 1.8 µg l^{-1} (used in Edition 1) to 4.18 µg l^{-1}.

In Edition 3, the source terms for the TBM soil conditioning chemicals (obtained from NNB GenCo's tunnel boring contractor) were revised.

In Edition 4, Figure 1 was updated to show muck bay drainage. Calculation of various discharge elements were provided in a new Appendix E. In Table 3, some values corrected: the ammonia background value was corrected to represent mean conditions.

In Edition 5, the mean background zinc concentration was corrected to 3.03 µg l^{-1} (previously a 50th percentile value of 2.62 µg l^{-1} was used) producing a new value for the adjusted EQS threshold of 3.77 µg l^{-1}. Minor change / correction to DIN values was carried out. None of these corrections influenced screening pass/fail decisions. In Table 6 Effective Volume Flux (EVF) calculations were corrected, but this did not change any assessments.

The discharge profile was complicated and varies with time during the construction of HPC and so several different cases were considered. The two worst-case discharge profiles were:

i. Case C (April to June 2019 on the August 2017 programme) which included discharges of 20 l s^{-1} of groundwater, 13.3 l s^{-1} of treated sewage and 30 l s^{-1} tunnelling discharge (which consists mostly of groundwater with soil conditioning chemicals from 1 TBM). This discharge had the maximum heavy metal discharge. The DIN discharge was at the predicted maximum loading and was the same as for Case D.

ii. Case D (June 2019 onwards) which includes up to 25 l s^{-1} of groundwater, 13.3 l s^{-1} of sewage and 6 - 7 l s^{-1} of tunnelling discharge from 2 TBMs). This discharge had the maximum concentration of TBM soil conditioning chemicals.

TBMs will be used to excavate the two cooling water intake tunnels and the cooling water discharge tunnel. The largest component of the discharge produced during tunnelling was groundwater.

Ground conditioning chemicals are used at the cutter head to optimise TBM efficiency and include anti-clogging agents, anti-wear components and soil-conditioning compounds. The exact chemical constituents of the ground conditioning chemicals will depend upon the ground conditions encountered on site, and therefore cannot be precisely specified in advance of drilling trials by the tunnelling contractor in 2018. To enable the discharge to be assessed, several potential drilling compounds were reviewed for toxicity and percentage concentration in the drilling fluids; representative products that would represent a worst-case discharge were then selected for assessment.

Changes made in Edition 6

i. Section 4.5 of this report contains revised estimates of the maximum concentration of ammoniacal nitrogen associated with the discharge from the sewage. Edition 5 included estimates of the sewage as a 95th percentile of 5 mg l^{-1}, however the EA wish to permit a maximum concentration and therefore 20 mg l^{-1} has been being used as the maximum concentration. It should be noted that it is the same treatment plant that is proposed in Edition 5 and Edition 6 of this report.

ii. Consideration of coliforms has also been included in sections 4.9 and 5.2.1, including consideration of the potential impact to shell fisheries in section 4.9.

iii. It has also been decided that there will no longer be a sewage discharge across the intertidal at Outlet 1. This has therefore been removed from in combination assessments considered in section 5.

iv. This edition also contains updates to the GETM modelling outputs. There had been concern about concentration spikes that were associated with a particular wind event. These were caused by a mis-match in the handling of the layers of the model (sigma co-ordinates) when it reached low water depths and the way the discharge chemical was being treated: a numerical solver was used to interpolate which produced some model instabilities resulting in erroneously high values. These model instabilities also resulted in some overall underestimation of mean concentrations. Updated modelling has been carried out using 15 layers, providing greater stability than the 20 layers previously modelled. The updated discharge time series has a much clearer tidal signal, and lower peak values, higher mean and higher 95th percentile values, but much lower maximum values than previously, as the erroneous spike no longer occurs. The updated GETM modelling approach is described in section 3 and model outputs are shown in section 4.

Changes made in Edition 7

This edition includes estimates of the effect of the additional nutrients and ammoniacal nitrogen due to the discharge of the breakdown products of hydrazine and other commissioning chemicals during the cold commissioning phase, during which drainage is expected from one or two HXA tanks per day. This has been included as a separate section (4.10). The methodology has three parts;

i) To include the discharge in the GETM model so that the dilution and spreading of the ammonia plume and the potential for impact upon designated features can be considered.

ii) Use of the CPM model to predict the impact upon phytoplankton production and macroalgae production in the wider estuary.

iii) To consider the jetty discharges in the context of a Water Framework and habitats assessment.

Changes made in Revision 10

Following client feedback, the text was edited in several sections to clarify where changes have been made to introduce the commissioning discharge assessment. A section of abbreviations/glossary has also been added at the beginning this report.

Changes made in Revision 11

Minor sections of text were updated following client comments and some edits were made to clarify the keys in several Figures.

Changes made in Revision 12

Following feedback from the Environment Agency additional details have been added to the report to explain the different wastewater streams more fully for the cold commissioning phase and to include reference to the cementitious wastewater discharge. The different discharge scenarios were updated in Table 1 to include new wastewater streams. Data in Table 3 have also been updated to show calculations made by the Environment Agency in the stage 1 Habitats Regulations Assessment. The different discharge rates modelled for hydrazine and commissioning chemical discharges are explained in the context of the use of a hydrazine treatment plant and post treatment storage prior to discharge. Explanation is provided that a separate report BEEMS technical report TR550 provides a more comprehensive assessment of biological quality elements and designated features.

Changes made in Revision 13

Following feedback from the Environment Agency additional details have been added to the report: Corrections and clarification have been made to Table 1 and it is highlighted that Case D discharges during the construction period are those that most represent the situation now and including the period when CWW and commissioning discharges would also take place. Recalculations by the Environment Agency made to groundwater datasets resulted in reductions in nitrogen loading figures and these are shown where applicable. Some small increases in metals discharges also resulted and are indicated but these do not change the assessment. Some further detail was added to explain that the in-combination effects of the small discharge of CWW are unlikely to result in significant changes to the assessment made for in combination inputs from Case D construction activity and from commissioning wastewater.

Changes made in Revision 14

Following further feedback from the Environment Agency (23/11/21) additional details have been added to the report: Corrections and clarification have been made to Table 25 the heading and table values have been edited so that it now shows H1 tests for the combined construction wastewater and the commissioning wastewater discharges for total ammonia and unionised ammonia.

Conclusions

Early versions of this report provided an assessment of the construction discharge only. From version 7 the commissioning inputs of un-ionised ammonia, phosphorus, and nitrogen in combination with the construction inputs of these chemicals are also considered. In the summary below the most precautionary assessment scenario is described. For heavy metals, tunnelling chemicals, and for coliforms and BOD associated with treated sewage, the most precautionary scenario occurred during the construction period. For those assessments that have been updated to incorporate combined commissioning inputs i.e. for DIN, phosphorus and ammoniacal nitrogen, the inputs from combined construction and commissioning are considered. The level of suspended solids concentrations in commissioning wastewater will vary but will be treated to meet agreed permit conditions.

Heavy metals

For Case D, both copper and zinc fail the Environment Agency screening tests. During peak ground water load (Case C) chromium also fails this test, although only marginally and for a period of approximately eight weeks when the flow is predicted to be at a maximum. If the annual average was used, then only zinc would be of potential concern as the copper Effective Volume Flux (EVF) is substantially below the threshold. As zinc was the substance of greatest exceedance this discharge was considered further by detailed modelling. The areas of exceedance for zinc at the surface were 0.3 Ha and 0.125 Ha for Cases C and D respectively. As the discharge is buoyant, exceedance at the bed was only expected within a very short distance (less than 5 m) of the discharge itself. Some small additional metals inputs occur via the CWW discharge, but the discharge rate and concentrations are so low that this is not expected to change the present in combination assessment for Case D construction activity inputs and those from commissioning.

There is no predicted exposure of designated bed features above the EQS at any time.

TBM soil conditioning chemicals

Chemical constituents of TBM ground conditioning products BASF Rheosoil 143 and Condat CLB F5/M failed the initial EQS screening and were investigated further using modelling approaches. With the worst-case chemical constituent (i.e. with the most toxic chemical group) there was no exceedance of the PNEC at the bed and the areas of exceedance at the surface were very small (0.19 ha for Rheosoil 143 and 1 ha for Condat CLB F5/M). This assessment used examples of typical soil conditioning chemicals (primarily different types of surfactants) with particularly low (i.e. the most conservative) PNEC values. Providing the chemical components of any other products selected for soil conditioning have an Effective Volume Flux value at or below 58.7, then areas of exceedance will be the same or less than those shown here for CLB F5 mono-alkyl sodium sulphate.

DIN (construction and commissioning)

Dissolved inorganic nitrogen (DIN) will be released from the jetty discharge point into the estuary during the construction period. Under the Water Framework Directive Standards, the Bridgwater Bay waterbody has ‘Moderate’ status for DIN. The jetty discharges result in a very localised elevation in DIN in the receiving waterbody and the initial screening test was passed (Table 3).

The average annual uplift from the jetty discharge during year 1 (from construction inputs only) was estimated at 0.36 μmol l^{-1} relative to a mean annual concentration of 75 μmol l^{-1} within Bridgwater Bay, and ‘Moderate’ status was unaffected. Due to high turbidity, productivity in the Severn is light-limited (Underwood, 2010) and the effects of minor additional DIN loading on the designated Severn Estuary features are deemed insignificant and not assessed further. In-combination effects of discharges from HPB are considered in Section 5 and it was concluded that there was no direct intersection between the HPB discharge and the jetty discharge. Based on the results of a Combined Phytoplankton and Macroalgae (CPM) model, this assessment would also apply during the period when the breakdown products of cold commissioning discharge chemical inputs make additional contributions to the construction discharges of nitrogen and phosphorus. Some small additional nitrogen inputs occur via the CWW discharge, but the discharge rate and concentrations are so low that this is not expected to change the present in combination assessment for Case D construction activity inputs and those from commissioning.

Ammoniacal nitrogen (construction and commissioning)

Using the EA calculator to determine the proportion of un-ionised ammonia in construction discharges containing ammoniacal nitrogen, the EQS for un-ionised ammonia (21 µg l^{-1}) was exceeded in Case C_{max} and D_{max}, but only in the immediate vicinity of the discharge (within less than 10 m). Rapid dilution rates mean that the EQS was only exceeded when groundwater discharges and sewage discharges were at their maximum. The total area of EQS exceedance was 0.005 ha and, even during maximum discharges, the initial screening test was passed (Table 3). When combined construction and cold commissioning inputs of un-ionised ammonia are considered, the area above the 21 ug l^{-1} threshold, when using the 95th percentile of ammoniacal nitrogen, is small (maximum 0.2 hectares). For the actual EQS when using the annual average there are no areas of exceedance and for the un-ionised ammonia concentrations associated with *Corallina* and *Sabellaria* features, short term values are less than 25% of the EQS. An additional assessment of the in-combination effects of concurrent sewage discharges from the temporary jetty and HPB are considered below.

For total ammonia concentrations, the modelling shows that at the 25m resolution of the model for the construction and commissioning phase there is no exceedance of values in relation to habitats standards for estuaries (WQTAG086) for ammonium for either the mean (1100 ug l^{-1} (as N)) or of the MAC (8000 ug l^{-1}(as N)). Some small additional ammoniacal nitrogen inputs occur via the CWW discharge, but the discharge rate and concentrations are so low that this is not expected to change the present in combination assessment for Case D construction activity inputs and those from commissioning.

Biological oxygen demand

The sewage treatment works is expected to achieve a maximum concentration of Biological Oxygen Demand (BOD) of 40 mg l^{-1} (i.e. draw down over 5 days) and the indicative Maximum Allowable Concentration (MAC) to be applied in the permit is therefore 40 mg l^{-1}. Using the 13.3 l s^{-1} discharge and a BOD of 40 mg l^{-1}, a daily BOD of 46 kg was calculated. This amount of oxygen would be transferred across 14364 m^2 l of the water surface in a day. The tidal excursion (how far a particle is advected) at Hinkley Point, even on the weakest (neap) tides, is many kilometres, thus there is ample resupply of oxygen from the atmosphere so that no change in oxygen concentration would be observed. No change to this assessment is expected for the additional cold commissioning inputs.

Suspended solids

The background suspended solids concentration in the receiving water is relatively high (with a mean of 264 mg l^{-1} and a minimum of 33 mg l^{-1}). Commissioning activities such as hydrostatic testing and flushing will result in variable suspended solids loadings within resultant effluents. The Commissioning Effluent Treatment Plant (CETP) will incorporate methods to reduce suspended solids to permitted levels prior to discharge.

Coliforms – bathing water standards and shellfish

The discharge point is not in designated bathing waters. Model predictions (which do not consider wave-driven mixing) indicate that treatment from the plant is sufficient to ensure that microbial concentrations in discharged waters comply with bathing water standards within a maximum of 2.8 km from the discharge point (without UV treatment) and within 10 m (with UV treatment). The nearest designated bathing waters are 12 km distant from the jetty discharge and the closest shell fishery is 32 km distant and so no effects on these features are predicted. No change to this assessment is expected for the additional cold commissioning inputs.

Potential in-combination effects with the HPB discharge

This report has considered the potential interaction of the jetty discharges and the sewage discharge from HPB (2.4 km distant). There is no overlap of the plume mixing zone and the HPB discharge, and no interaction occurs because of the physical separation of the discharge locations and the small discharge volume from the jetty.

During the main construction period the total annual loading of DIN has been considered for the two impacted Water Framework Directive designated waterbodies (Bridgwater Bay and River Parrett). The combined effect of HPC (construction discharge at the jetty) plus HPB is to uplift the DIN concentration in the Bridgwater Bay water body by 0.58 µmol l^{-1} and the Parrett waterbody by 2.52 µmol l^{-1}. There would therefore be no change of status: the present mean is 75 µmol l^{-1} and the 99th percentile concentration for Good status in turbid waters is 180 µmol l^{-1}. When considering the additional cold commissioning inputs, the use of a CPM model confirmed that there was no influence of combined inputs of nutrients on phytoplankton production in the estuary.

It is not known what the actual discharge concentration of DIN is from Hinkley Point B, however assuming the same standard of secondary treatment as Hinkley Point C would imply an extent of exceedance of approximately 1.8km. This theoretical exceedance could only occur in very calm conditions. Under such calm conditions the plume would be long and thin and would not interact with the temporary jetty discharge, as the tidal stream lines are physically separate. In practice for most of the time, wave mixing will rapidly dilute the discharged plume so that no interaction could occur.

If UV treatment is applied at HPC then no microbial interaction with HPB is likely.

The thermal plume discharge from HPB has been considered and is expected to raise the mean background sea temperature at the jetty discharge location (where exceedance of the EQS's occurs) by approximately 1°C, this small temperature rise compared to the annual seasonal variation is considered unlikely to have any effect on the toxicity of any of the chemicals or metals considered.

Consideration of the effects of combined discharges from construction and cold commissioning on Water Framework Directive waterbodies and habitats

Due to the high turbidity environment, productivity in the Severn Estuary is light-limited (Underwood, 2010) and the effects of a DIN loading from combined construction and cold commissioning discharges on phytoplankton in the Severn Estuary are considered insignificant. To test this understanding, modelling was undertaken to assess the effects of additional nutrients on phytoplankton production using a Combined Phytoplankton and Macroalgae (CPM) model (Appendix F). Low phytoplankton production was predicted but the addition of nutrients from construction and cold commissioning, including inputs from the HPB, had no effect on production, due to the light limitation. The additional inputs from cold commissioning therefore cause no deterioration in the water body status under the WFD for phytoplankton and have no significant influence on the Marine Strategy Framework Directive (MSFD) area Celtic Sea.

Test for inclusion of habitats in WFD assessment

The tests for inclusion of habitats in a WFD assessment are based on the extent of the footprint of an activity. In this case for combined construction and cold commissioning discharge, the tests are whether habitats contravene any of the following criteria:

i. 0.5km² or larger
ii. 1% or more of the water body's area
iii. within 500m of any higher sensitivity habitat
iv. 1% or more of any lower sensitivity habitat

For tests i., ii. and iv. these criteria are not met. For test iii, the jetty discharge is within 500 metres of *Sabellaria* and *Corallina* habitat and therefore requires further assessment.

Potential effects on higher and lower sensitivity WFD habitats

During the construction period the predicted plume discharge from the jetty is a fresh water source, and is buoyant, therefore the highest concentrations are associated with surface waters. The highest areas of exceedance of standards for all parameters of relevance to a WFD assessment was for one of the tunnelling chemicals, Condat CLB F5/M, for which an area of 1 ha at the surface exceeds the relevant EQS. At the bed, the relevant concentration was predicted to be below EQS within 5 metres of the discharge. Neither mean bed concentrations nor 95th percentile concentrations exceed the EQS, and benthic features should therefore remain unaffected.

Ammoniacal nitrogen discharge is at its maximum during the construction period when cold commissioning wastewater discharges occur. Assessment of combined discharges showed no areas of exceedance for either total ammonia concentrations or the mean un-ionised ammonia EQS at the surface or the bed. An area of only 0.2 ha at the surface was predicted to exceed the EQS for un-ionised ammonia as a 95th percentile. More detailed time series analysis, considering more extreme summer temperatures when the proportion of un-ionised ammonia is likely to be maximal, confirmed that concentrations were less than 25% of the EQS at the locations closest to *Corallina* and *Sabellaria* features. The same assessment would apply to lower sensitivity habitat close to the jetty discharge.

A habitats assessment provided in BEEMS TR443 established that there was either no pathway for effects or no likely significant effects arising from jetty discharges of construction chemical inputs during Case C and Case D, which are considered the most significant inputs during the construction period.

The predicted discharge concentrations of hydrazine used in cold commissioning were evaluated for toxicological effects in BEEM TR445. A discharge concentration of 15 μg l^{-1} was sufficiently precautionary that the acute PNEC was never exceeded at the *Corallina* features and only at *Sabellaria* stations D and E. Furthermore, the plume was very short lived (1-2 hours) and concentrations were well below the acute PNEC (4 ng l^{-1} as a 95th percentile) at all features.

1 Background

Cefas has been commissioned by NNB Generation Company (HPC) Ltd (NNB GenCo) to assess the priority substances and specific pollutants present in various discharges, to be made under a proposed construction Water Discharge Activity (CWDA) permit application, at the location of the temporary jetty at Hinkley Point C (HPC) (to be known as Outlet 12). Dilution and dispersion of the substances in the marine environment have been investigated using a validated GETM (General Estuarine Transport Model) model of Hinkley Point (see BEEMS Technical Report TR267 Edition 2).

The flow rates used for the modelling construction and commissioning discharges are shown in Table 1. The contaminants of concern are:

1. Groundwater from the dewatering system which contains metals and dissolved inorganic nitrogen (DIN) and ammoniacal nitrogen.
2. Treated sewage discharge which contains DIN and ammoniacal nitrogen from three permanent treatment units.
3. Effluent from tunnel excavations containing small amounts of Tunnel Boring Machine (TBM) soil conditioning chemicals and variable quantities of groundwater containing metals and DIN. Input of tunnelling effluent is scheduled to stop in January 2022.
4. Cementitious wastewater discharge (CWW).
5. Commissioning discharge of hydrazine.
6. Commissioning discharge considering hydrazine, ethanolamine contribution to ammoniacal nitrogen,
7. Commissioning discharge considering hydrazine, ethanolamine contribution to nitrogen and trisodium phosphate contribution to phosphorus.

Dewatering of deep excavations is required during the construction of HPC. In this process, groundwater is pumped from a network of deep boreholes and discharged sub-tidally at a location near the seaward end of the HPC temporary jetty.

NNB GenCo 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 conditions, 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 marine environment and interest features to be completed, reasonable worst-case values have been selected from these datasets and from the March 2017 data upon which Edition 1 of this report was based. This report contains the results of modelling these updated worst-case values.

The output from the permanent sewage treatment plants is discharged via the HPC temporary jetty.

The main bulk of the tunnelling material (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.

One of the issues when considering all three discharge streams 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.

1.1 Indicative construction discharge schedule

In August 2017 based on the best knowledge of the likely sequencing of different phases of the construction period, a series of discharge scenarios was developed taking account of the highest likely wastewater inputs from different construction sources. These Cases A to D were used to assess the maximal inputs of different contaminants of concern. Case E is omitted here but essentially covers the latter period of construction when tunnelling inputs are completed. This schedule 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 cover the likely changes. The indicative sequence, duration and start point for different activities as envisaged in August 2017 is provided in Table 1 and Figure 1. For the assessment of the contaminant inputs from the cementitious waste water (CWW) and commissioning discharges the construction activities and discharges that are occurring in combination are best represented by those described for Case D. 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. Even in the worst-case modelling condition no such intersection exists, and therefore we conclude that the areas of intersection will not be changed because of seasonal influences.

Table 1. Indicative sequencing of the relevant discharges based upon August 2017 construction plans. (Recent data on the actual flow rates for groundwater and tunnel effluent indicate that the values used here provide precautionary assumed overlaps between different activities and contaminant source contributions.)

Main site Groundwater	Sewage	Week	Tunnelling wastes (and associated) discharges	Case
De-watering discharge at Jetty, 20 l s^{-}		1	NA	Case A 20 l s^{-1} (jetty)
20 l s^{-1}		17	Approximately 7 l s^{-1}	N/A
20 l s^{-1}	sewage treatment plant discharge (jetty) 13.3 l s^{-1}	25	12 l s^{-1} ramping up to 22 l s^{-1} as SCL works ramp up. Tunnelling for intake 1 continues.	Case B 55 l s^{-1} (jetty)
20 l s^{-1}	13.3 l s^{-1}	49	30 l s^{-1} (ca. 26.7 l s^{-1} groundwater also including ca.,3 l s^{-1} soil conditioning chemicals from the use of 1 TBM).	**Case C** Peak Ca.,63 l s^{-1} (jetty)
20 l s^{-1}	30 l s^{-1}. Rare but potentially maximum discharge.	49	30 l s^{-1} (ca. 26.7 l s^{-1} groundwater also including ca.3 l s^{-1} soil conditioning chemicals from the use of 1 TBM).	**Case C1max** Peak Ca., 80 l s^{-1}
20 l s^{-1}	13.3 l s^{-1}	81	SCL works complete. Tunnelling continues HPC Intake 1, Outfall, and Intake 2. Maximum use of TBM soil conditioning chemicals corresponds to the output from 2 TBMs working simultaneously. 6 l s^{-1}	**Case D** 40 l s^{-1} (original tunnelling assessment)[2] 38.3 l s^{-1} assessed for combined commissioning input at jetty[3]
(20 l s^{-1})[4]	(13.3 l s^{-1})[4]	NA[5]	Cementitious wastewater (CWW) plus other Case D inputs	**Case F** (0.6 l s^{-1} CWW)[6]
(20 l s^{-1})[4]	(13.3 l s^{-1})[4]	NA[5]	Commissioning discharge – this input contributes nitrogen and ammoniacal nitrogen from addition of ammonia and breakdown of hydrazine, ethanolamine, and phosphorus from trisodium phosphate see section 3.5 and 4.10 plus other Case D inputs	**Case J**[7] (70 l s^{-1} commissioning discharge)

[1] There has been no treated sewage discharge from the jetty as of 1st June 2021 but discharges are scheduled to start in the next few months; [2] For the original 2017 assessment of tunnelling chemicals a minimal groundwater dilution flow (20 l s^{-1}) was assumed during Case D. This effectively produced a most conservative scenario for tunnelling chemicals as it minimises dilution (assuming 20 l s^{-1} groundwater + 13.3 l s^{-1} treated sewage + 6 l s^{-1} tunnelling chemical which was rounded up to 40 l s^{-1} discharge);

[3] The total volume for assessment of DIN during Case D 38.3 l s^{-1} includes 13.3 l s^{-1} sewage contribution + 20 l s^{-1} general groundwater input + 5 l s^{-1} groundwater from tunnelling. The additional 6 l s^{-1} tunnelling chemical make-up water will not add DIN but will dilute the overall concentration so to provide the most conservative assessment this was not included in the flow rates for the DIN calculation.

[4] The total volume of groundwater (including 5 l s^{-1} from tunnelling) and sewage contributions of chemicals of concern during Case D are considered in combination with additions of the same contaminants from CWW or commissioning inputs.

[5] NA - not applicable as start timing not identified in 2017 scheduling

[6] During Case F cementitious wastewater input contributions are evaluated in combination with those for Case D

[7] During Case J the construction discharge for DIN and ammoniacal nitrogen uses the Case D example at 25 l s^{-1} groundwater with additional contributions from commissioning inputs.

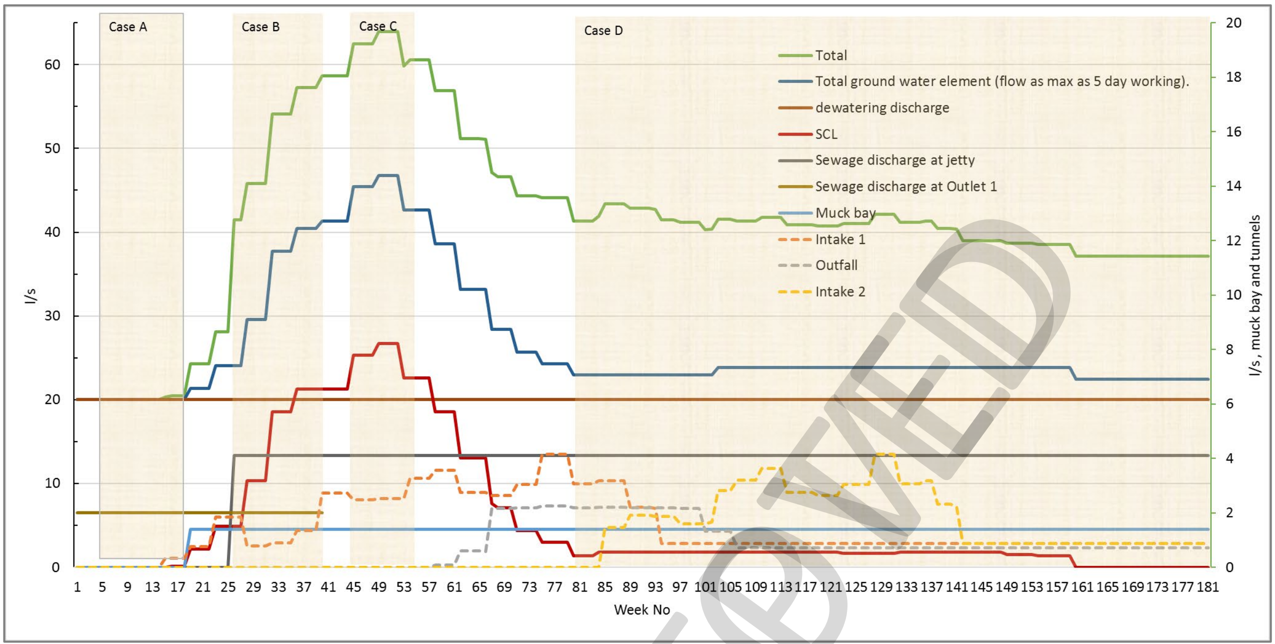

Figure 1. Likely flow volumes discharged at the jetty location from the start of tunnelling. Discharge volumes from ‘Muck Bay’ and TBM tunnelling for HPC intake 1, outfall and intake 2 are shown on the right hand axis. Timing is according to August 2017 scheduling and selected scenarios for assessment represent the most conservative based on the assumed overlap of activities contributing to various contaminant sources.

Groundwater comprises the main dewatering flow (which remains constant at 20 l s^{-1} through the period considered) plus the contributions of groundwater resulting from the tunnelling and associated operations. Figure 1 shows that the groundwater discharge starts at 20 l s^{-1} from dewatering (Case A) and then, at around week 17, is added to by the discharge from the SCL (spray concrete-lined) works for approximately 50 weeks, reaching a maximum of around 46 l s^{-1} groundwater (Case C). Thereafter, the groundwater element of the discharge reverts to levels of around 25 l s^{-1} (Case D). For the EVF calculation of groundwater derived substances, only the volume of groundwater has been used, with no assumption of additional dilution from the sewage discharge. During Case J groundwater flow rate is set at 25 l s^{-1} (as for the original Case D construction assessment of DIN and ammoniacal nitrogen) but additional commissioning inputs of these substances are also included (see section 3.5 and 4.10).

Figure 1 shows that the maximum discharges of flows that contain metals and DIN will occur during Case C (between weeks 45 and 53 when the groundwater element reaches 46 l s^{-1}). Case C is relatively transitory. Case C1, which includes an extreme case of sewage discharge, is also likely to be highly transitory. Once the SCL works are complete (Case D) the total groundwater discharge falls to approximately 25 l s^{-1}. The waste from the TBM soil conditioning chemicals contains its highest concentration during Case D. The total discharge during Case D is 38.3 l s^{-1} (40 l s^{-1} was used for the tunnelling chemicals assessment as this includes minimum groundwater flow 20 l s^{-1}, 13.3 l s^{-1} sewage and tunnelling chemicals) and this value has been used in the calculation of conditioning chemical discharge concentration and EVF.

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 (above the EQS) and Test 5 (EVF > water depth), see section 2) it is necessary to conduct further detailed modelling to determine the extent and magnitude of the predicted exceedance of the EQS in the receiving waterbody.

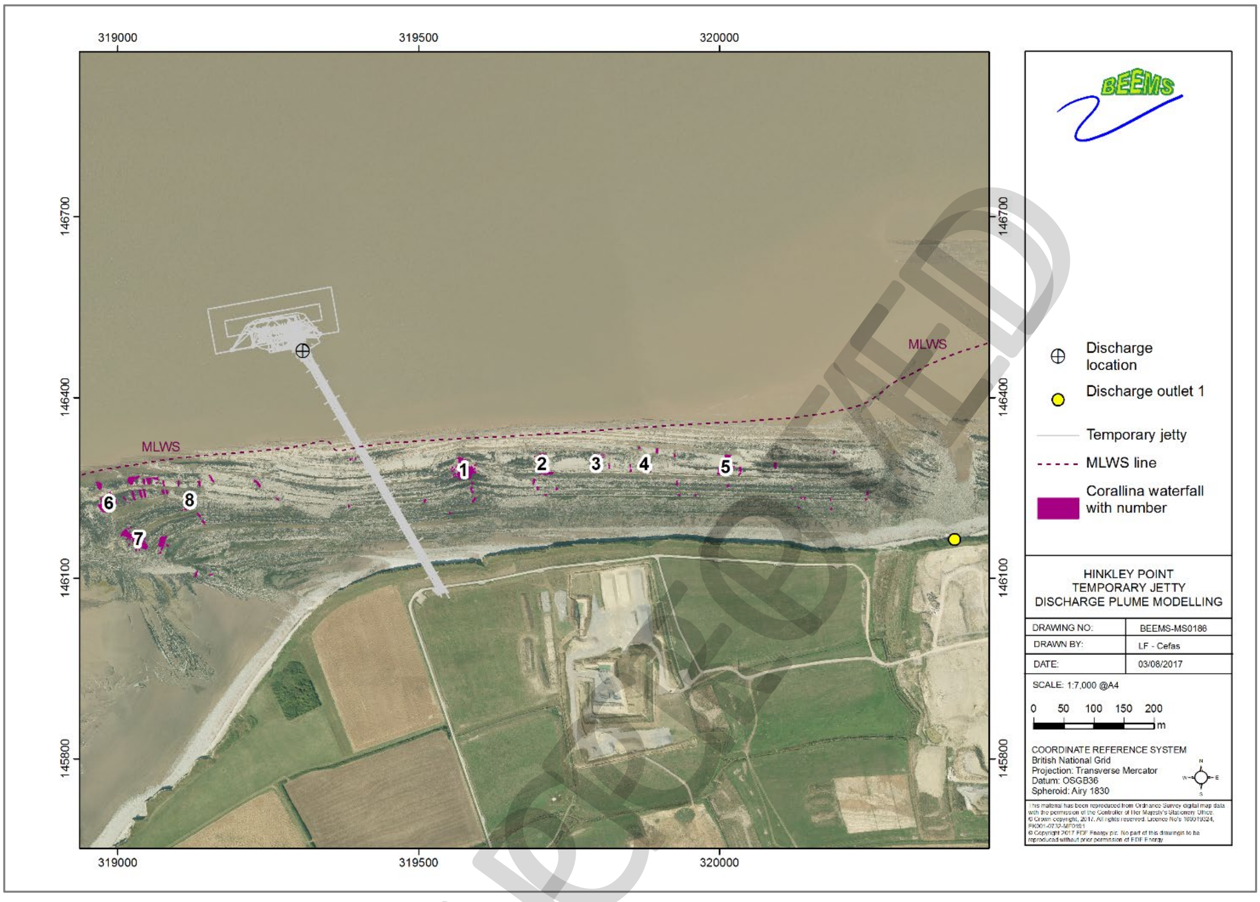

Figure 2. Location of the temporary jetty and proposed discharge point (shown by a cross within a circle). The main *Corallina* features of interest shown in purple and numbered for future reference in this report. The existing cross shore discharge point (Outlet 1) is shown by a yellow circle.

2 Application of Environment Agency guidance for the assessment of the subtidal discharge.

The EA screening approach applies to the discharge from the jetty because the discharge is to the subtidal environment and beyond 50m from mean low water spring (MLWS) tidal level. The proposed construction discharge is a low volume of groundwater, sewage treatment effluent and tunnelling waste (see Table 1) with concentrations of some contaminants exceeding EQS levels. The properties of the proposed discharge are shown in Table 2. The commissioning discharge and cementitious water discharges are discussed in the construction and cold commissioning section 3.5.

Table 2. Proposed jetty discharge characteristics. The discharge location is shown in Figure 2.

Discharge Characteristics	Value
Location OSBG	319315E 146475N
Location WGS84	51° 12.7056' N 003° 9.3894' W (51.21176 N 3.15649 W)
Charted water depth (surface to bed) at discharge location	At least 3.0 m
Discharge flow	Varies with Case.
Discharge salinity	1 PSU

Groundwater priority and specific contaminant data

When calculating summary statistics for all substances, any values below the method detection limit were adjusted to a value of half 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 was 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). 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). NNB GenCo 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 and from the March 2017 data. Summary statistics for the concentrations of substances measured in the site groundwater carried forward to the modelling assessment are shown in Table 3.

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. As this construction discharge will be subtidal a further test ("Test 5") is recommended, comparing the discharge specific Effective Volume Flux (EVF) with the location specific Allowable Effective Volume Flux (AEVF). If the EVF is not greater than the AEVF, then the discharge is considered insignificant and is screened out.

Relative to chart datum the discharge depth for construction related effluents will be at least 3.0 metres therefore a maximum AEVF value of 3.0 is used for comparison in Table 3.

The grey shaded discharge concentrations in Table 3 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.

The Environment Agency considered the datasets submitted for the assessment of construction discharges in December 2017. They confirmed that most of the values used within the screening were conservative, however a few (shown in bold and underlined Table 3) had slightly higher values. This was not considered to be an issue as zinc was still the substance which had the highest EQS exceedance, and therefore was still the ‘contaminant of concern’ which was most relevant to be carried forward to the modelling stages. The slight discrepancies between the Zinc 95th percentile values were also not considered to be an issue because it was not expected that this slight increase (1.37%) to the input data would vary the outcome results of the modelling assessments.

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. The average turbidity concentration measured at Hinkley Point (Amec, 2009) was 214 NTU. This defines Hinkley as turbid with associated 99th percentile winter DIN values for transitional and coastal waters of 2520 µg l^{-1} and 3780 µg l^{-1} thresholds for Good and Moderate respectively (Water Framework Directive Standards and Classification Directions, 2015, Appendix B). It should be noted that a portion of the DIN in groundwater is nitrate/nitrite which may not all readily convert to ammonia, but total conversion to ammonia was assumed to ensure that the assessment made was conservative.

Table 3. Groundwater contaminants and concentrations likely to be present in the construction dewatering discharge and comparison to EQS for three cases. AA refers annual average concentration and MAC refers to the maximum allowable concentration. EVF (m^3 s^{-1}) has been derived using 95th percentile discharge concentrations and the AA EQS (except for mercury where the MAC EQS has been used). The shaded values indicate those used in the screening test assessment. These data are based on Environment Agency calculation from NNB GenCo data sources. Underlined updated values had non-significant increases relative to original Cefas calculations.

Contaminant	**Assessed discharged concentration µg l^{-1}**		**Saltwater AA EQS µg l^{-1}**	**Saltwater MAC EQS (as 95%ile) (µg l^{-1})**	**Back-ground conc-entration (µg l^{-1})**	**(EVF) Case A and Case D**	**EVF Case C**	**TraC Water test 5 EVF< 3.0 Pass/Fail**
	Mean	**95%ile (used in EA Screening test)**						
Un-ionised ammonia (N)	258.75	123.5	21	-	**4.6**	**0.15**	**0.352**	**Pass**
DIN groundwater	1860.92	4073	2520^{1}		1050	0.06	0.129	Pass
Cyanide	0.025	50	1	-	0	1.00	2.34	Pass
Total cadmium	0.09	0.460	0.2	-	**0**	**0.05**	**0.12**	**Pass**
Total chromium	4.58	24	0.6^{2}	32	0.02	0.83	1.93	Pass
Total lead	0.85	3	1.3	14	0.02	0.05	0.11	Pass
Total copper	31.7	221	4.76	-	3.95	**5.46**	**12.17**	**Fail**
Total zinc	427.2	1642.15	6.8	-	3.035	**8.72**	**20.37**	**Fail**
Total mercury	0.2	0.49	-	0.07^{3}	0.02	0.2	0.46	Pass
DIN Sewage sources		20,000^{4}	2520		1050	0.19	0.41	Pass

[1] 99th percentile (180 µmol) standard for period 1st November – 28th February for dissolved inorganic nitrogen for Good status, Appendix B, Table 17.

[2] The EQS in seawater is set for dissolved hexavalent chromium only but this is dissolved total chromium (all species).

[3] The EQS for mercury is only set as a 95th percentile.

[4] A max value not 95th percentile, ammoniacal nitrogen as a proxy for total nitrogen from sewage treatment (µg l^{-1}) as other contributions e.g. NO_2, NO_3 are expected to be small.

The Effective Volume Flux of the discharge (EVF) is defined as:

EVF = (EFR x 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 (μg l^{-1})

EQS = EQS (AA) of the substance of concern (μg l^{-1})

BC = mean background concentration at the discharge location (μg l^{-1})

For Case A and Case D, which together represent most of the total tunnelling time, both copper and zinc fail the screening tests. During peak ground water load (Case C) chromium also fails this test, although only marginally and for a period of only approximately 8 weeks when the flow is predicted to be at a maximum. If the annual average is used, only zinc would be of potential concern (the copper EVF is substantially below the threshold). As zinc is the substance of greatest exceedance then this report considers this discharge further, with detailed modelling in a real-world simulation described in section 3. Calculation of EVF values as shown in Table 3 are provided in more detail in Appendix C, Table 22..

2.1 Total loads for Cadmium and Mercury.

There are specific requirements for annual loads of cadmium and mercury compounds. Figure 3 shows that the criteria not to exceed 5kg and 1kg (respectively) are met, for both cadmium and mercury respectively.

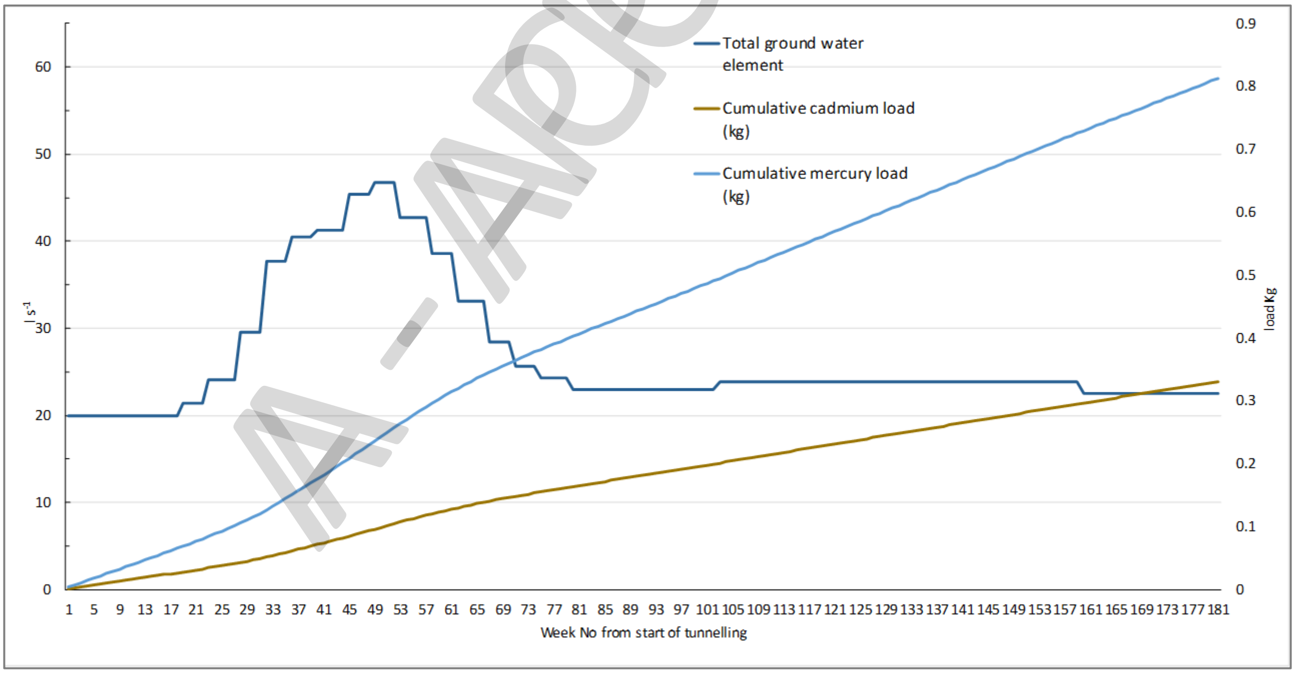

Figure 3. Three-year timeline of groundwater discharge (l s^{-1} left axis) and resulting cumulative metal load for Mercury and Cadmium (kg right axis).

3 Discharge Assessment Methodology

3.1 Modelling approach.

The release and mixing of zinc in the construction discharge was modelled using the validated Hinkley Point 25 m resolution GETM model. This is a 3D hydrodynamic model with an inbuilt passive tracer to represent zinc. As a worst case, it was assumed that there was no loss of dissolved zinc due to sediment absorption or biological uptake. Using these assumptions allowed concentrations to be scaled, as the modelled concentration was simply a function of dilution. The model setup, calibration and validation are described in British Energy Estuarine & Marine Studies (BEEMS) Technical Report TR267 Edition 2. As with the 100m resolution Hinkley Point GETM model (BEEMS Technical Report TR177) the surface is forced with reanalysed data from a meteorological model (ERA40 interim from ECMWF). The boundary conditions were forced by a broader 3D GETM domain, described in BEEMS Technical Report TR177.

The construction discharge characteristics are shown in Table 2. The discharge outfall is attached to a jetty pile and located approximately 1 m above the seabed (approximately 2 m below lowest astronomical tide (LAT)). CORMIX modelling (shown in Appendix D of this report) indicates that the plume will be buoyant and form a surface pool (or pond) at slack water which will become increasingly elongated as the tidal flow increases, forming a long thin streak at peak tidal flow. CORMIX is unable to replicate many of the features simulated by the GETM model, and GETM is therefore a better model to use away from the near field (further than 10s of metres from the outfall). Specifically, GETM can replicate wind driven behaviour and has precise bathymetry so that interactions with the tidal flow (e.g. eddies) are well replicated. Neither the CORMIX nor the GETM model includes the effects of waves which enhance vertical mixing and increase dilution. The modelling predictions of plume areas above the EQS are therefore conservative: the actual discharge will be subject to more mixing and dilution (caused by wave action) than the models are able to replicate and so the actual concentrations in the environment will be lower than those predicted.

The mean background concentration of zinc in the environment is 3.03 µg l^{-1} (See Appendix A**)** whilst the EQS is 6.8 µg l^{-1}. When comparing the model results against the EQS, an adjusted value of 3.77 µg l^{-1} was used as a threshold to account for the background concentration of zinc, calculated by simply subtracting the background concentration from the EQS concentration.

3.2 Discussion of initial mixing conditions

The greatest challenge in modelling a small volume, buoyant flow is to sufficiently replicate the initial mixing whilst retaining the ability to simulate real wind and bathymetric features.

In this study, the GETM model domain used a discrete grid with dimensions of 25 m by 25 m and 15 vertical layers in a sigma co-ordinate system in which the layer thickness changed with water depth. The discharge flow for Case D (25 l s^{-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.

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 east), 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, around slack tide, a pool of the discharged water will form at the surface which will be advected westwards as the ebb tide increases. As the tidal range is large in the Severn Estuary, this surface layer of water will be separated vertically from the bed, and the discharged water will not meet sensitive features such as *Sabellaria* or *Corallina* patches. As the tidal flow velocity increases, the strong tidal flows and rough topography of the Severn Estuary generate strong vertical mixing which ensures a large reduction in the concentrations of contaminants in the discharged water.

The period around low water slack tide is the time of greatest *potential* concern. It would be expected that the slack water period at low tide would also result in ponding, and that this ponded water would then be advected as the flood tide increases. As the water depth at this time is low, it has the *potential* for interaction with the bed and to be advected onto the sensitive areas of the rock platform. As the flow increases after low water slack tide, the water depth increases and the potential for interaction with the bed at concentrations of concern decreases. It is therefore the period around low water slack tide that needs the best simulation from the model. The CORMIX model system was used to understand the initial mixing condition (Appendix D). It indicated that at 25m distance from the discharge the dilution was approximately 22-fold. CORMIX modelling also showed that the plume rapidly comes to the surface (because of its buoyancy) so that only a very small footprint of exposure (radius of up to 5 m or 78 m^2) occurs at the bed.

The discharge varies with time. During Case A and Case D it is small compared to the model grid size (approximately 20 – 25 l s^{-1} when considering groundwater alone) and therefore initial dilution due to mixing in the model is potentially overestimated. This was overcome by simulating discharge into the upper grid cell of the model only, successfully replicating the near-field mixing suggested by the CORMIX simulation. At low water slack tide, the vertical cell size at the surface in the GETM model at the outfall location is 0.2 m and the total volume in the upper grid cell approximately 125 m^3. During Case B and Case C conditions the initial mixing condition is less of a concern where volumes of discharge peak at 63 l s^{-1}.

As the Cormix modelling suggested that initial dilution was 22-fold at a distance of 25 m from the discharge (i.e. the same size as a single grid cell) then the discharge volume of 20 l s^{-1} met this dilution criterion within 284 seconds or approximately 5 minutes. For the larger Case C discharge, 22-fold dilution was achieved in 95 seconds.

The period of near slack water (but not zero velocity) in the model is typically around 30 minutes, much longer than the worst case 5 minutes given above, thus the GETM model will correctly represent the concentrations of zinc around low water and thus replicate the low water ponding situation well. The ponded water is then advected by the tides. The model is therefore able to replicate the period of concern (low water slack tide) accurately. The advection of the ponded water is shown in Appendix E.

The maximum concentration at the point of discharge (within 25 m) may be underestimated, but away from that grid cell (25 m by 25 m) the concentrations are well represented.

While the tide advects water along the coast, with a small cross-shore component, it is the wind direction that gives the greatest variability in the cross-shore component and possible impact on to the shore and sensitive habitat.

3.3 Analysis of wind scenarios.

The tide will move the plume along the coast, but it is expected that the winds from the northern quadrant will have the greatest potential to push the plume onto the intertidal areas where *Corallina officinallis* and *Sabellaria* sp. are found. The year 2008 has been used as the representative year for all the Hinkley Point C thermal and chemical modelling (BEEMS Technical Report TR177) and hydrodynamic data collected in that year was used to validate the models. To maintain consistency with previous modelling work, 2008 was, therefore used as the modelling year in this study. Analysis of the wind speed and direction for the year 2008 (see Figure 4) shows that the month of November exhibited both the highest percentage of days with northerly winds and highest percentage of days with average wind speed in the 5 -15 m s^{-1} range from N and NW directions. Choosing the month of November to perform the simulation ensures the worst-case scenario for impact and a realistic variability in weather forcing.

The current operational Hinkley Point B discharge was included in the simulation (equivalent to Run A in BEEMS Technical Report TR267 Ed.2) for the period of 21/10/2008 to 30/10/2008 to spin up the temperature and salinity across the domain and with the discharge simulation run from 1/11/2008 to 20/11/2008. However, it was not expected that the absence of the HPB plume (such as during an HPB outage) would affect the results as there would be little interaction between the discharge at the jetty and the HPB thermal plume. On the flood tide, the jetty discharge does not reach the HPB outfall at significant concentrations and, on the ebb tide, the thermal plume from HPB mostly passes to the north of the jetty.

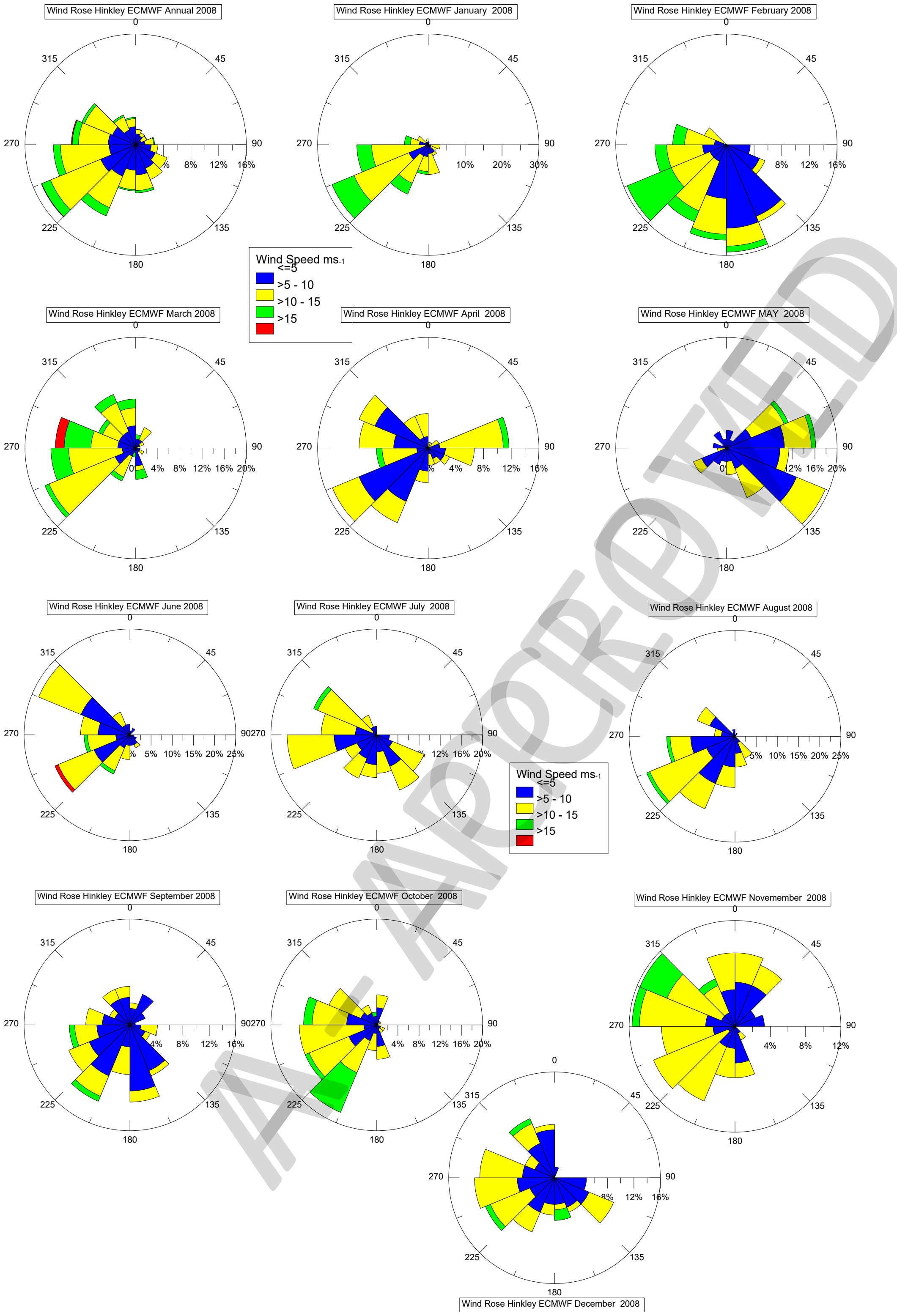

Figure 4. Wind rose for 2008 showing annual and monthly rows. November has the strongest component of winds from the North and was therefore selected as a worst case for the modelling.

3.4 Tunnelling materials and chemicals.

Tunnel boring machines (TBMs) will be used to excavate two tunnels required for the cooling water intakes and one for the cooling water discharge. Tunnels will be constructed in sections or rings. One ring is equivalent to 1.5 metres of tunnel length and an estimated maximum of 24 rings per intake tunnel per day and 16 rings for the outfall tunnel per day will be completed.

By far the largest volume of wastewater produced by tunnelling operations comprises groundwater from the deepest excavations completed during early stages of the SCL works. This groundwater discharge is considered alongside the main dewatering discharge, as it will be of similar composition and therefore could also contain levels of zinc of potential concern. There are also much smaller quantities of water which contain chemicals from the tunnelling operations, and those chemicals are considered here.

To obtain optimum performance with TBMs, ground-conditioning chemicals are used at the cutter head. These chemicals improve ground properties for cutting and for the initial removal using a screw conveyor. During the subsequent transport of removed materials from the cutting face on a conveyor belt, some residual fluids associated with the conditioned ground material will leach out and be captured in the pit at the bottom of the tunnel. These fluids, along with small amounts of natural groundwater from the cutting face, will then be pumped out and discharged at the jetty location.

Chemical use in tunnelling is associated with three broad functions which are:

(i) Fuelling and lubrication of the TBM

(ii) TBM protection greases / sealants

(iii) Ground conditioning

Table 4 provides a description of these main chemical applications in tunnelling, the most likely chemical types and their properties and indicates the fate of residual wastes.

Table 4. General chemical use, treatment and disposal associated with tunnelling operations

Chemical function	Chemical type	Description of use	Disposal route
Fuelling and lubrication	Hydraulic oils	Various uses on TBM	Spills when filling or seal leaks treated with absorbent granules, granules disposed of by licenced waste disposal
	Other oils	Various uses on TBM	As above
	Diesel	Backup generators	As above
Sealant	Grease	Approx. 2.5 kg per ring used in positive loss protection	Returned to muck bay as contained within excavated spoil. Remainder in barrel returned to surface, washed and waste disposed of by licenced waste disposal
	Tail skin grease	1.5 kg m^2 left on tunnel wall lining	In tunnel encased on outer surface of ring. Remainder in barrel returned to surface, washed and waste disposed of by licenced waste disposal
Ground conditioning	Various	circa 50l per ring if system running at 100 %	Spoil returned to muck bay, residual fluids lost to pit bottom are recovered and pumped to jetty

Fuelling and lubrication of the TBM will be managed to minimise the possibility of any oil/chemical spills but any potential losses will be contained by appropriate treatment and disposal. The sealant greases are formulated to be impervious to water and preferentially associate with the ground materials. All sealant used will therefore either remain associated with the tunnel walls or retained within the spoil. During ground conditioning, different chemicals may be used as anti-clogging agents, as anti-wear components and for soil conditioning. The exact conditioning products are likely to be specific to the TBM chosen and to the substrate encountered which will not be known until trial boring commences. To enable the discharge to be assessed, several potential drilling compounds were reviewed for toxicity and percentage concentration in the drilling fluids, and products that would represent a worst-case discharge were selected for assessment. Chemical constituents of TBM ground conditioning products BASF Rheosoil 143 and CLB F5 M failed the initial EQS screening and were investigated further using modelling approaches for these products based on the proportion of specific active substances and their PNECs (described in Table 5). The main chemical groups included are surfactants and 2-methyl-2,4 pentanediol (also known as hexylene glycol). These chemicals are very soluble and those that have not bonded to particles would run to the pit bottom and subsequently be discharged at the jetty.

It is expected that 48 litres of ground conditioning product will be used per ring for the intake tunnels and 64 litres for the outfall tunnel. For each product, the discharge assessment assumes the use of the highest hazard chemical based on quantity and toxicity that is present (highest effective volume flux). Based on a relative maximum product density of 1.05 and assuming maximum percentage composition for a component active substance, the total quantity of each substance used per ring and for 40 rings per day (see section 3.4.1) was calculated (Table 5 and Appendix C, Table 23). Note that the total quantity estimates for each chemical are considered conservative / worst cases as in practice more than 1 product (including some with lower toxicity) may be used at the same time.

Table 5. Example products for use in ground conditioning, their properties and percentage of key component substances and associated Predicted No Effect Concentrations for each substance or surrogate value for a group of similar substances. Details of calculations in Appendix C, Table 23.

Chemical function	**Product**	**Main active substance(s)**	**Active mass (kg) per day assuming 100% use for 1 intake tunnel and 1 outfall tunnel.**	**Predicted no effect concentration (PNEC) for aquatic environment (µg l^{-1})**
Anti-clogging agent	BASF Rheosoil 143	Sodium lauryl ether sulfate (<30%)	68.5 kg[1] (based on 40 rings per day)	40[2]
Soil conditioning-additive	CLB F5 M	2,4-Pentanediol, 2-methyl- (≤10%)	22.8kg[1] total (based on 40 rings per day).	4300[3]
		Alcohols, C10-16, ethoxylated, sulfates, sodium salts – (≤10%)		35[2]
		Mono-C10-16-alkyl, Sodium sulfate (≤10%)		4.5[4]

[1] This value takes account of substance density (1.05), % active substance, and assumes 90% associated to spoil (see later discussion); [2]see Table 15 HERA 2004; [3]see SIDS, 2001, [4]see Table 13 HERA, 2002

The PNEC values shown in Table 5 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). In the case of mono-C10-16-alkyl sodium sulphate we assessed the C14 toxicity (as this generated the most conservative PNEC) whereas the substance will be composed of a range of carbon chain lengths.

3.4.1 Screening methodology assessment.

Theoretically, a maximum of 24 rings could be installed per intake tunnel per day and 16 rings for the outfall tunnel. There is overlap in time of construction between the HPC cooling water Intake 1 and the cooling water outfall and between the outfall and Intake 2. The current drilling programme (Figure 1) shows a short overlap between the drilling of all 3 tunnels. However, for operational reasons including power availability, all three TBMs will not be operating at full capacity simultaneously. Using a realistic total construction estimate of 40 rings per day gives a total mass of 68.5 kg per day for BASF Rheosoil (Table 5). This assumes that overall, 10% of the active substance of the product used leaches out of the soil and is then discharged via the jetty. This is considered a conservative estimate of the level of adsorption to the mineral material removed from the tunnel for each ring.

Various literature sources show that at surfactant solution concentrations of several hundred mg l^{-1} there is adsorption of between 3 – 19 mg of anionic surfactants per gram of mineral (i.e. kaolinite) associated with the solution (Lv *et al*., 2011, Yekeen *et al*., 2017). Based on the predicted surfactant concentration in the conditioning fluids and the large quantity of mineral material removed per ring it is likely that all but a few percent of surfactant will be adsorbed to the mineral waste but a conservative 90% is assumed here. Case D is the most likely time when peak ring installation rates (and hence peak usage of soil conditioning chemicals) will occur.

Table 6. Environment Agency screening assessment of surfactant components of products. Example chemicals for use in ground conditioning, their properties and fate (for details of calculations see Appendix C, Table 24).

Conditioning product	Estimated Discharge concentration mg l^{-1} of active substance. Case D	Saltwater AA EQS[1] µg l^{-1}	Background concentration µg l^{-1}	Effective volume flux (Case D) Total flow 40 l/s ($m^3 s^{-1}$)	TraC Water test 5 EVF< 3.0 (Pass/Fail)
BASF Rheosoil 143	19.8	40	0	19.80	Fail
CLB F5 M Ethoxylated sulphates	6.6	35	0	7.54	Fail
CLB F5 M Mono- alkyl sodium sulphate	6.6	4.5	0	58.67	Fail

[1] these EQS values derived from HERA 2004 for both BASF Rheosoil 143 (sodium lauryl ether sulfate) and for CLB 5M (Alcohols, C10-16, ethoxylated, sulfates, sodium salts –(≤10%) Mono-C10-16-alkyl, Sodium sulfate (≤10%)

As these chemicals fail the TRAC 5 screening test they are considered further in the next section.

3.5 Assessment of construction and cold commissioning inputs.

Edition 6 of this report considered the construction discharge inputs. During the latter phase of the construction period (best represented by Case D construction discharge inputs) cold commissioning of the reactors and associated pipework will take place. During this process, a range of tests will be conducted, and conditioning will be undertaken with demineralised water (potable water may be used in some cases) and various chemical additives. The discharge of commissioning wastewater will contribute to intermittent discharges of commissioning chemicals and their breakdown products. During cold commissioning there is no available cooling water system therefore discharge is planned via the jetty. The commissioning discharge has been assessed for inputs of hydrazine using a discharge rate of 83.3 l s^{-1} and this assessment is described in BEEMs technical report TR445. Here the breakdown products of that hydrazine and other commissioning chemicals are assessed in combination with construction inputs for Case D (see Table 1).

Testing of the primary and secondary circuits requires them to be filled and flushed several times each with demineralised water and treatment chemicals. As a precautionary assessment the maximum daily discharge volume is taken to be 1500 m^3d^{-1}, equivalent to the contents of the two 750 m^3 HXA tanks that serve this waste stream. The discharge rate is expected to be 37 l s^{-1} per tank or 70 l s^{-1} for discharge of both. The discharge is expected to last for a period of 5.63 hours. The modelled discharge rate is lower than that modelled for the hydrazine discharge modelling which used a rate of 83.3 l s^{-1} over a 5 hour period (BEEMS TR445). The higher discharge rate was based on information available at the time of modelling and the lower discharge rate is considered more accurate for the HXA tanks. In terms of the hydrazine modelling for commissioning, as the discharge concentration would be the same for either discharge rate, the higher rate of 83.3 l s^{-1} is considered to provide a slightly more conservative assessment. However, for the hydrazine and other commissioning chemical breakdown products modelling the 70 l s^{-1} has been used.

Following work on the commissioning effluent treatment plant (CETP) it was identified that this development will create an intermediate stage before discharge of the HXA wastewater. The CETP would have a much lower predicted discharge rate of 11 l s^{-1} but there may also be further storage just post treatment to provide a means of monitoring effluent quality and to allow for batch discharge via the jetty. A further wastewater stream will be derived from the demineralised water plant with an indicative discharge rate of 17 l s^{-1}. This discharge may also be routed to a storage tank prior to discharge from the jetty.

The discharge modelling conducted for hydrazine in TR445 and for the hydrazine breakdown products in this report (TR428) provide a conservative assessment as it assumes maximal discharge rates from the jetty (70 – 83 l s^{-1}) with this waste stream made up entirely of either commissioning chemical breakdown products or of hydrazine at one of several treatment levels. However, it is likely that with dilution by other waste streams either hydrazine or the commissioning chemical breakdown products will represent a smaller fraction of the total discharge modelled.

Previous assessments (83 l/s) are considered conservative as the lower mass flow rate and further dilution (of the 11 l/s discharge) will mean a smaller initial discharge concentration than previously assessed (which showed no impact of the features considered). Furthermore, while the total mass of hydrazine released is the same, it is released over 24 hours rather than 5 hours, so that decay becomes more relevant, and will further reduce the concentrations below levels previously modelled. Previously modelling showed no impact of designated features above PNEC, and the reduction in mass flux of hydrazine will reduce potential exposure even further.

Although the discharge rates modelled are considered representative of total discharge rates from the jetty the hydrazine concentration discharged would be lower and so discharges may occur over a longer period than modelled, although based on operational practice this is unlikely to exceed 8 hours a day.

The chemicals present during commissioning are expected to be hydrazine, an oxygen scavenging chemical, ammonia for pH adjustment, ethanolamine, and trisodium phosphate. An initial screening of the discharge of these chemicals (Appendix C Table 25) confirms that hydrazine and un-ionised ammonia would not pass, and both require more detailed assessment. Hydrazine has been assessed in detail in BEEMS TR445. Ammonia input from commissioning is contributed both directly and potentially from the breakdown of hydrazine and ethanolamine. Ammonia contributions from construction inputs during Case D and from commissioning inputs are shown in Appendix C Table 26 and Table 27 and are assessed in section 4.10. Phosphorus inputs are derived based on the conservative assumption that the total mass PO_4-P present in the trisodium phosphate used in commissioning will be discharged and is available for plant growth. The nitrogen and phosphorus inputs present during cold commissioning and the potential contribution to plant growth in the estuary are assessed in the following sections.

3.5.1 Nutrient input assessment.

As phosphate is not normally the limiting nutrient in marine systems in near coastal water of the UK, the assessment of construction nutrient inputs in Edition 6 of this report focussed on nitrogen only. The influence of the nitrogen loadings upon waterbody nutrient status is discussed in section 4.5.2. but more detailed modelling was not considered necessary. When taking account of the additional nutrient inputs during the cold commissioning, an updated assessment was made in this report version (Ed7) using a combined phytoplankton macroalgal model (CPM) (Aldridge et al., 2008). This model includes the combined construction and cold commissioning inputs of nitrogen and phosphorus which are all discharged at the construction outfall at the jetty location just before the jetty head.

3.5.2 Other chemical input assessments.

Assessment of the construction inputs of ammoniacal nitrogen in Edition 6 of this report focussed on the proportion of un-ionised ammonia in the construction discharge as influenced by local seawater physicochemical parameters. The CORMIX model is used to determine the point at which the discharge is sufficiently mixed such that the proportion of un-ionised ammonia falls below its annual average EQS of 21 μg l^{-1} (NH_3-N).

In this Edition 7 an assessment of the combined cold commissioning and construction inputs of ammoniacal nitrogen is made. For the combined assessment reference is made to the un-ionised ammonia EQS and to the total ammonia concentration as referenced in ammonia standards for estuaries (WQTAG086, 2005).

3.5.3 Cementitious washwater

The Hinkley Point C project continues to use concrete and cementitious grout for a number of applications. Cement and grout equipment and containers require washing out, for example at the end of each shift, which creates a cementitious wash water. Although there is the potential to reuse some wash water in the mix, in many circumstances reuse is not possible due to quality specifications. Currently excess CWW is being removed from site by tanker for off-site treatment leading to increased vehicle movements and fuel use, and social and economic impacts. NNB HPC would like to be able to discharge CWW via Activity F to reach a more sustainable approach, however, to do this a variation to the currently agreed activity is seen as the most appropriate way forward.

NNB HPC propose to vary the permit to:

- change the discharge location for CWW to Outlet 12; and
- increase the permitted flow rate to 50m^3/day which is considered sufficient for all CWW discharged through to the completion of the project.

It is recognised that the current permitted discharge location (Outlet 1) which discharges to the sensitive foreshore has higher potential to impact the environment due to the potential for direct contact with receptors such as Sabellaria spp. and Corallina spp. Changing the discharge to Outlet 12 located at the HPC jetty would reduce the potential for impact to the environment as it is a subtidal location where there is greater opportunity for dilution and dispersion to occur. Detailed modelling was also produced for the previous CWDA variation which enabled discharge of tunnelling effluent and groundwater from this location.

A review of the likely volumes of CWW that cannot be re-used to make new concrete or grout has indicated that 10m^3/day as allowed under the existing permit is insufficient. It is considered that marine works may produce up to 20m^3/day and the main civils works may produce up to 30m^3/day giving a total of 50m^3/day although it is unlikely that both sources will be producing CWW at maximum capacity at the same time.

NNB HPC will provide a cementitious wash water characterisation report as per permit condition PO2 when the required information becomes available. NNB HPC recognise that no discharge can commence under Activity F until a submission under PO2 is approved by the EA.

Treatment to remove suspended solids and to adjust pH will be required to facilitate discharge. The precise treatment system is yet to be determined but is likely to comprise a lamella settlement step, likely enhanced with coagulant and flocculent and a pH correction step which will utilise carbon dioxide to neutralise the excess alkalinity. All the treatment chemicals to be used have previously been approved for use by the Environment Agency in connection with treatment of surface water which is discharged via the same outfall. A cement water characterisation report is in preparation. The ground, granulated blast furnace slag (GGBS) and the cement are commonly used and well understood ingredients within cementitious products; the principal substances that could conceivably give rise to environmental effects are metals, anions, and elevated pH. The wash water will be treated to reduce the pH to between 6 and 9 as required under the CWDA permit (Environment Agency, 2018). Therefore, this risk will be removed and does not require further consideration. Given the receiving water is saline, anions are not considered a risk and will be disregarded. This is because of the high chloride and sulphate concentrations naturally present in saline waters. Based on a preliminary characterisation the potential for in combination effects of the concrete wash water with other construction and commissioning discharges is considered in section 4.10.4.

4 Results

4.1 Modelling of the discharge for Zinc in relation to *Corallina*

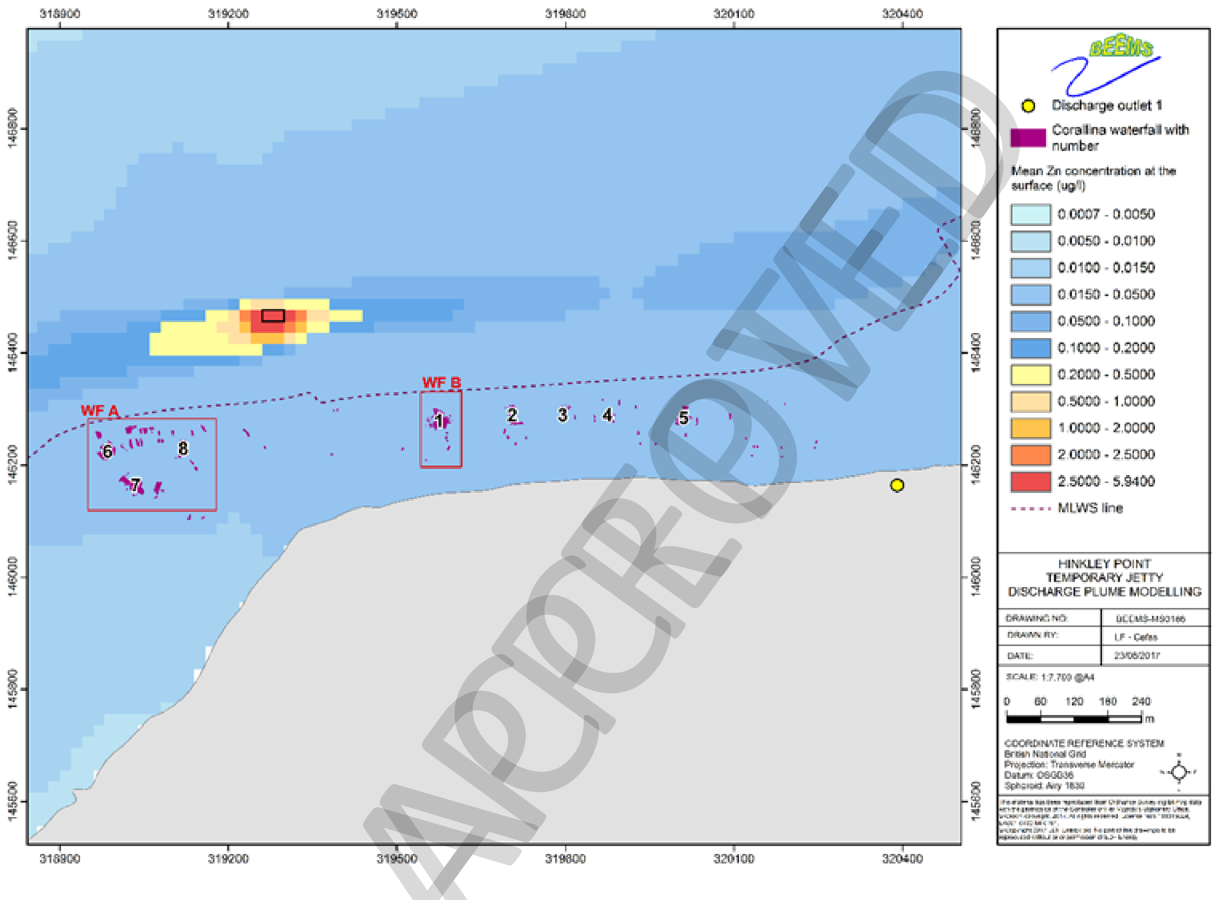

Figure 5. Distribution of average (monthly mean) surface concentrations of zinc for Case D in relation to the *Corallina* features. The EQS is exceeded for the small area by the discharge itself. Features labelled WF are the *Corallina* waterfalls referred to in the HPC jetty monitoring reports (BEEMS TR256). The comparative EQS is 3.77 µg l^{-1}.

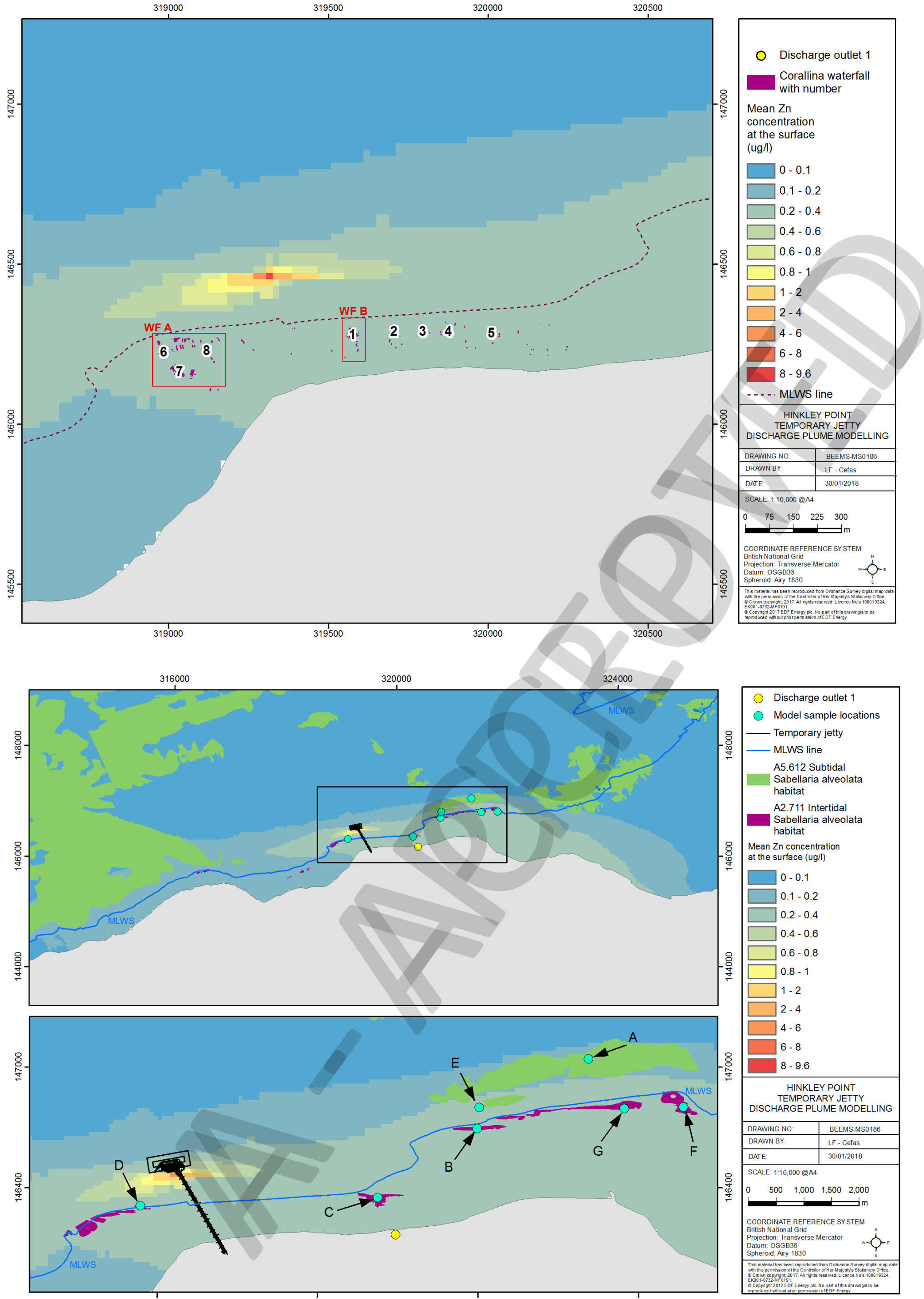

Figure 6. Distribution of average (monthly mean) surface concentrations of zinc for Case C in relation to the *Corallina* features. The EQS is exceed for the small area by the discharge itself. Features labelled WF are the *Corallina* waterfalls referred to in the HPC jetty monitoring report (BEEMS TR256). The comparative EQS is 3.77 µg l^{-1}.

The predicted exposure of *Corallina* to zinc for Case D and Case C are shown Figure 5 and Figure 6 respectively, together with locations where *Corallina* features are present. For zinc, the EQS is defined as an annual average. As described in Section 3.1, the modelling is performed above the background, and all tables and plots show the surplus concentration above background and refer to the EQS concentration above background levels. Zinc has a background concentration of 3.03 µg l^{-1} meaning that the threshold value for exceeding the EQS is 3.77 µg l^{-1} (Table 3). For Case C, the mean seabed concentration at each *Corallina* position increased by approximately 1% of the EQS (Table 7).

Importantly, dilution is significant across the main tidal excursion axis, i.e. there is a very rapid reduction in concentration to the north and south from the discharge plume.

The areas above the EQS for the surface are 0.125 Ha for Case D and 0.3 Ha for Case C.

Table 7. Zinc concentration (µg l^{-1}) at *Corallina* feature locations (Figure 5) for total zinc discharges corresponding to 22 l s^{-1} at 1620 µg l^{-1} Zn (Case D) and 46 l s^{-1} at 1620 µg l^{-1} Zn (Case C). The threshold for discharges to exceed the EQS is 3.77 µg l^{-1}, based on the background concentration.

Feature No. (see Figure 5)	OSGB Easting	OSGB Northing	Latitude N (°)	Longitude E (°)	Mean Case D (µg l^{-1})		Max Case D (µg l^{-1})		Mean Case C (µg l^{-1})		Max Case C (µg l^{-1})	
					Surface	Bed	Surface	Bed	Surface	Bed	Surface	Bed
1	319575	146280	51.2100	3.1527	0.10	0.10	0.37	0.37	0.24	0.24	0.87	0.87
2	319705	146290	51.2101	3.1509	0.10	0.10	0.64	0.64	0.24	0.24	1.50	1.50
3	319795	146290	51.2102	3.1496	0.11	0.10	0.61	0.61	0.26	0.24	1.44	1.15
4	319875	146290	51.2102	3.1484	0.12	0.12	0.39	0.39	0.28	0.28	0.92	0.92
5	320010	146285	51.2101	3.1465	0.12	0.11	0.49	0.49	0.29	0.26	1.15	1.15
6	318985	146225	51.2095	3.1612	0.10	0.10	0.59	0.59	0.24	0.22	1.38	1.38
7	319035	146165	51.2089	3.1604	0.11	0.10	0.29	0.29	0.25	0.23	0.69	0.69
8	319120	146230	51.2095	3.1592	0.11	0.10	0.29	0.29	0.25	0.23	0.69	0.69

Note, there is no exceedance of the EQS. Feature 5 has the highest mean concentration but feature 2 the highest maximum bed concentrations, however maximums are significantly below the EQS.

4.2 Modelling of the discharge for Zinc in relation to *Sabellaria*

On a larger spatial scale than the *Corallina* features, there are intertidal and subtidal patches of *Sabellaria* reef which may be exposed to the total discharge. The EQS for zinc is defined as a mean value and there is no intersection of discharge water above the annual average EQS (adjusted to 3.77 µg l^{-1}) with patches of *Sabellaria* (Figure 7 to Figure 10). The concentrations of zinc at *Sabellaria* features are summarised in Table 8. In all cases the mean EQS is not exceeded and the 95th percentile exposure is below the annual average EQS.

Table 8. Zinc concentrations at *Sabellaria* patches A and E (subtidal) and B, C, D, F and G (intertidal). For locations see Figure 8.

Feature	**Mean seabed µg l^{-1}**		**Seabed µg l^{-1} (95th percentile)**	
	Case D	**Case C**	**Case D**	**Case C**
Subtidal *Sabellaria* A (Easting 321350 Northing 147040)	0.03	0.14	0.09	0.20
Intertidal *Sabellaria* B (Easting 320800 Northing 146694)	0.10	0.24	0.23	0.54
Intertidal *Sabellaria* C (Easting 320300 Northing146351)	0.10	0.24	0.20	0.47
Intertidal *Sabellaria* D (Easting 319118 Northing 16309)	0.10	0.23	0.22	0.53
Subtidal *Sabellaria* E (Easting 320800 Northing 146800)	0.10	0.22	0.28	0.65
Intertidal *Sabellaria* F (Easting 321824 Northing146800)	0.11	0.25	0.23	0.55
Intertidal *Sabellaria* G (Easting 321529 Northing146793)	0.11	0.27	0.24	0.56

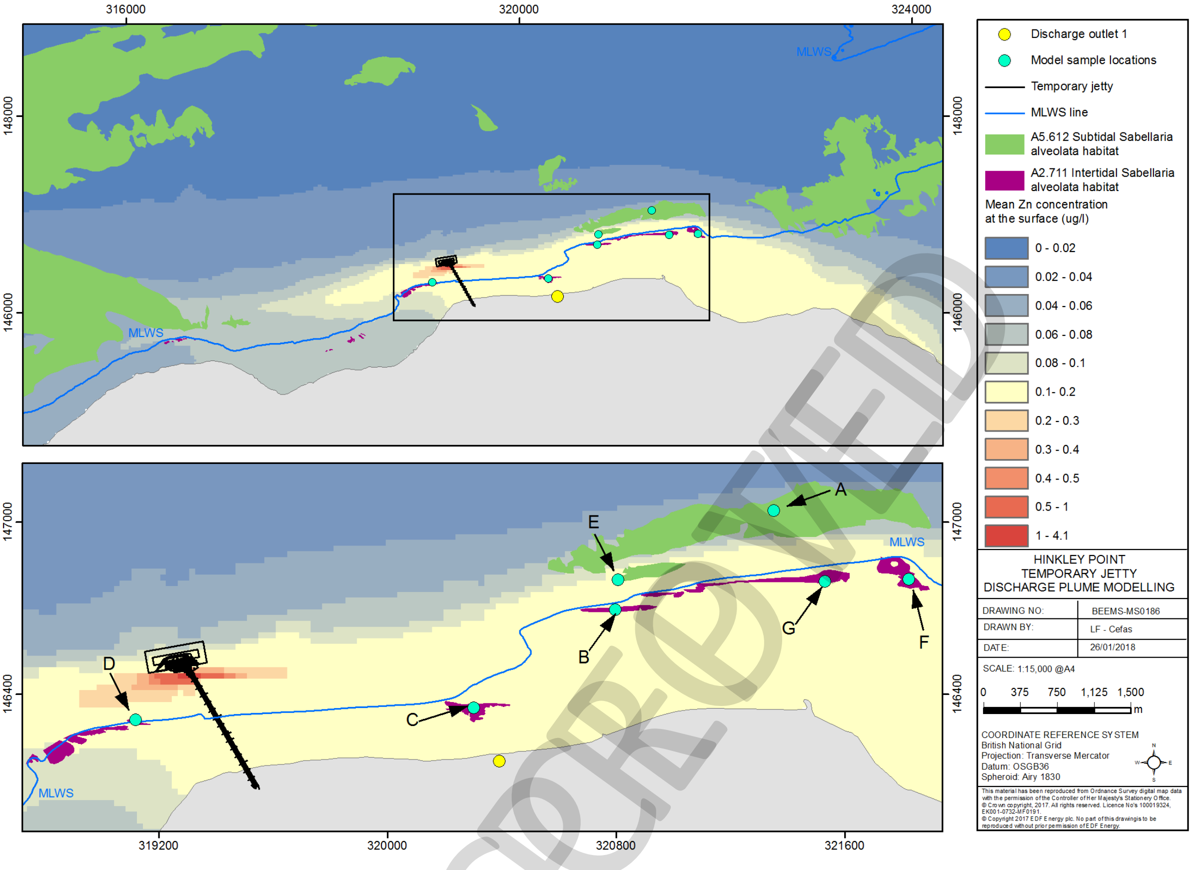

Figure 7. Mean surface discharge concentration of zinc in µg l^{-1} for case D with the location of *Sabellaria* shown (upper), and subtidal *Sabellaria* patch A and intertidal *Sabellaria* patch B, C, D, F and G marked. The EQS for zinc is 3.77 µg l^{-1} above background concentration. The cyan dots mark the *Sabellaria* positions that are listed in Table 8.

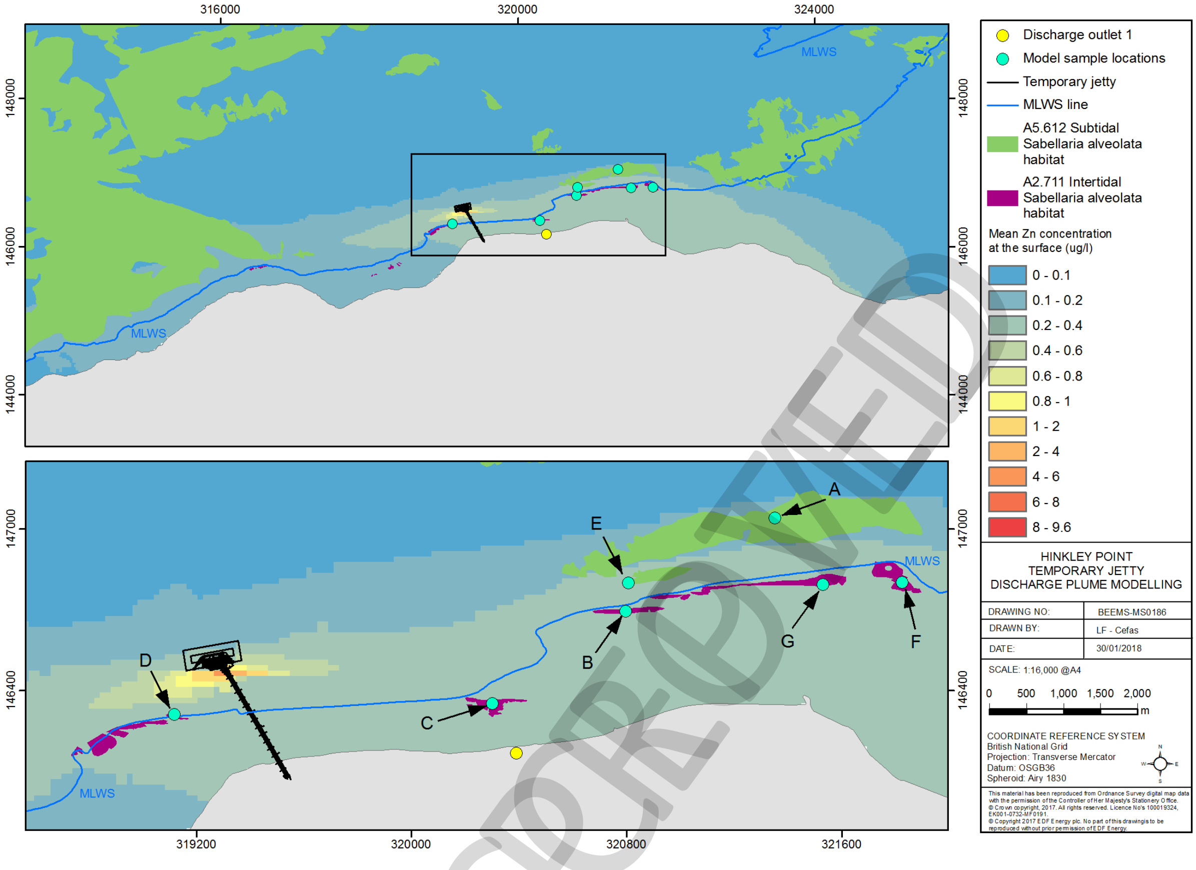

Figure 8. Mean surface discharge concentration of zinc in µg l^{-1} for case C with the location of *Sabellaria* shown (upper), and subtidal *Sabellaria* patches A and E, intertidal *Sabellaria* patches B, C, D F and G. The EQS for zinc is 3.77 µg l^{-1} above background concentration. The cyan dots mark the *Sabellaria* positions that are listed in Table 8.

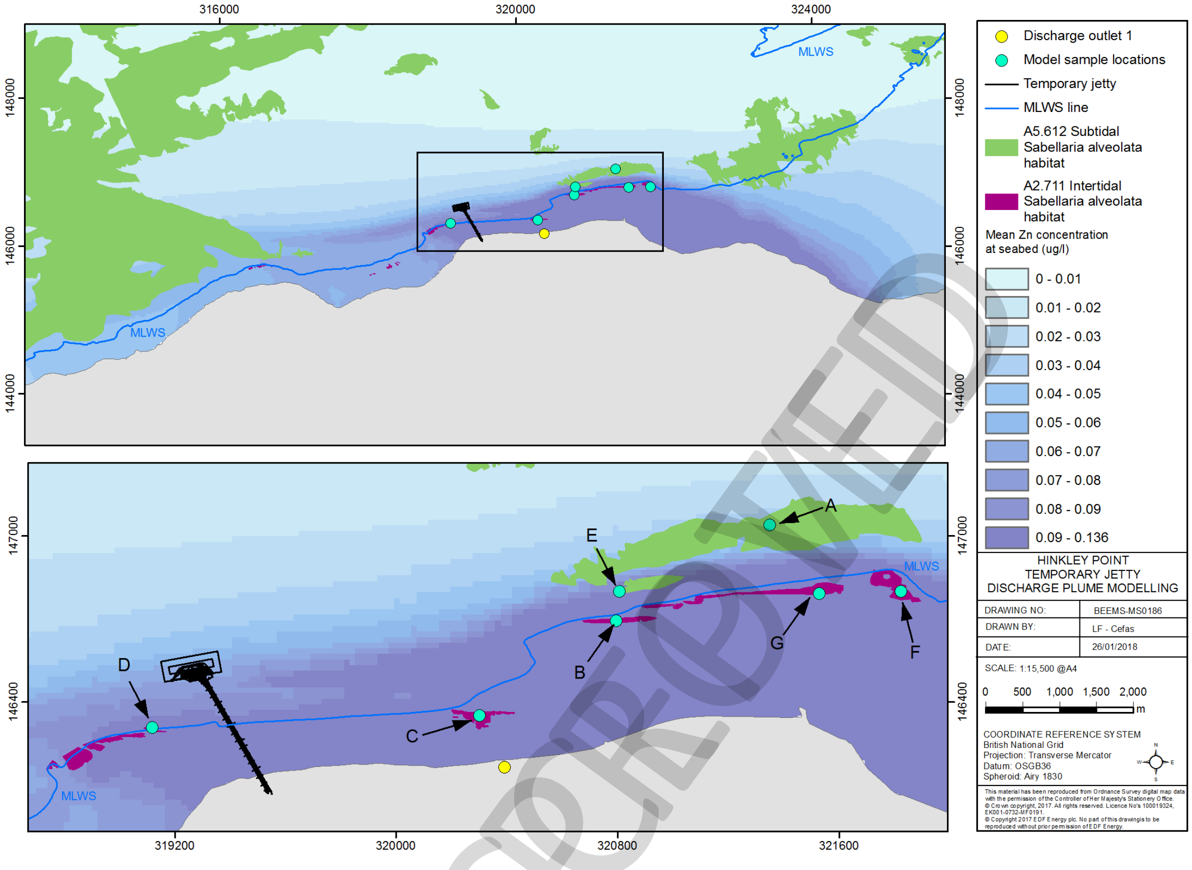

Figure 9. Mean bed discharge concentration of zinc in µg l^{-1} for case D with the location of *Sabellaria* shown (upper), and subtidal *Sabellaria* patches A and E, and intertidal *Sabellaria* patches B, C, D, G, F. The EQS for zinc is 3.77 µg l^{-1} above background concentration. The cyan dots mark the *Sabellaria* positions that are listed in Table 8.

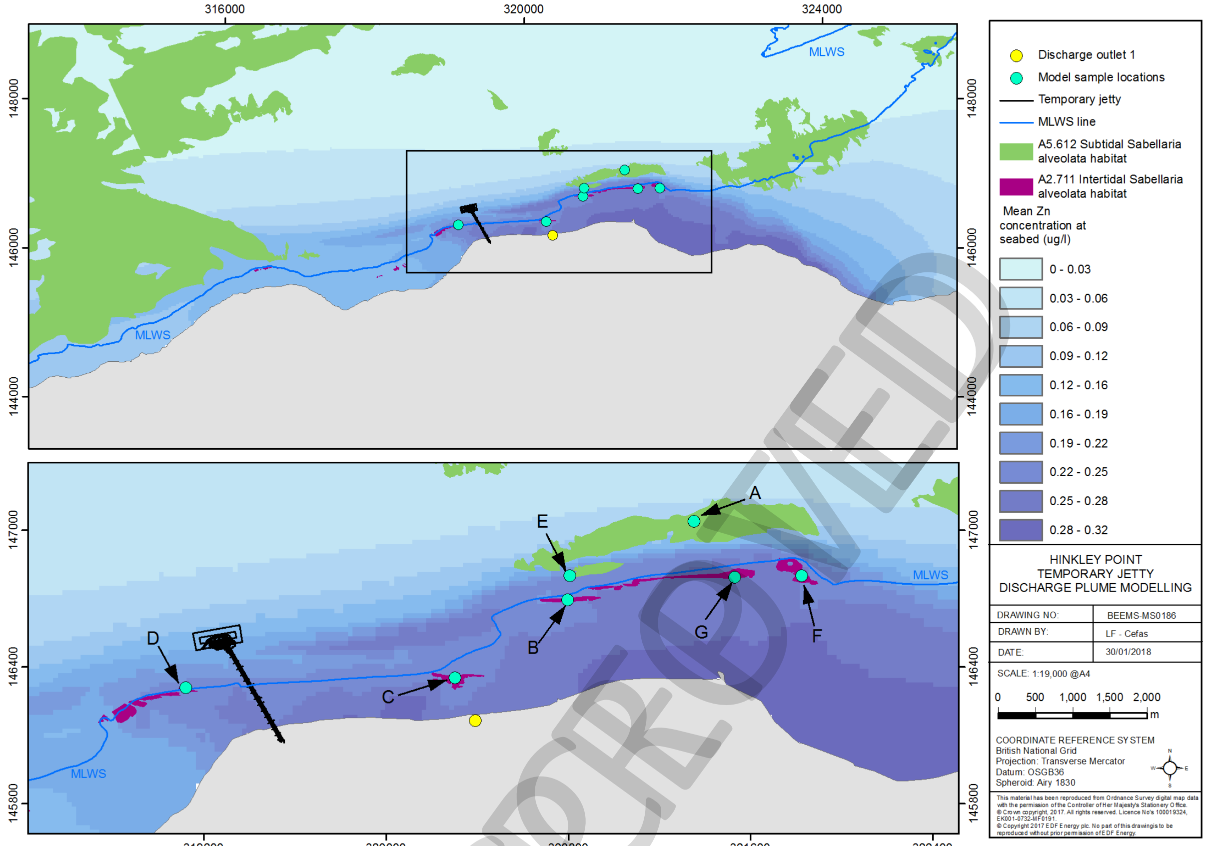

Figure 10. Mean bed discharge concentration of zinc in µg l^{-1} for Case C with the location of *Sabellaria* shown (upper), and subtidal *Sabellaria* patches A and E, and intertidal *Sabellaria* patches B, C, D, E, F and G marked. The EQS for zinc is 3.77 µg l^{-1} above background concentration. The cyan dots mark the *Sabellaria* positions that are listed in Table 8.

4.3 Modelling of conditioning chemical BASF Rheosoil 143 in relation to *Sabellaria*.

Having failed the screening test, this compound is modelled in an identical way to zinc. As the modelling of zinc does not assume any substance decay, and predicted concentrations come only from dilution, these results have been scaled from the model simulations undertaken for zinc by using a multiplier to correctly simulate the mass of discharged chemical. The exact chemical to be used may change depending on the tunnelling machine employed and substrata encountered. This modelling is included to show the likely spatial extent of a discharge of 40 l s^{-1} at concentration of 19.83 mg l^{-1} with an EQS of 40 µg l^{-1}. The tunnelling operations which use this chemical are likely to occur during the Case D period (40 l s^{-1}) however the results are insensitive to this flow volume as it is the total mass of material that is discharged that is the primary consideration.

The modelling results for BASF Rheosoil 143 are shown in Figure 11 and Figure 12 which show that there is no exceedance of mean PNEC (surrogate EQS) at the bed; there is a small area at the surface where the EQS is exceeded. The 95th percentile concentrations at the bed are shown in Figure 13.

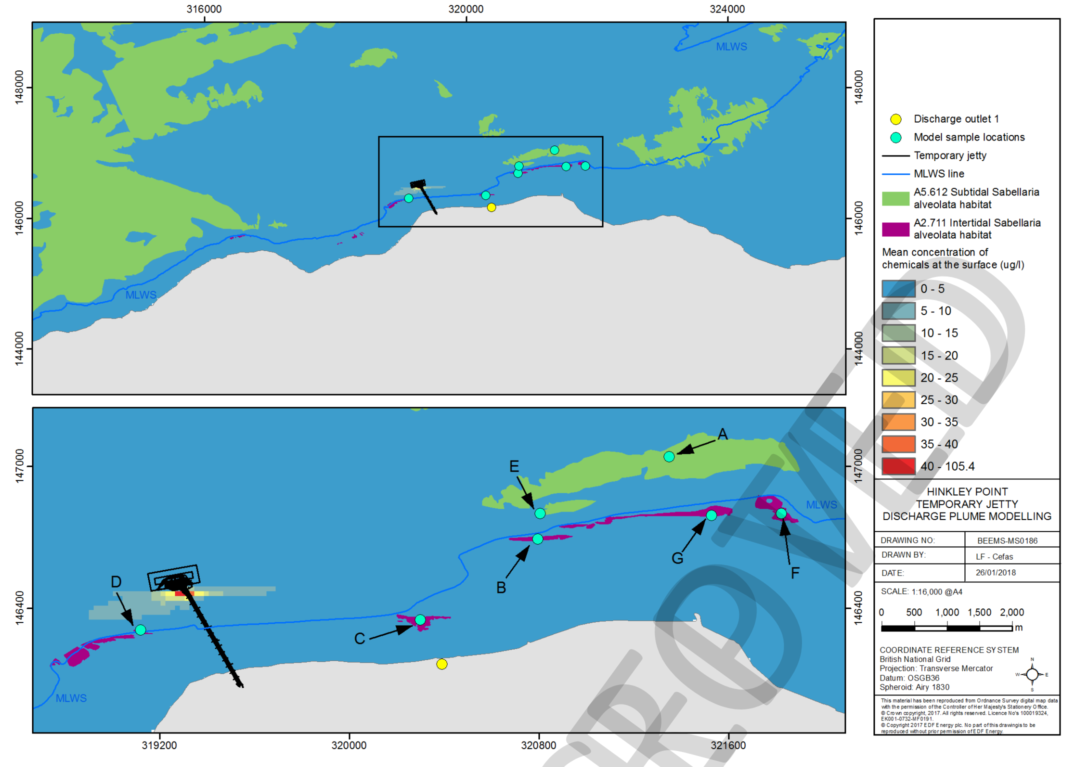

Figure 11. Mean surface concentration of BASF Rheosoil 143 in µg l^{-1}. The PNEC (surrogate EQS) is 40 µg l^{-1}. Subtidal *Sabellaria* patches A and E and intertidal patches B, C, D, E, F and G are marked.

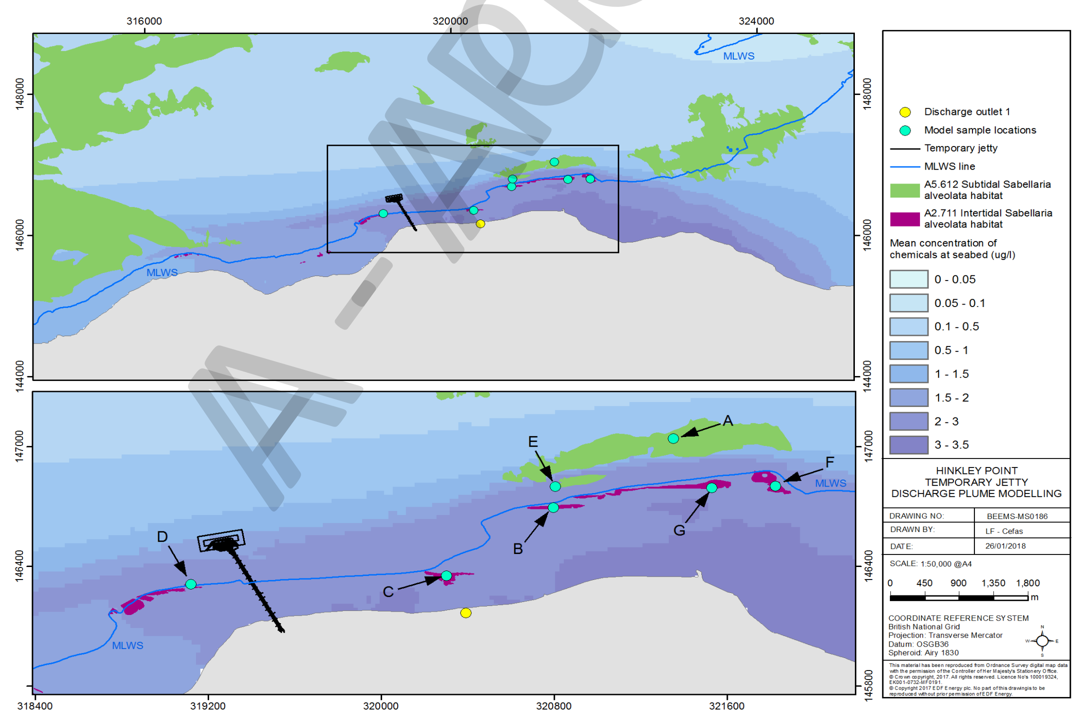

Figure 12. Mean bed concentration of BASF Rheosoil 143 in µg l^{-1}. The PNEC (surrogate EQS) is 40 µg l^{-1}. Subtidal *Sabellaria* patches A and E and intertidal patches B, C, D, F and G are marked.

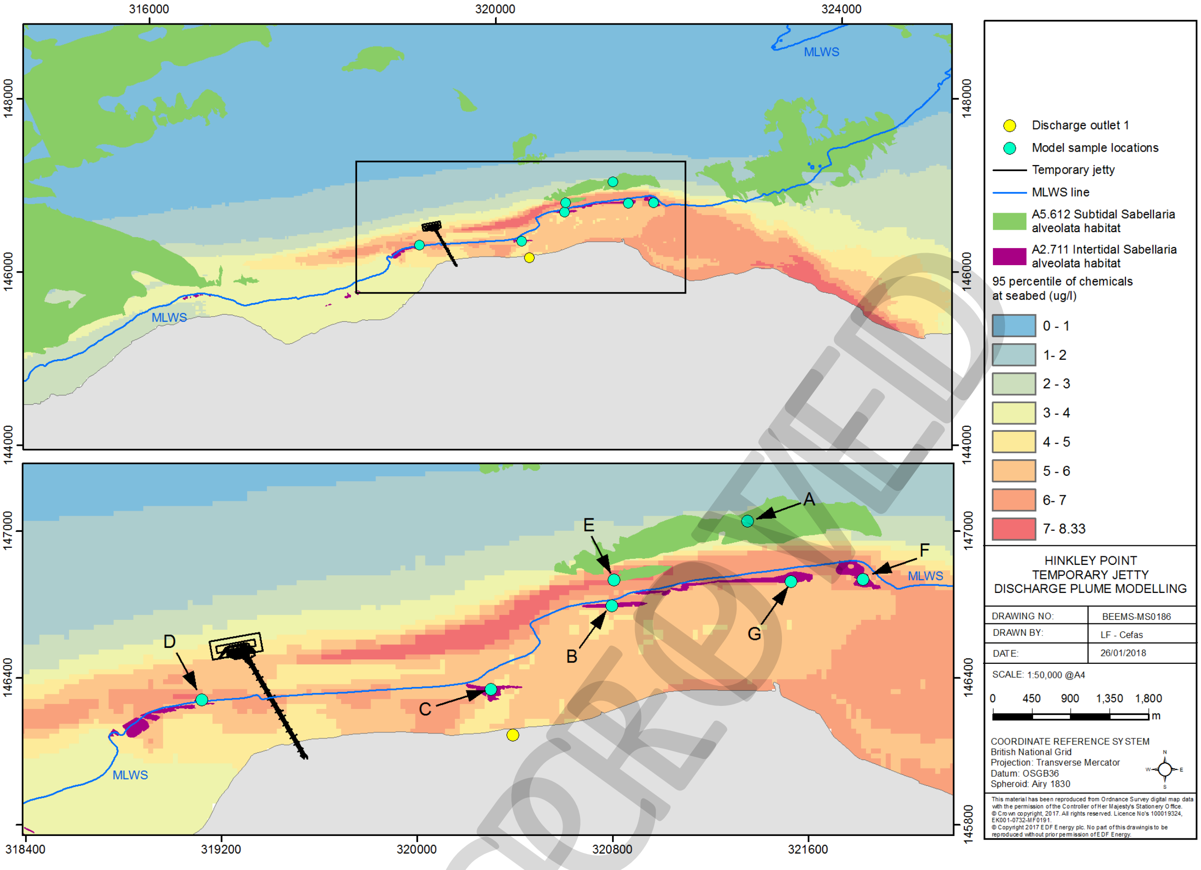

Figure 13. 95th percentile bed concentration of BASF Rheosoil 143 in µg l^{-1}. The PNEC (surrogate EQS) is 40 µg l^{-1}. Subtidal *Sabellaria* patches A and E and intertidal patches B, C, D, F and G are marked.

4.4 Modelling of conditioning chemical Condat CLB F5/M in relation to *Sabellaria*

Results of Condat CLB F5/M modelling are shown in Figure 14 and Figure 15. This modelling shows the likely spatial extent of a discharge of 40 l s^{-1} with a concentration of 6.6 mg l^{-1} and an EQS of 4.5 µg l^{-1}. No exceedance of the EQS concentration is predicted to occur at the bed, though a small area of exceedance (0.96 ha) is predicted at the surface. Note the scales are different between surface and bottom plots. 95th percentile concentrations at the seabed are shown in Figure 16.

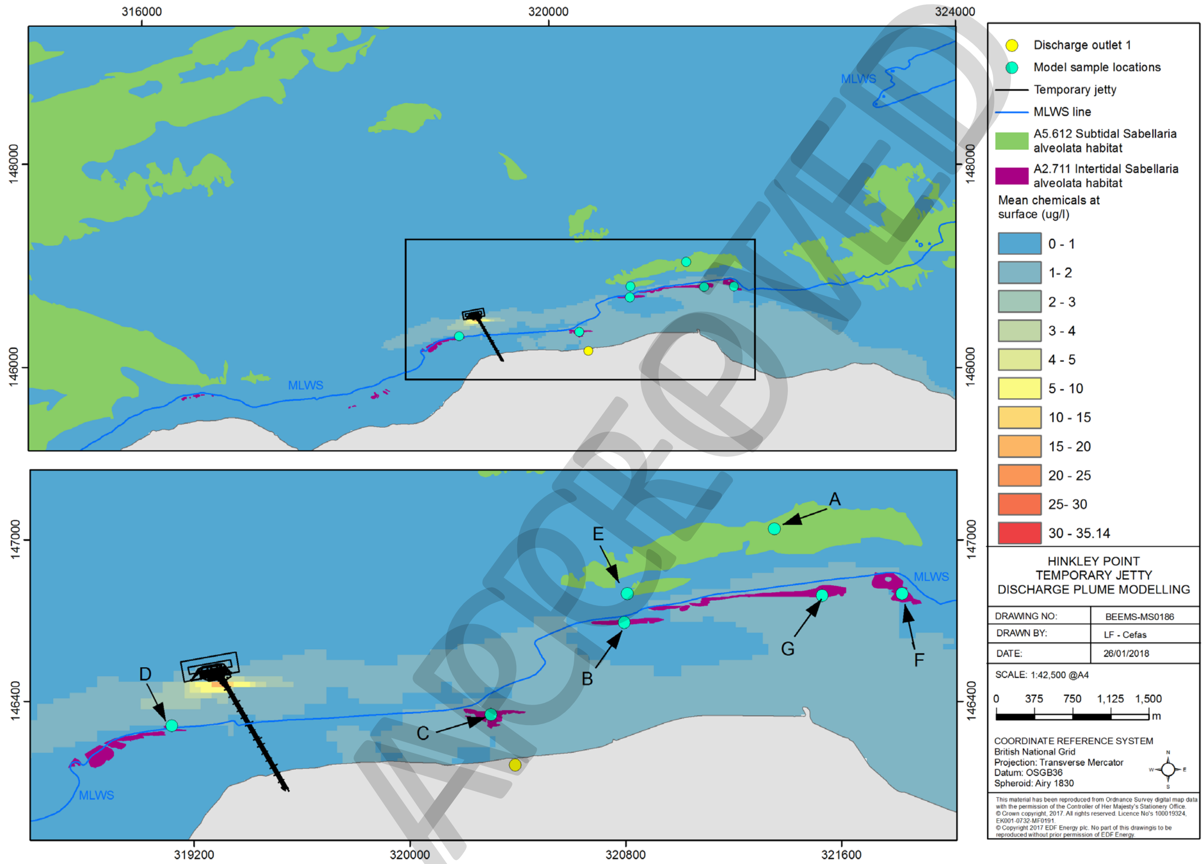

Figure 14. Mean surface concentration of CLB 5 in µg l^{-1}. The PNEC (surrogate EQS is 4.5 µg l^{-1}) with the location of *Sabellaria* delineated. Subtidal *Sabellaria* patch A, E and intertidal *Sabellaria* patches B, C, D, F and G marked.

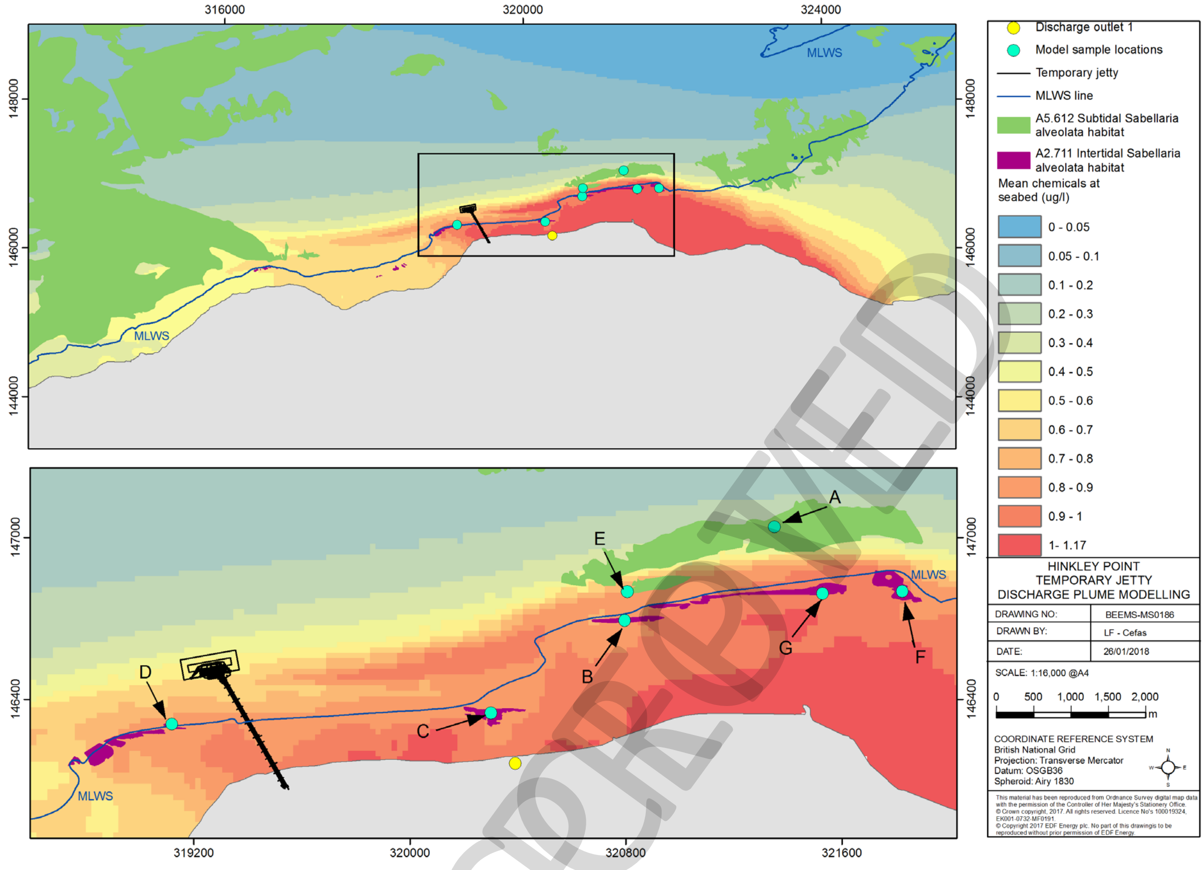

Figure 15. Mean bed concentration of CLB 5 in µg l^{-1}. The PNEC (surrogate EQS) is 4.5 µg l^{-1} with the location of *Sabellaria* delineated. Subtidal *Sabellaria* patch A, E and intertidal *Sabellaria* patches B, C, D, E and G marked. No exceedance of the PNEC is predicted at the bed.

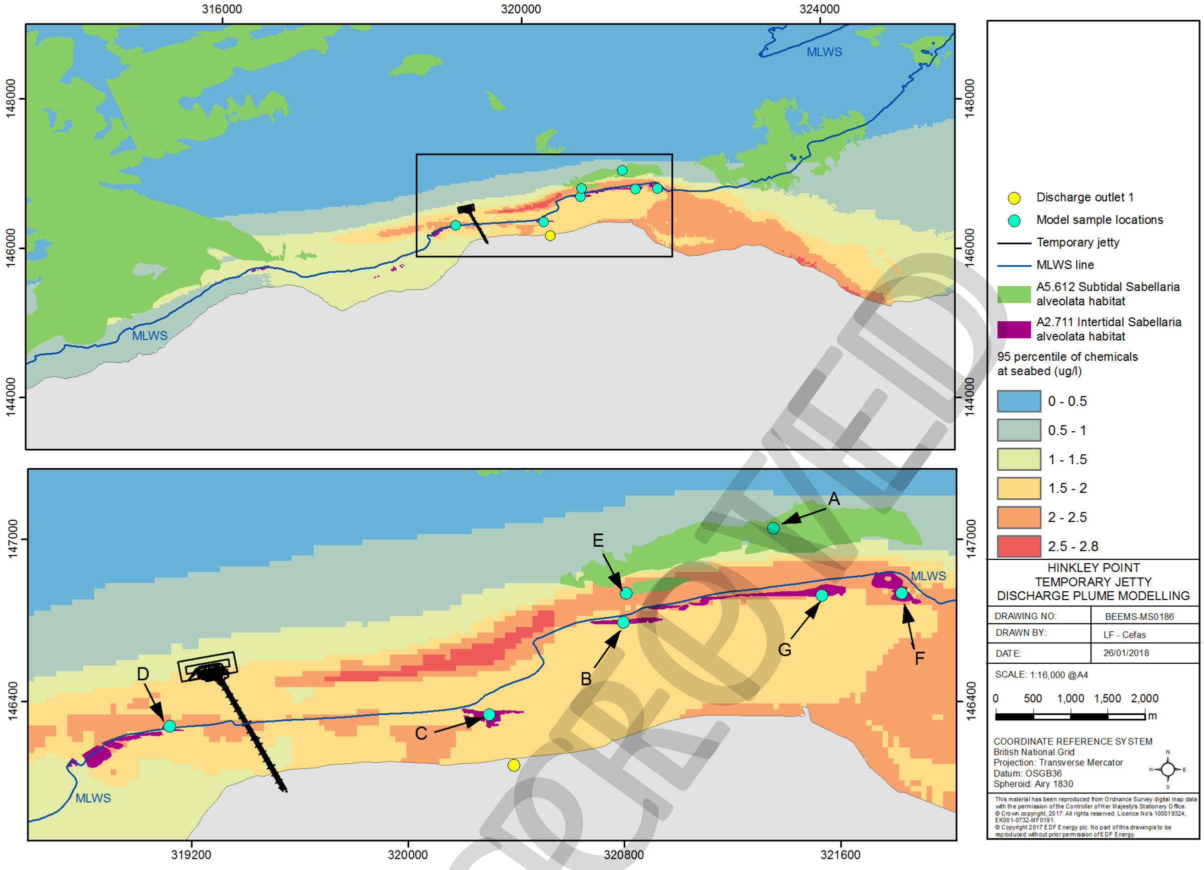

Figure 16. 95th percentile concentration of CLB 5 in µg l^{-1} at the seabed. The PNEC (surrogate EQS) is 4.5 µg l^{-1}. Subtidal *Sabellaria* patches A, E and intertidal *Sabellaria* patches B, C, D, E and G are marked.

Table 9. Concentrations of active substances of conditioning products, occurring at *Sabellaria* patches A, E (subtidal) B, C, D, F and G (intertidal). Feature locations are shown in Figure 16.

Feature	**Mean seabed concentration (µg l^{-1})**		**95th percentile seabed concentration (µg l^{-1})**	
	CLB 5 (PNEC/EQS 4.5 µg l^{-1}).	BASF Rheosoil 143 (PNEC/EQS 40 µg l^{-1})	CLB 5 (PNEC/EQS 4.5 µg l^{-1}).	BASF Rheosoil 143 (PNEC/EQS 40 µg l^{-1})
Subtidal *Sabellaria* A Easting 321350 Northing 147040	0.53	1.58	0.74	2.21
Intertidal *Sabellaria* B Easting 320800 Northing 146694	0.87	2.60	1.96	5.87
Intertidal *Sabellaria* C Easting 320300 Northing146351	0.86	2.57	1.70	5.10
Intertidal *Sabellaria* D Easting 319118 Northing 16309	0.84	2.52	1.93	5.79
Subtidal *Sabellaria* E Easting 320800 Northing 146800	0.79	2.37	2.37	7.12
Intertidal *Sabellaria* F Easting 321824 Northing146800	0.91	2.73	1.99	5.96
Intertidal *Sabellaria* G Easting 321529 Northing146793	0.97	2.90	2.03	6.09
Corallina Position 5 Easting 320010 Northing 146285	0.94	2.84	2.01	6.01

It can be seen from the figures and table above is that neither mean bed concentrations nor 95th percentile concentrations exceed the EQS, and benthic features should therefore remain unaffected. There is a small area of exceedance at the surface near the discharge (Table 10).

Table 10. Summary of exceedance areas for BASF Rheosoil 143 and CLB F5

Discharged chemical	**Area of exceedance at surface**	**Area of exceedance at bed**
BASF Rheosoil 143 (Sodium lauryl ether sulfate.)	1875 m^2 (0.19 ha)	0
CLB F5 (Mono-C10-16-alkyl, Sodium sulfate (≤10%))	10,000 m^2 (1 ha)	0

Location G has the highest mean concentrations of conditioning products (Table 9). A time series of CLB 5 concentration at this location is therefore shown in Figure 17 to demonstrate the nature of the exposure. The PNEC for CLB 5 is 4.5.

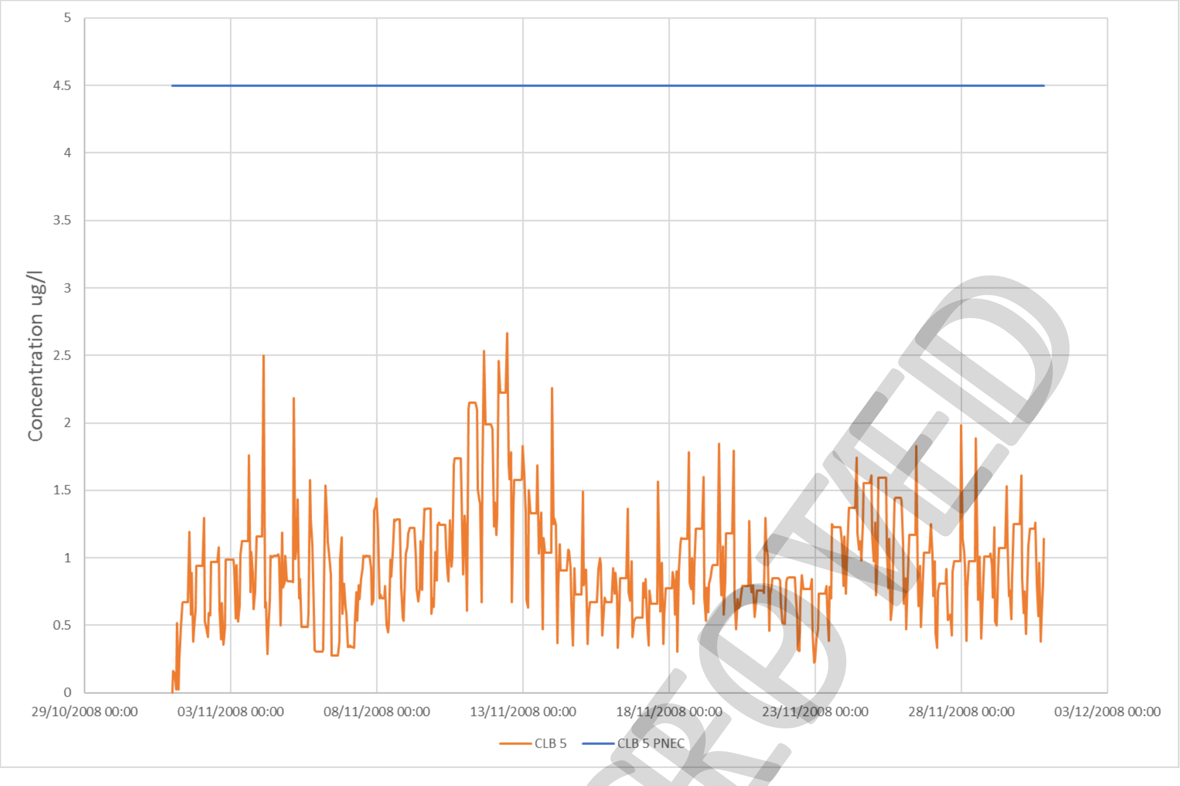

Figure 17. Time series at location G (see Figure 16)of concentration (µg l^{-1}) for CLB 5. The EQS is 4.5 µg l^{-1} and no effect concentration (NOEC) is 45 µg l^{-1}. The NOEC for Mono-C10-16-alkyl (active substance with lowest PNEC for CLB5) comes from HERA (2002) Risk Assessment.

The NOEC is a concentration which would be relevant to peaks, which could occasionally exceed the PNEC. Edition 5 of this reported indicated that a maximum spike would exceed the PNEC. However, in the revised modelling presented here in Edition 6, no values are expected to exceed the PNEC. Figure 17 shows that the concentration varies tidally, with peak concentrations around 2.7 µg l^{-1} on 11th Nov.

4.5 Total loading of Dissolved Inorganic Nitrogen (DIN) concentration during construction only (not including cold commissioning).

Background winter DIN concentrations in Bridgwater Bay, are typically 75 µmol (minimum 34.3, maximum 123) or, as N, 1.05 mg l^{-1} (minimum 0.5, maximum 1.7) (source: Environment Agency GB6708074, see Appendix B).

The discharge of DIN at the jetty is made up of the following sources:

1. The total dewatering discharge (with a maximum flow during Case D of approximately 25 l s^{-1}) with a groundwater mean concentration of 2.95 mg l^{-1} as N (this latter was recalculated by the Environment Agency and resulted in a reduced mean of 1.861 mg l^{-1} as N);

The sewage treatment from the main plant construction with a flow of 1150 m^3 day^{-1} or 13.3 l s^{-1}. With secondary treatment, has maximum of 20 mg l^{-1} of ammoniacal nitrogen as N. This results in a DIN discharge of 38.3 l s^{-1} at 3.5 mg l^{-1} (2.95 x 25 +5 x 13.3/ 40) (the recalculated value is 1.86 x 25 + 5 x 13.3/ 40 =2.82 mg l^{-1} DIN calculations for different Case examples are provided in Appendix C Table 28.

Maximum concentrations and flow for nitrogen inputs during construction.

The maximum concentration in the sewage discharge could be up to 20 mg l^{-1} of ammoniacal nitrogen as N (based on permit limits for the sewage treatment plant). The mean flow rate is 13.3 l s^{-1} but flow may peak intermittently up to 30 l s^{-1}. It should be stressed that the 95th percentile concentration of the sewage treatment plant is still 5 mg l^{-1} as stated in Edition 5 of this report. This value has been used as previously and is still a conservative estimate of the total loading discharged. The original DIN discharge concentrations and their derivation for each discharge Case are shown in Appendix C Table 28. These values were updated following recalculation by the Environment Agency of groundwater DIN values and these figures are also shown. The updated groundwater values result in a decrease in DIN input concentrations for each Case. However, a more comprehensive assessment of nutrient loadings was subsequently made using a Combined phytoplankton macroalgal model and this is more relevant now than a consideration of individual Case discharge values.

4.5.1 Localised effect of elevated DIN.

The effect of increasing DIN concentration over a small area is unlikely to have any effect on localised phytoplankton production in the estuary as the extremely turbid conditions in the Bristol Channel cause phytoplankton production to be light limited (rather than DIN limited) throughout the year (Underwood, 2010). A more comprehensive updated assessment was made in this report version (Ed7) using a combined phytoplankton macroalgal model (CPM) (Aldridge et al., 2008), and taking account of combined construction and cold commissioning annual inputs of nitrogen and phosphorus and the results are provided in **section 4.10** and more details on the model are provided in Appendix F. Updated values for groundwater DIN based on a recalculation by the Environment Agency result in an overall lower annual loading of nitrogen as shown in Appendix F so the original CPM modelling is precautionary.

4.5.2 Cumulative annual loading for construction inputs of nitrogen only (not including cold commissioning) and effect on water body classification

Because of variations in groundwater discharge, the annual loading varies and is 4934 kg, 4655 kg, 4316 kg of N for years 1,2 and 3 respectively (the calculation of loadings is shown in Appendix C, Table 29). There are two Water Framework Directive (WFD) waterbodies close to the discharge: Bridgwater Bay (surface area 9183.5 ha) and the Parrett (7069.0 ha), with the discharge at the jetty location and Outlet 1 directly into Bridgwater Bay, and near to the Parrett. HPB discharges directly into the Parrett waterbody. The volume of Bridgwater Bay at Mean Sea Level (MSL) is 9.77 x 10^{8} m^{3} (a mean depth of 10.6m). The Parrett has a smaller volume (2.24 x 10^{8} m^{3}) and mean depth (3.6 m).

Over a year the high degree of mixing is likely to spread the discharge throughout the waterbody. The DIN standard is usually expressed as µmol l^{-1}. The transitional and coastal waterbody is classified as turbid, with the standards as given in Appendix B. The annual uplift due to the jetty discharge in Bridgwater Bay for year 1 is 4934 kg = 3.52 x10^{5} µmol / 9.77 x 10^{11} litres = 0.36 µmol l^{-1}. The mean background concentration identified here is 75 µmol l^{-1} which falls within a good waterbody classification under the Water Framework Directive (99th percentile value 180 µmol^{-1} for turbid waters). The proposed discharge from the jetty is, therefore, a relatively small addition which would not change the classification. Even if the maximum flow of 30 l s^{-1} for the sewage discharge is considered to occur for the whole period (which is extremely unlikely) the discharge becomes 7566 kg and the uplift becomes 0.553 µmol^{-1} which would still not change the waterbody classification. Adopting the updated groundwater calculations derived by the Environment Agency the nitrogen loading figures and resulting uplift would be further reduced.

4.6 Consideration of un-ionised ammonia concentration for construction only (not including cold commissioning)

Ammonia enters freshwater and marine water bodies from sewage effluent inputs, from industrial and agricultural activities and from the breakdown of organic matter. In general, the unionised form of ammonia is more toxic than the ionised form. At higher pH values, unionised ammonia represents a greater proportion of the total ammonia concentration. Temperature increase also raises the relative proportion of unionised 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 unionised ammonia, but a pH increase from a pH of 7 to a pH of 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 unionised 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 11). Of these factors 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 21 µg l^{-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 6085 µg l^{-1} (6085 x 0.7777 (conversion of NH_4 to N only) = 4732 µg l^{-1} as N) and a treated sewage effluent maximum concentration of 20000 µg l^{-1} as N. 20000 µg l^{-1} as N represents the design standard of the sewage treatment plant. This is one end member of the mixing relationship and mean values of sea water temperature, pH, and salinity used for the other.

The data used in support of the two components of the mixing relationship have not been updated with more recent values from monitoring data as the variability around the starting parameters for the groundwater was not considered likely to significantly alter the starting proportion of un-ionised ammonia, and the seawater parameters were derived from a sampling grid over four quarters and provided a comprehensive assessment of variability. The original mixing relationship components were:

a. Construction wastewater discharge, with salinity derived from the average of groundwater conductivity data (1312 µs cm), average pH (7.3) and 95th percentile of ammoniacal nitrogen (Atkins, 2016 and permit), and an average temperature of 12.5ºC (BEEMS TR186).

b. seawater, with a mean temperature of 12.5ºC, 50th percentile of salinity (31.5) and seawater pH (7.86) (BEEMS TR186). The average ammoniacal nitrogen in the sea water background was 124 µg l^{-1} as N (Amec, 2009).

Cases C_{max}, $C1_{max}$, D_{max} and sewage only are considered. For Cases C and D, small sources which would dilute the concentration, but which may not be present all of the time have not been considered (e.g. there could be 4 litres per second of additional water not containing ammoniacal nitrogen).

1) Case C_{max} total discharge is 59.3 l s^{-1} with a 95th percentile concentration of 8157 µg l^{-1} ammoniacal Nitrogen as N. (4732 x 46 +13.3 x 20000/ 59.3)
2) Case $C1_{max}$ total discharge is 76.3 l s^{-1} with a 95th percentile concentration of 10759 µg l^{-1} ammoniacal Nitrogen as N. (4732 x 46 +30.3 x 20000/ 76.3)
3) Case D_{max} total discharge is 38.3 l s^{-1} with a 95th percentile concentration of 10034 µg l^{-1} ammoniacal Nitrogen as N. (4732 x 25 +13.3 x 20000/ 38.3)
4) Sewage only discharge is13.3 l s^{-1} at a planned maximum of 20,000 µg l^{-1} ammoniacal Nitrogen as N.

Table 11. Unionised 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) (µg l^{-1})	Salinity	Temp °C	pH	Un-ionised ammonia (µg l^{-1})
Case C $_{max}$	8,157	1	12.5	7.3	36.4
Case C1$_{max}$	10,795	1	12.5	7.3	48.1
Case D $_{max}$	10,034	1	12.5	7.3	44.8
Sewage discharge only	20,000	1	12.5	7.3	89.2

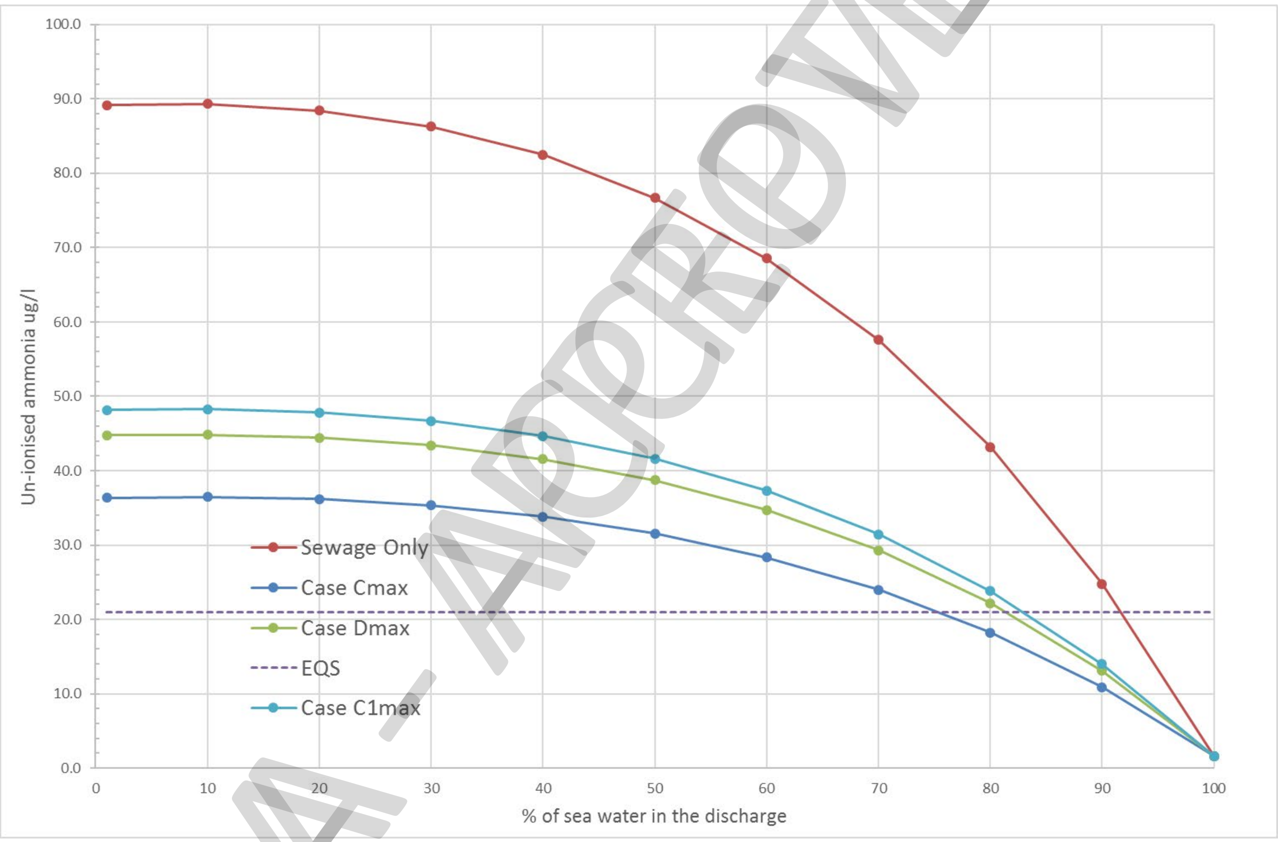

Figure 18. The change in production of un-ionised ammonia (µg l^{-1}) as the discharge is mixed with seawater for sewage only, and cases C, C1$_{max}$ and D$_{max}$.

The calculations shown in Figure 18 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. While the Case C discharge is mostly likely 63 l s^{-1} it has been conservatively modelled as a 90 l s^{-1} discharge as this is a potential permitting value, 90 l s^{-1} also incorporates the C1 case. The Case D discharge is mostly likely 36 l s^{-1} but has been considered has a 45 l s^{-1} to ensure that estimates are conservative.

It is evident from Figure 18 that there is exceedance of the EQS (21 µg l^{-1}) when less than 75% mixing has occurred for Case C, 82% mixing for Cases D and C1 and 92% for the sewage only case. In relation to Case C, it can be seen from

Figure 28 (Appendix D) that a dilution factor of 4, (80% mixing) occurs after 8m in the minimum dilution case at low tide for a discharge of 90 l s^{-1}.

Figure 28 is also relevant to case C1, showing that a 1:10 dilution occurs after approximately 16 m. The Case D situation corresponds to **Figure** 27 (45 l s^{-1}) where 82% mixing (required to dilute the discharge to EQS level) occurs approximately 7 m from the discharge point. The sewage only case **(**Figure 29), which is unlikely to occur, would be compliant with a dilution of between 1:9 and 1:10. This dilution is likely to have occurred within 3 m of the discharge.

4.7 Biological Oxygen demand.

The sewage treatment works is expected to achieve a maximum concentration of BOD of 40 mg l^{-1} (i.e. draw down over 5 days) and the indicative MAC to be applied in the permit is therefore 40 mg l^{-1}. The Severn has strong tides and the receiving waters near the discharge 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 100 mmol m^{-2} d^{-1} (Hull, 2016) or 3.2 g m^{-2} d^{-1}. Using the 13.3 l s^{-1} discharge and a BOD of 40 mg l^{-1}, a daily BOD of 46 kg was calculated. This amount of oxygen would be transferred across 14364 m^2 in a day. The tidal excursion (how far a particle is advected) at Hinkley Point, even on the weakest (neap) tides, is many kilometres, thus there is ample resupply of oxygen from the atmosphere so that no change in oxygen concentration would be observed. The EQS for dissolved oxygen in the receiving water is 4.16 mg l^{-1} (5th percentile) and the likely background concentration is more than 7.5 mg l^{-1}.

4.8 Total Loadings of Suspended Solids

The background suspended solids concentration in the receiving water is relatively high (mean = 264 mg l^{-1}, minimum 33 mg l^{-1}). Commissioning activities such as hydrostatic testing and flushing will result in variable suspended solids loadings within resultant effluents. The Commissioning Effluent Treatment Plant (CETP) will incorporate methods to reduce suspended solids to achieve permitted levels prior to discharge.

4.9 Coliforms – bathing water standards and shellfish

Monitoring of the existing sewage treatment (EDFE, Proctor e-mail, 28th March) provides estimates of maximum discharge concentrations of inputs into the sewage treatment plant. Secondary treatment implies a 100 factor (2 log) reduction in Coliforms and Enteroccci. If UV treatment is applied a 5.4 log reduction would occur. The dilution factor required to reduce the coliform concentrations to levels that would comply with bathing water standards 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 13.3 l s^{-1} sewage discharge (Figure 29, Appendix D). The maximum flow rate of 30 l s^{-1} could potentially occur although only briefly, dilution has been conservatively estimated using the 45 l s^{-1} simulation (Case D, Figure 27, Appendix D). The discharge plume is buoyant and will be on the surface, 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 underestimate as surface wave mixing will increase the mixing rate. Typical wave conditions (1m Hs) will ensure rates of mixing 10 times higher than that estimated by Cormix hence the concentration of *E.coli* cells is likely to exceed the bathing water standard only within 200 m of the discharge for the 13.3 l s^{-1} case even without UV treatment. With UV treatment even at the higher discharge volume (30 l s^{-1}) exceedance is limited to within 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 point is not in designated bathing waters. Treatment from the plant is sufficient to ensure that microbial concentrations in discharged waters comply with bathing water standards within a maximum of 2.8 km from the discharge point (without UV treatment) and within 10 m (with UV treatment). The nearest designated bathing waters (Blue Anchor West, latitude 51.18° N, longitude 003.401°

W and Berrow North of Unity farm, latitude 51.28º N, longitude 003.018º W) are approximately 12 km distant. 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. Porlock Bay Oysters is the shell fishery closest to the discharge (the fishery is approximately 32 km to the West). The predicted changes to coliform concentrations at this distance from the site are expected to be negligible and no effect to any shell fishery is therefore predicted.

Table 12 Estimate of coliform exceedance with treatment level.

Species	**Standard cells/ 100ml**	**Discharge concentration cells / 100ml**	**2nd treatment 2 log reduction**	**Dilution factor required for discharge to meet bathing water standard**	**Maximum potential distance from the discharge for discharged water to meet bathing water standard** **13.3 l s^{-1}**	**30 l s^{-1}**	**UV treatment reduction[1]**	**Dilution factor required for discharge to meet bathing water standard**	**Maximum distance from the discharge for discharged water to meet bathing water standard**
E.coli	500	240,000,000	2400000	4800	~1.8 km	~2.8 km	955.5	1.9	<1 m pass immediately on discharge, for both cases.
Entero-cocci	200	13,600,000	136000	680	<200 m	~520 m	541.4	2.7	<10 m from 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

4.10 Construction and cold commissioning discharge

During the last period of construction, there will be cold commissioning of the turbines and the associated discharge of chemicals (denoted as Case J, Table 1) primarily hydrazine used to condition the turbines and associated pipework. During cold commissioning, the cooling water system is not available so discharges must occur via the jetty outfall. The modelling of hydrazine has been reported elsewhere (BEEMS TR445) however, ammonia, hydrazine and ethanolamine are added during commissioning and the breakdown of these will potentially contribute to DIN and un-ionised ammonia and so are further assessed in this report. Trisodium phosphate is also added during commissioning so phosphate contributions from this source are also considered with phosphorus inputs from sewage and groundwater. These discharges will occur during the Case D construction period when flows are around 38 l/s. Treated concrete wash water will also be discharged and inputs will overlap with Case D inputs of groundwater and treated sewage and the chemical breakdown products from the commissioning, so this is considered below.

4.10.1 Effect of nutrient (DIN and phosphorus) loading on primary production.

The total loading due to DIN and phosphorus has been considered using the CPM model (Aldridge *et al*., 2008), more details of the model are given in Appendix F. The effect of the HPC construction and commissioning discharge has been included by incorporating additional total annual loadings of 14575 kg, and 4429 kg for nitrogen and phosphorus, respectively. A more detailed breakdown of source contributions is provided in Appendix C Tables 28 and 29.

To generate some phytoplankton growth data that could be compared between background and elevated nutrient input levels the model was run at a light attenuation coefficient of Kd =1. This is still a turbid environment, just not as turbid as the Severn is for most of the time. Results of the model output show that there is no difference between the Bridgwater Bay reference case or the HPC construction/commissioning run for either phytoplankton production or for macroalgae (Table 13). This can be simply explained as the system is always light limited (Underwood 2010), so that the addition of more nutrients does not affect production.

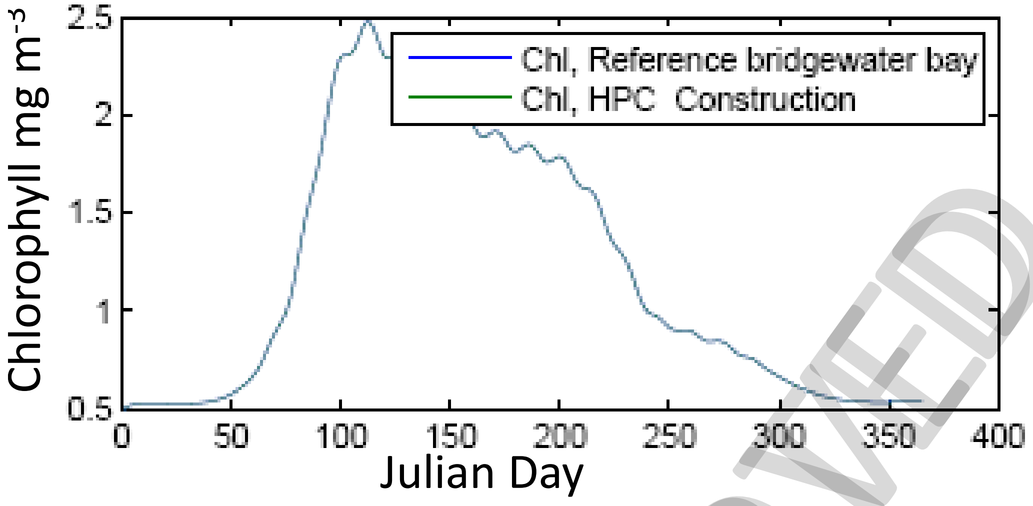

Figure 19 : Instantaneous phytoplankton levels (mg Chlorophyll m^{-3}), for Bridgwater Bay with no power station discharge, and HPC construction. Note that additional nutrient discharges from HPC have no effect on background chlorophyll concentrations (and the reference and construction lines are the same).

Table 13 Phytoplankton and macroalgae production

Scenario	**Phyto Annual Gross Production, (g C m^{-2} y^{-1})**	**Macro Annual Gross Production, (g C m^{-2} y^{-1})**
Bridgwater Bay	11.05	18.43
HPC Construction	11.05	18.43

4.10.2 Ammoniacal Nitrogen

Due to the breakdown of chemicals added during the commissioning process some ammoniacal nitrogen will be generated. This is estimated to have a concentration of 271 mg l^{-1} (Calculation of this value is shown Appendix C Table 28) which is discharged over 5.63 hrs at either 37 l/s or 70 l/s depending on whether there is drainage from one or two HXA tanks per day.

This cold commissioning discharge needs to be considered alongside the construction discharge from groundwater and sewage. As this will occur late in the construction process, Case D flow rate (38 l/s) is most appropriate. Thus, the cases with maximum load of total ammonia to consider are:

1. A continuous discharge (38.3 l/s, at 10.03 mg l^{-1}) + a pulse discharge at midday (37 l/s, 271 mg l^{-1}) for 5.63 h.
2. A continuous discharge (38.3 l/s, at 10.03 mg l^{-1}) + a pulse discharge at midday (70 l/s, 271 mg l^{-1}) for 5.95 h.

These two scenarios were therefore modelled in GETM and treated as passive tracers, in a similar manner to the approach adopted for the conditioning chemicals, using a month-long simulation of the likely behaviour over a spring-neap cycle.

There are also standards, for total ammonia, for which the concentration should not be exceeded:

a) 1100 μg l^{-1}-N annual average (AA)
b) 8000 μg l^{-1}-N maximum acceptable concentration (MAC) (interpreted as 95th percentile).

The mean background ammoniacal Nitrogen (NH$_4$-N) concentration is 124 μg l^{-1} measured in an annual survey at Hinkley Point (Amec, 2009). This has been included in the plots below (Figure 20 and Figure 21) which show the total ammonia discharge plume prediction in relation to the Corallina feature. For *Sabellaria* the nearest habitat to the discharge is in the intertidal area close to the *Corallina* at station 8. Other areas of *Sabellaria* (as shown in Figure 6) are more distant from the discharge.

As the discharge from the jetty is a fresh water source it is therefore very buoyant, and the highest concentrations will be associated with the surface. The results below are therefore shown for the surface and also from the highest volume case. The model output does **not** show a failure of either the mean or the 95th percentile for either model run, at either the surface or the bed. (There will most likely be a small area of exceedance at the discharge location, but this will be less than the 25m grid cell of the model). The maximum value in the mean file is 1031μg l^{-1} and 4450 μg l^{-1} for the 95th percentile.

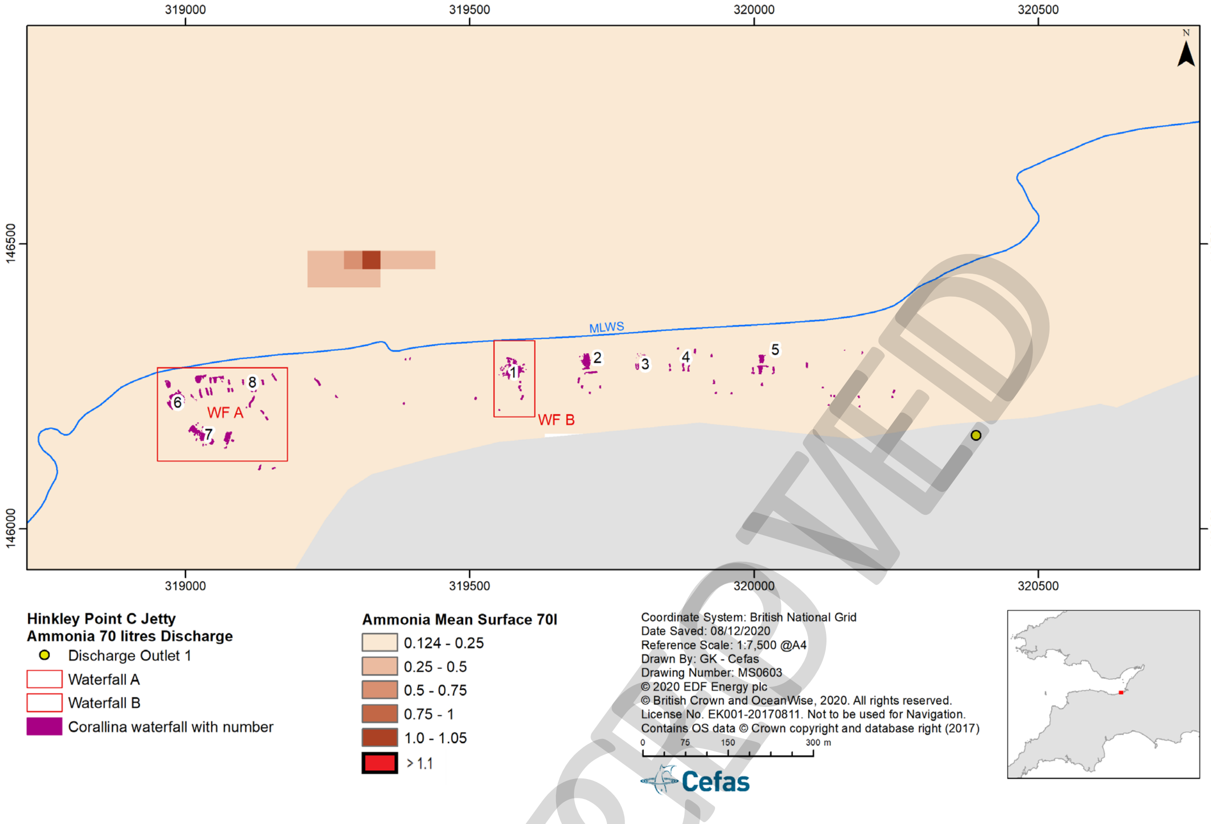

Figure 20 Surface mean ammonia concentration (mg l^{-1}) for the 70 l/s discharge simulation. No values > 1100 µg l^{-1} (PNEC). The figure includes *Corallina* waterfalls. The closest *Sabellaria* to the discharge is in the intertidal near station 8.

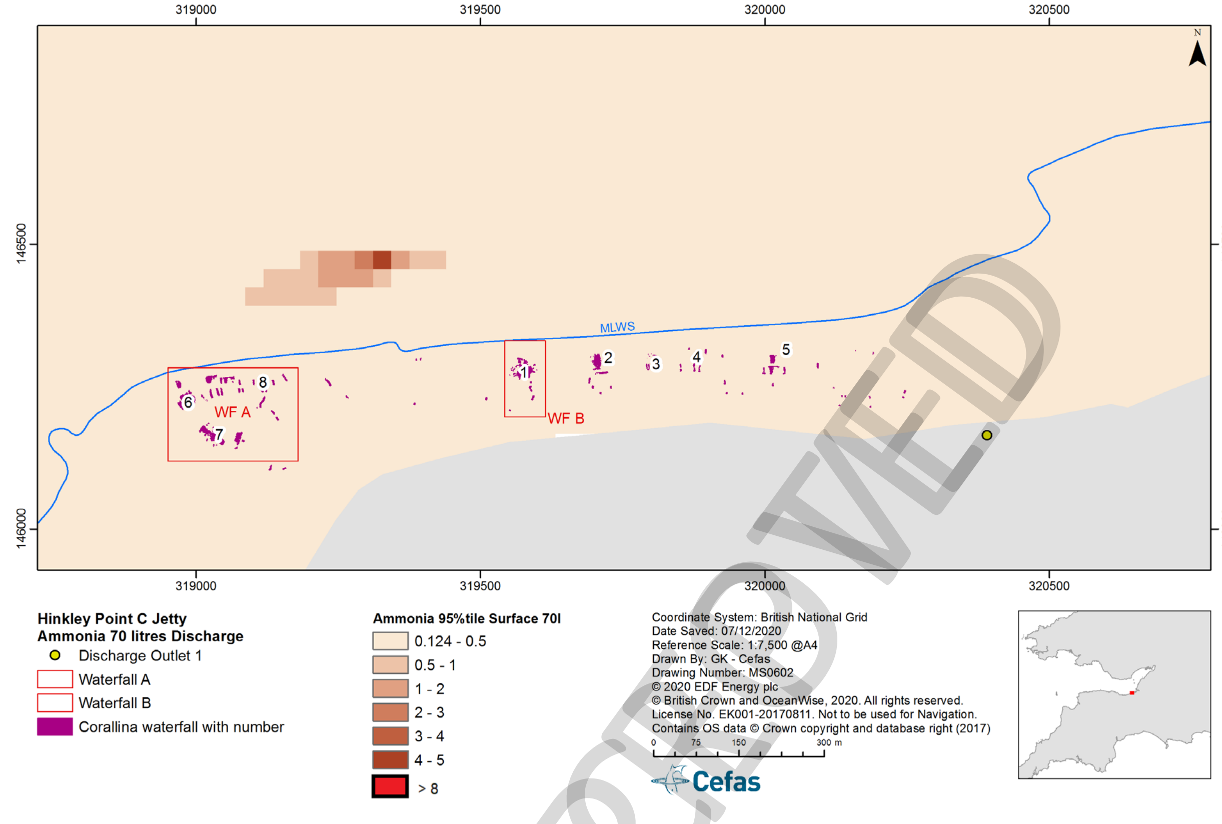

Figure 21 95th percentile surface concentration (mg l-1) of ammonia for 70 l/s. No value exceeds > 8000 µg l-1 MAC. The figure includes Corallina waterfalls. The closest *Sabellaria* to the discharge is in the intertidal near station 8.

4.10.3 Consideration of un-ionised ammonia concentration

The concentration of un-ionised ammonia can 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.

The EQS for un-ionised ammonia is 21 µg l^{-1} expressed as an annual average, however being consistent with the previous screening, this value is compared with the 95th percentile source contributions. The annual mean values were temperature 12.5 °C, pH 7.86 and salinity 31.5 g/kg. The values have been calculated by taking the GETM output, adding the total ammonia background (0.124 mg l^{-1}) and then using the EA calculator to generate the proportion of un-ionised ammonia.

4.10.4 Consideration of combined inputs of concrete washwater

During the period when commissioning chemicals and construction wastewater (as described for Case D) are being discharged at the jetty a maximum daily discharge of treated concrete wash water of 50 m^3/day may also occur. The discharge rate for the concrete wash water (CWW) would be equivalent to a very low continuous daily discharge of 0.57 l/s^{-1}. Preliminary characterisation of untreated concrete wash water indicates the presence of retarder and accelerator chemicals but also trace contaminant metals and ammoniacal and dissolved inorganic nitrogen. The CWW discharge represents just over 2% of the Case D groundwater discharge (25 l/s^{-1}). Because of the very low CWW discharge rate and its low relative percentage contribution compared to groundwater inputs there are likely to be some small but non-significant elevations in the overall discharge concentrations of selected metals. However, as the combined discharge rate of e.g. groundwater and CWW would still be very low ca. 26 l/s^{-1}, an increase of a few percent above that of the original groundwater metal concentrations would have negligible influence on the small mixing zone where the EQS might be exceeded. The dissolved nitrogen and ammoniacal nitrogen contributions are also indicated to be very small at around a half of that for the groundwater and so the concentration in the combined discharge is likely to be relatively unchanged or slightly lower than that already assessed.

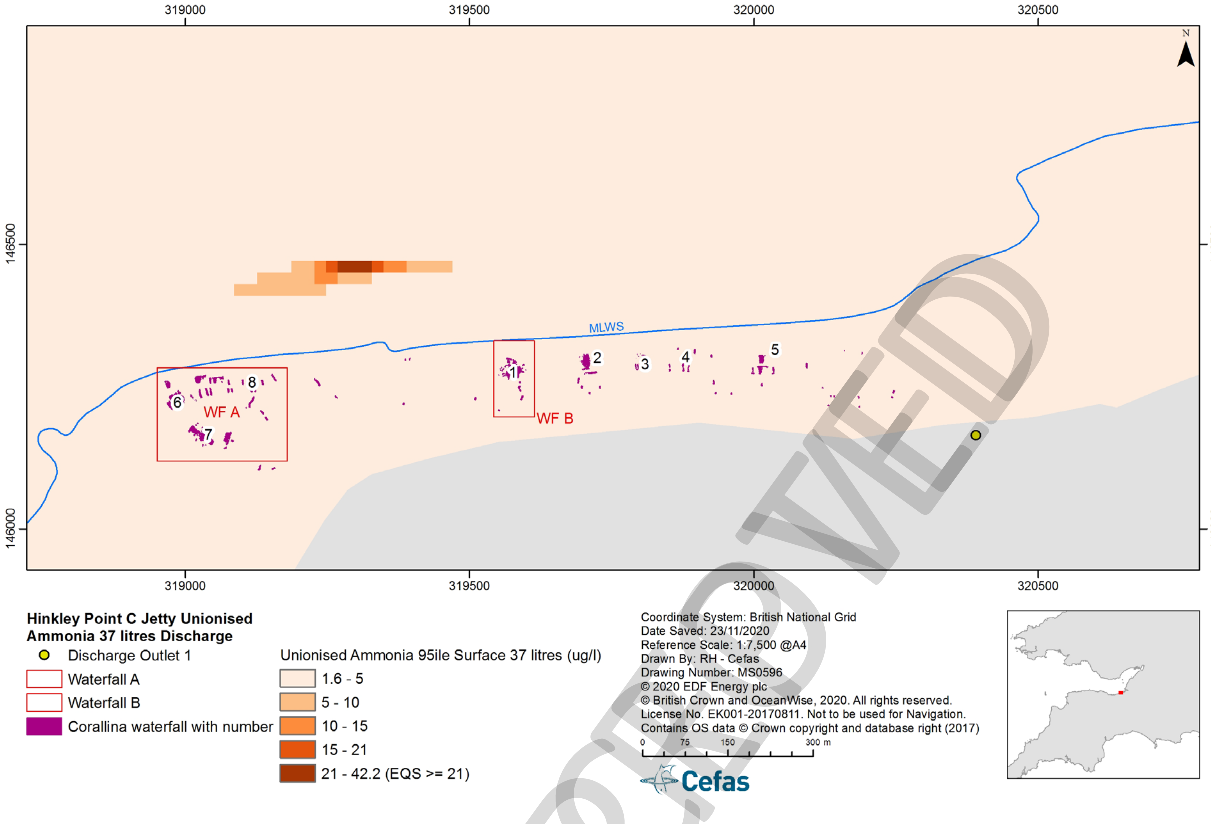

Figure 22 Un-ionised Ammonia Surface Scenario 1(38 l/second at 10 mg l^{-1}+ 37 l/second at 271 mg l^{-1}) 95th Percentile Ammonia. The figure includes *Corallina* waterfalls. The closest *Sabellaria* to the discharge is in the intertidal near station 8.

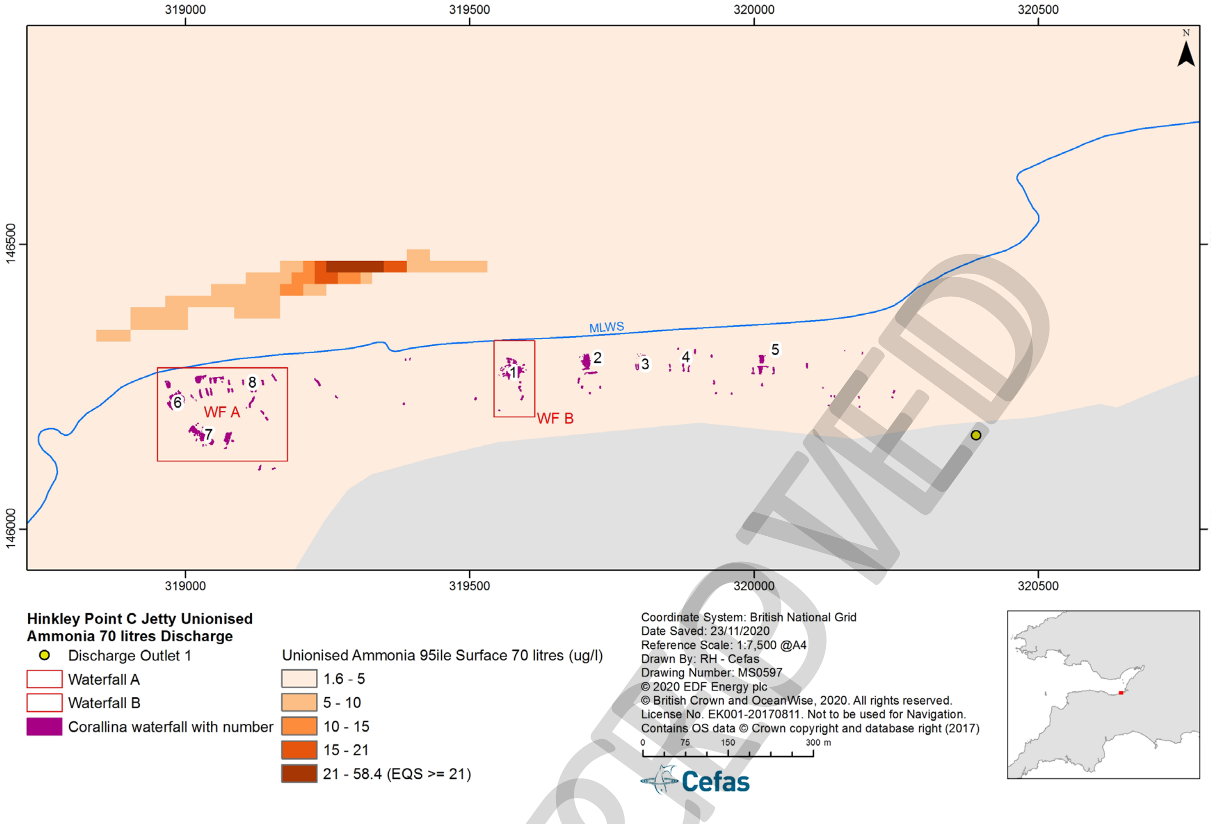

Figure 23 Un-ionised Ammonia Surface Scenario 2 (38 l/second at 10 mg l^{-1}+ 70 l/second at 271 mg l^{-1}) 95th Percentile Ammonia. The figure includes *Corallina* waterfalls. The closest *Sabellaria* to the discharge is in the intertidal near station 8.

Note the area above the 21 µg l^{-1} threshold, when using the 95th percentile of ammoniacal nitrogen is small. For the actual EQS when using the annual average there are no areas of exceedance.

Table 14 Area of exceedance for Un-ionised ammonia

Scenario	**Area > 21 µg l^{-1} Bed**	**Area > 21 µg l^{-1} Surface**
38 l/second at 10 mg l^{-1}+ 37 l/second at 271 mg l^{-1} Mean	No exceedance	No exceedance
38 l/second at 10 mg l^{-1}+ 70 l/second at 271 mg l^{-1}Mean	No exceedance	No exceedance
38 l/second at 10 mg l^{-1}+ 37 l/second at 271 mg l^{-1} 95th percentile	No exceedance	0.12 Hectares
38 l/second at 10 mg l^{-1}+ 70 l/second at 271 mg l^{-1} 95th percentile	No exceedance	0.20 Hectares

Evident from the above is that, based on mean and 95th percentile assessments, there are no areas of exceedance at the bed. However, there was a small area of exceedance of the un-ionised ammonia EQS of either 0.12 or 0.2 hectares dependent upon whether the contents of one HXA tank or two are discharged following treatment. As the areas of concern are the designated features of *Corallina* and *Sabellaria*, more detailed time series were assessed from the *Corallina* marked in Figure 22 and for the *Sabellaria* Figure 16 and are shown below. The values of un-ionised ammonia have been derived using mean temperature, salinity, and pH.

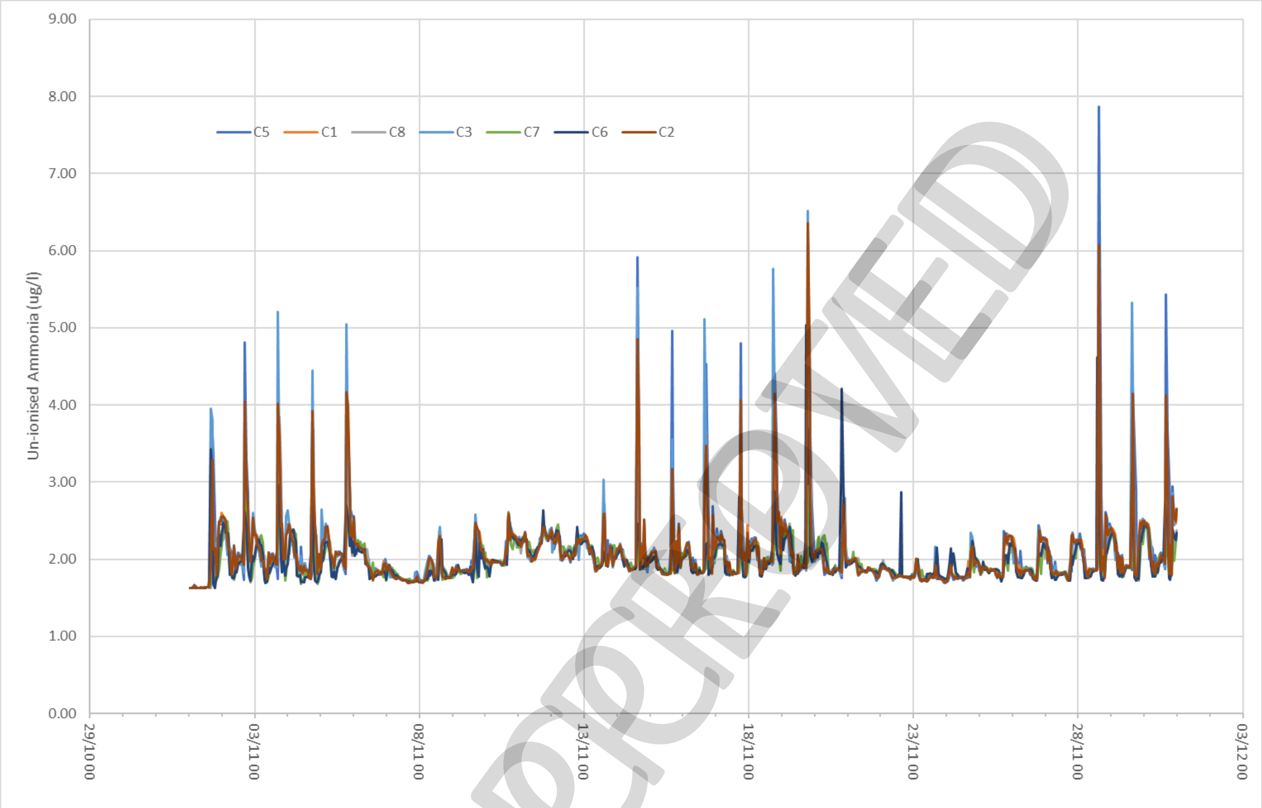

Figure 24 Time series of un-ionised ammonia at the locations of *Corallina* for the 38 l/second at 10 mg l^{-1}+70 l/second at 271 mg l^{-1} scenario.

Evident from Figure 24 is that no *Corallina* features are exposed to high level of un-ionised ammonia, using annual means (as is the standard) however during summer the temperature will be significantly elevated. Therefore, mean and 95th percentile values at this location have been derived for summertime when temperatures will be much higher, using the 98th percentile temperature of 20.4 °C. Apparent, from the table below is that even in summer mean values are still low <4 µg l^{-1}.

Table 15 Summary of Un-ionised ammonia (μg l^{-1}) at *Corallina* features (C1 – C8) for mean and elevated summer temperatures (letters correspond to the locations in Figure 20).

	C1	C2	C3	C4	C5	C6	C7	C8
Mean, using mean values	2.01	2.06	2.07	2.04	2.08	1.99	1.96	2.0
95th, using mean values	2.49	2.58	2.60	2.57	2.69	2.44	2.33	2.4
Mean Using summer T	3.65	3.74	3.75	3.70	3.78	3.61	3.56	3.62
95th, using summer T	4.51	4.67	4.72	4.67	4.87	4.42	4.22	4.35

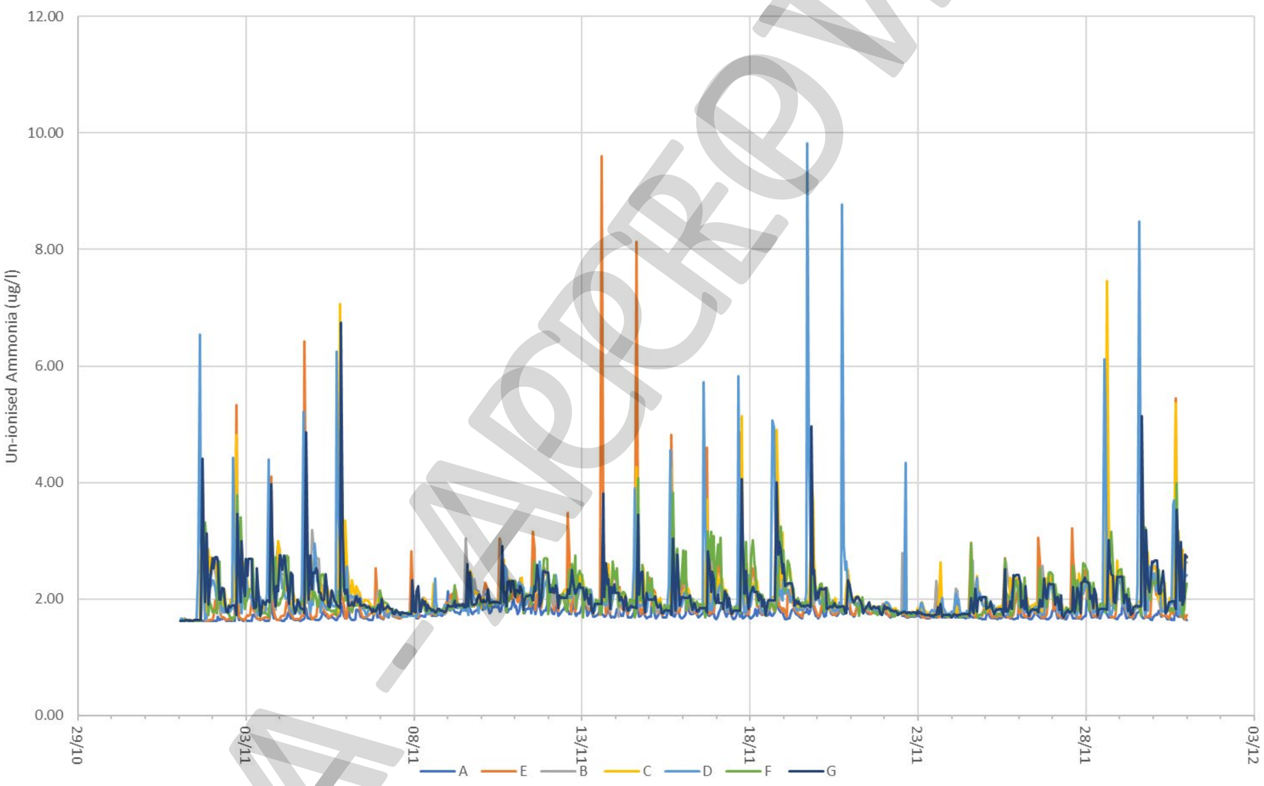

Figure 25 Time series of un-ionised ammonia at the locations of *Sabellaria* for the 38 l/second at 10 mg l^{-1}+70 l/second at 271 mg l^{-1} scenario using mean conditions of temperature, salinity, and pH.

Evident from Figure 25 is that no *Sabelleria* features are exposed to high level of un-ionised ammonia, using annual means (as is the standard) however during summer the temperature will be significantly elevated. Therefore, mean and 95th percentile values at this location have been derived for the summer period when temperatures will be much higher, using the 98th percentile temperature of 20.4 °C. Apparent, from the table below is that even in summer mean values are still low <5 μg l^{-1}.

Table 16 Summary of un-ionised ammonia (µg l^{-1}) at *Sabellaria* features (A – G) for mean and elevated summer temperatures (letters correspond to the locations on Figure 16).

Feature	**Mean seabed concentration (µg l^{-1})**		**95th percentile concentration (µg l^{-1})**	
	Annual	Summer	Using mean values	Summer
Subtidal *Sabellaria* A Easting 321350 Northing 147040	1.74	3.21	1.90	3.46
Intertidal *Sabellaria* B Easting 320800 Northing 146694	2.01	3.71	2.60	4.77
Intertidal *Sabellaria* C Easting 320300 Northing146351	2.08	3.85	2.68	4.91
Intertidal *Sabellaria* D Easting 319118 Northing 16309	2.07	3.83	2.56	4.67
Subtidal *Sabellaria* E Easting 320800 Northing 146800	1.95	3.61	2.54	4.67
Intertidal *Sabellaria* F Easting 321824 Northing146800	2.03	3.75	2.72	4.94
Intertidal *Sabellaria* G Easting 321529 Northing146793	2.05	3.79	2.71	4.94

5 Interactions between discharges

The HPC power station will include 2 reactors these being Unit 1 & Unit 2. Progress on the construction of Unit 1 is approximately one year ahead of Unit 2. This will mean that Unit 1 will reach HFT (Hot Functional testing) stage approximately one year ahead of Unit 2. At the point of HFT onwards resulting effluent will be managed under the OWDA permit. On this basis for a period of approximately one year effluent from Unit 2 will be discharging under the CWDA permit at the jetty and effluent from Unit 1 under the OWDA permit at the permanent power station outfall.

The un-ionised ammonia CWDA discharge at the jetty that includes the scenario of units 1 and 2 undergoing simultaneous cold flush testing is predicted to have limited influence on *Corallina* and *Sabellaria* features and any influence would be reduced at the jetty location once the first permanent outfall is operational. The permanent outfall discharge would occur further offshore, and dilution and dispersion of this un-ionised ammonia loading is expected to influence a very limited mixing zone around the discharge point, and to have negligible impact. The nutrient assessment was conducted using a box model so the location of the discharge would not, in this case, change the input parameters or final predictions (because a particularly conservative suspended particulate matter level of 10 mg/l was used in the model, see Appendix F).

5.1 Interaction with HPB thermal plume.

The best estimates of the geographic influence of the thermal plume from Hinkley B are found in BEEMS Technical Report TR267. This report uses high resolution modelling (25 m grid) to produce mean estimates of temperature uplift for the existing station.

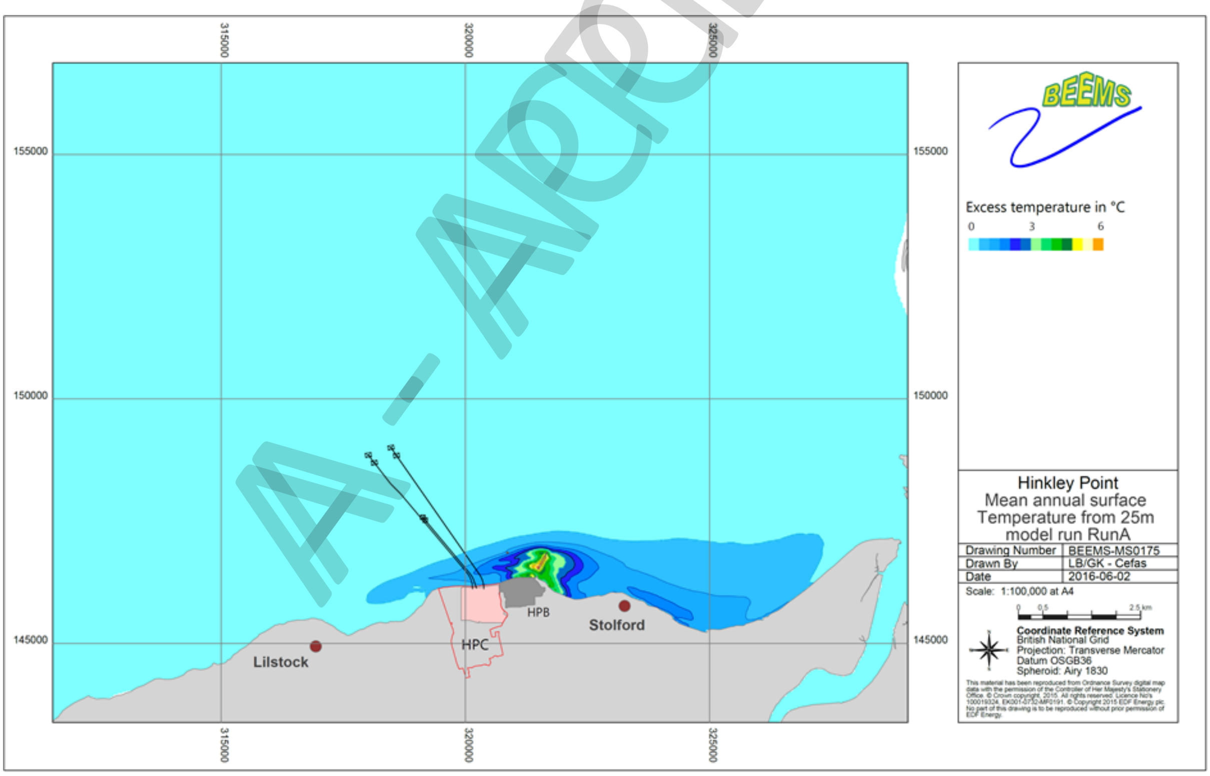

Figure 26. Mean thermal plume uplift due to HPB, from high resolution 25 m model, (BEEMS TR267)

At the location of the jetty outfall (which is where values above the EQS occur), the mean increase in temperature is 1.02°C. This should be viewed within the context of the natural seasonal cycle, where mean

February temperatures are 6.6°C and August 19.4°C (BEEMS Technical Report 187). The typical inter-annual variation in monthly mean temperatures is 1.1°C.

It is not anticipated that this temperature change would affect the chemistry or toxicity of metals in the jetty discharge. The mean temperature uplift at *Sabellaria* locations near HPC and HPB are shown in Table 17.

Table 17. Mean temperature uplift due to HPB at *Sabellaria* locations at the bed with positions as those previously e.g. Figure 16.

Location	Mean temperature uplift (°C)
A	0.41
B	1.18
C	0.78
D	0.68
E	0.94
F	1.27
G	4.17

5.2 Discharge of waste by Hinkley B and Hinkley A

There is permitted discharge of groundwater of 50 $m^3 d^{-1}$ until March 2018 from Hinkley Point A (permit EPR/EB3392VY). The discharge is confined to two hours before and two hours after high tide.

In addition to the thermal plume discharge (see above), Hinkley B has a permit (HPB Consent no 070408) to discharge up to 1000 $m^3 d^{-1}$ of treated sewage with ammoniacal nitrogen concentrations up to 30 mg l^{-1} and suspended solids up to 60 mg l^{-1}. For DIN, this equates to an annual load of 10950 kg. These discharges are released at a discharge point close to the sea wall.

There is an east west separation of approximately 2.4 km between the jetty discharge and HPB/HPA outlet channel.

From a DIN perspective it is unlikely that the total discharge from the jetty would be detectable beyond a short distance (<50 m) from the jetty. Similarly, the discharges from HPB and HPA are small and will have undergone significant dilution by the time they have been advected to the small area where the jetty discharge may be detectable. The physical separation of 2.4 km between the jetty discharge and the HPA/HPB discharge channel is therefore considered sufficient to ensure there is no interaction between the discharges.

For WFD purposes, the HPC sewage discharge(s) will increase the total loading of DIN in the two local waterbodies in addition to the uplift already caused by the HPB discharge. HPB discharges into the Parrett waterbody, and the permitted discharge of 10,950 kg annually is calculated to uplift the Parrett waterbody concentration by 3.49 µmol l^{-1} (if the discharge is completely released into the Parret water body alone). As the background DIN concentration is high this does not affect the WFD status classification. If the jetty discharge is added to the HPB DIN discharge, the uplift would increase to 5.05 µmol l^{-1}. The long-term fate of the DIN discharge from the temporary jetty is likely to be shared between the two WFD waterbodies (Bridgwater Bay and Parret), and this is also true of the HPB discharge because the outfall is near the junction of these two waterbodies. Thus, using a shared equal split between the two bodies the combined effect of HPC (construction discharge at the jetty) and HPB is calculated to uplift the Bridgwater Bay waterbody by 0.58 µmol l^{-1} and the Parrett waterbody by 2.52 µmol l^{-1}. The WFD classification of these waterbodies would be unaffected. Considering the additional inputs of nutrients during the commissioning period the results from the CPM model show that that there is no difference between the Bridgwater bay reference case or the HPC construction run for either phytoplankton production or for macroalgae.

5.2.1 Coliforms from HPB

CORMIX dilution rates (see Appendix D) have been used to determine the maximum distance from the discharge at which bathing water standards could be exceeded. The HPB discharge permit specifies that the discharge can only take place either side of high water when water depth is similar to that of the HPC discharge. The highly conservative Cormix estimates of mixing and the exceedance distances calculated are therefore a useful conservative guide.

Table 18 Coliforms discharge from HPB

Species	Standard cells/100ml	Maximum discharge concentration cells/100ml	2nd treatment. 2 log reduction.	Dilution factor to meet standard	Extent of exceedance
E.coli	500	240,000,000	2,400,000	4800	~ 1.8 km
Enterococci	200	13,600,000	136,000	680	<200m

It is not known what the actual microbiological discharge concentration is from Hinkley Point B, however assuming the same standard of secondary treatment as Hinkley C would imply a maximum potential extent of exceedance for *E.coli* of approximately 1.8 km (Table 18). This theoretical exceedance could only occur in very calm conditions. Under such calm conditions the plume would be long and thin and would not interact with the temporary jetty discharge, as the tidal stream lines are separate. In practice most of the time, wave mixing will mix the discharge rapidly so that no interaction could occur.

6 Consideration of effects of combined discharges for Water Framework Directive waterbodies and Habitats

This assessment determines whether there would be any deterioration in the water body status under the Water Framework Directive (WFD) from the combined construction discharges including cold commissioning discharges. The assessment considers effects on the WFD water bodies and associated Marine Strategy Framework Directive (MSFD) sea area within the local area of the HPC jetty outfall:

a. Bridgwater Bay (coastal water body, C21): construction and cold commissioning discharges will take place in this water body via the jetty outfall. The HPB intake is also in this water body.

b. Parrett Estuary (transitional water body, T18): The HPB cooling water discharge is into this water body.

c. MSFD sea area: Celtic Sea

This assessment considers the potential effects of the combined construction and cold commissioning discharge on nutrient concentrations, biochemical oxygen demand, total ammonia, un-ionised ammonia, phytoplankton production and specific habitats.

The assessment methodology considered whether there was any deterioration in status in either of the Bridgwater Bay or Parrett Estuary water bodies; if none were identified then no deterioration could be concluded for adjoining water bodies both upstream and downstream of the discharges. If a potential deterioration were identified, the resulting effect on other WFD water bodies outside of those initially selected would be undertaken within the WFD ‘Further Assessment’ stage. A comprehensive assessment of the effect of combined construction and cold commissioning discharges on all classification elements relevant to Hinkley Point are considered in BEEMS Technical report TR550.

6.1 Assessment Results

6.1.1 Water Quality

Dissolved inorganic nitrogen loading and nutrient influence on phytoplankton

The cold commissioning process is predicted to release additional dissolved inorganic nitrogen (DIN) into the construction discharge to the Estuary. Under the WFD standards, the Bridgwater Bay water body has ‘Moderate’ status for DIN. During Case D construction discharges include up to 25 $l\ s^{-1}$ groundwater (2951 $\mu g\ l^{-1}$ DIN) and 13.3 $l\ s^{-1}$ treated sewage (average value of 5000 $\mu g\ l^{-1}$ DIN). Over a year the high degree of mixing is likely to spread the discharge throughout the waterbody. The DIN standard is usually expressed as $\mu mol\ l^{-1}$. The transitional and coastal waterbody is classified as turbid, with the standards as given in Appendix C. The annual uplift in nitrogen due to the jetty discharge in Bridgwater Bay for construction inputs during Case D is 4423 kg = 3.16×10^{5} μmol / the volume of Bridgwater Bay (9.77×10^{11} litres) = 0.32 $\mu mol\ l^{-1}$. During cold commissioning, an additional annual loading of nitrogen of 3862 kg may result from the breakdown of commissioning chemicals. The combined construction and cold commissioning loading of nitrogen is estimated as 8286 kg/year, and this would represent an addition of 0.61 $\mu mol\ l^{-1}$ to Bridgwater Bay. The mean background concentration identified here is 75 $\mu mol\ l^{-1}$ which falls within a good waterbody classification under the Water Framework Directive (99th percentile value 180 μmol^{-1} for turbid waters). The proposed discharge from the jetty including construction and cold commissioning inputs is, therefore, a relatively small annual addition which would not change the classification. The nitrogen loading is further reduced based on an Environment Agency recalculation of the groundwater source data (see Appendix C Table 29). The influence of both nitrogen and phosphorus inputs on phytoplankton status was evaluated using a Combined Phytoplankton and Macroalgae (CPM)model (Appendix F). Without using unrealistically low values of suspended sediment concentration (SSC), no phytoplankton production was predicted to occur, and this assessment considered maximal annual sewage treatment loadings (Table 26) which are likely to be more variable and lower over a whole year period.

In terms of the most recent MSFD eutrophication assessment, the elevated dissolved inorganic nitrogen and phosphorus from the combined construction and cold commissioning inputs have very localised influence and would not change the current MSFD status of “good” for the Atlantic Celtic Sea sub-region. The most recent eutrophication assessment published in 2019 (https://moat.cefas.co.uk/pressures-from-human-activities/eutrophication/) by Defra, showed that only a small number of eutrophication problems remain in coastal and estuarine waters, representing 0.03% of the total UK Exclusive Economic Zone, and 0.41% of estuarine and coastal waters. The closest “problem area” to HPC according to this assessment is the Loughbor estuary, West Wales, and as the additional output of nutrients would be very localised, it would not contribute to the elevated concentrations observed there. Currently, there are no major outstanding issues for eutrophication in the UK as a whole and the inputs indicated for this assessment would make a negligible contribution to the overall loading for the Severn.

Biochemical oxygen demand (BOD)

No change in oxygen status for the Bridgwater Bay waterbody is predicted from the discharges during construction or from the additional cold commissioning inputs.

Chemical inputs from groundwater, treated sewage, tunnelling and cold commissioning.

In addition to the potential influence of nutrient inputs via the jetty discharge from construction and cold commissioning other chemical inputs primarily those from groundwater and tunnelling chemicals must be evaluated for potential toxicological effects. A habitats assessment provided in BEEMS TR443 established that there was either no effects pathway or likely significant effects from jetty discharges of construction chemical inputs during Case C and Case D which are considered to encompass the most significant inputs of the construction period. Separately the predicted discharge concentrations of hydrazine which is used in cold commissioning were evaluated for toxicological effects in BEEM TR445. A discharge concentration of 15 μg l^{-1}, is sufficiently precautionary so that the acute PNEC is never exceeded at the *Corallina* features and only at *Sabellaria* stations D and E. Furthermore, the plume is very short lived (1-2 hours) and concentrations are well below the acute PNEC (4 ng l^{-1} as a 95th percentile) at all features.

6.1.2 Test for inclusion of habitats in the WFD assessment

The tests for inclusion of habitats in a WFD assessment are considered in Table 19:

Table 19 Tests to determine if habitats areas are affected by the combined construction and cold commissioning discharges.

Test	Predicted activity footprint	Result
i. 0.5 km² or larger	Heavy metals, Tunnelling chemicals, dissolved inorganic nitrogen and phosphorus, total ammonia and un-ionised ammonia, biological oxygen demand, suspended solids	Areas affected are below test value
ii. 1% or more of the water body's area	Heavy metals, Tunnelling chemicals, dissolved inorganic nitrogen and phosphorus, total ammonia and un-ionised ammonia, biological oxygen demand, suspended solids	Areas affected are below test value
iii. within 500 m of any higher sensitivity habitat	Heavy metals, Tunnelling chemicals, dissolved inorganic nitrogen and phosphorus, total ammonia and un-ionised ammonia, biological oxygen demand, suspended solids	The jetty discharge point is less than 500 m from *Sabellaria* and *Corallina* features
iv. 1% or more of any lower sensitivity habitat	Heavy metals, Tunnelling chemicals, dissolved inorganic nitrogen and phosphorus, total ammonia and un-ionised ammonia, biological oxygen demand, suspended solids	Is below test value

Tests i., ii. and iv. are met but the jetty discharge is within 500 metres of *Sabellaria* and *Corallina* habitat.

Potential effects on higher and lower sensitivity WFD habitats

The discharge from the jetty is within 500 m of higher sensitivity habitat polychaete reef and with *Corallina* habitat. However, the predicted plume discharge from the jetty is a fresh water source it is therefore very buoyant, the highest values are associated with the surface. The highest areas of exceedance of standards for all parameters of relevance to a WFD assessment was for one of the tunnelling chemicals Condat CLB F5/M for which an area of 1 ha at the surface exceeds the relevant EQS. At the bed, the relevant concentration was predicted to be below EQS within 5 metres of the discharge. Neither mean bed concentrations nor 95th percentile concentrations exceed the EQS, and benthic features should therefore remain unaffected. There is a small area of exceedance at the surface near the point of discharge.

For the other discharges considered the area above EQS was much more limited. The assessment of the ammoniacal nitrogen discharge when at maximum levels with combined construction and cold commissioning inputs showed no areas of exceedance for total ammonia concentrations nor at the mean un-ionised ammonia EQS at the surface or bed and an area of only 0.2 ha at the surface for the un-ionised ammonia as a 95th percentile. More detailed time series analysis considering more extreme summer temperatures when the proportion of un-ionised ammonia is likely to be maximal confirmed that concentrations were less than 25% of the EQS at the closest locations of *Corallina* and *Sabellaria* features. The same assessment would apply to lower sensitivity habitat close to the jetty discharge.

7 Summary for construction and commissioning

For the construction discharge there is a small (1 ha) mixing zone (the area where the relevant EQSs are exceeded) around the jetty point of discharge itself. The mixing zone will have EQS exceedances for concentrations of zinc, copper and TBM ground conditioning chemicals. There will also be localised increases in DIN. The area of exceedance is largest for zinc and conditioning chemicals and the modelling has therefore focused on these substances for the combined commissioning inputs and for those from CWW discharge is:.

- Case D, comprising 20 $l\ s^{-1}$ groundwater, 13.3 $l\ s^{-1}$ of treated sewage and ca., 5 $l\ s^{-1}$ of tunnelling groundwater discharge).

Where discharges during the construction period contribute the highest loadings of a given contaminant, the summary text remains unchanged from earlier versions of this report. However, updates are provided for the assessment of ammoniacal nitrogen inputs as these receive contributions from both construction discharges and from the breakdown of commissioning chemicals and are assessed both in terms of the total ammonia and of the proportion of the input that would form un-ionised ammonia. Breakdown of commissioning chemicals will also contribute additional inputs to the nitrogen and phosphorus loading, and these are assessed using a combined phytoplankton and macroalgal box model.

Heavy metals

For Case D, both copper and zinc fail the Environment Agency screening tests. During peak ground water load (Case C) chromium also fails this test, although only marginally and for a period of approximately eight weeks when the flow is predicted to be at a maximum. If the annual average were used, then only zinc would be of potential concern as the copper Effective Volume Flux (EVF) is substantially below the threshold. As zinc was the substance of greatest exceedance this discharge was considered further by detailed modelling. The areas of exceedance for zinc at the surface were 0.3 Ha and 0.125 Ha for Cases C and D, respectively. As the discharge is buoyant, exceedance at the bed was only expected within a very short distance (less than 5 m) of the discharge itself. Some small additional metals inputs occur via the CWW discharge, but the discharge rate and concentrations are so low that this is not expected to change the present assessment.

There is no predicted exposure of designated bed features above the EQS at any time.

TBM soil conditioning chemicals

Chemical constituents of TBM ground conditioning products BASF Rheosoil 143 and Condat CLB F5/M failed the initial EQS screening and were investigated further using modelling approaches. With the worst-case chemical constituent (i.e., with the most toxic chemical group) there was no exceedance of the PNEC at the bed and the areas of exceedance at the surface were very small (0.19 ha for Rheosoil 143 and 1 ha for Condat CLB F5/M). This assessment used examples of typical soil conditioning chemicals (primarily different types of surfactants) with particularly low (i.e., the most conservative) PNEC values. Providing the chemical components of any other products selected for soil conditioning have an Effective Volume Flux value at or below 58.7, then areas of exceedance will be the same or less than those shown here for CLB F5 mono- alkyl sodium sulphate.

DIN and phosphorus inputs during construction and commissioning

The jetty discharge will release dissolved inorganic nitrogen (DIN) into the estuary. Under the Water Framework Directive Standards, the Bridgwater Bay waterbody has ‘Moderate’ status for DIN. The jetty discharges result in a very localised elevation in DIN in the receiving waterbody and the initial screening test was passed (Table 3).

The average annual uplift from the jetty discharge during year 1 was estimated at 0.36 µmol l^{-1} relative to a mean annual concentration of 75 µmol l^{-1} within Bridgwater Bay and status is unaffected. Due to the high turbidity environment, productivity in the Severn is light-limited (Underwood, 2010) and the effects of minor DIN loading on the designated Severn Estuary features are deemed insignificant and not assessed further. In-combination effects of discharges from HPB are considered in Section 5 and it is concluded that there is no direct intersection between the HPB discharge and the jetty discharge. Based on the results of a CPM model this assessment would also apply during the period when the breakdown of cold commissioning discharge inputs makes a further contribution to nitrogen and phosphorus loadings. Some small additional nitrogen inputs occur via the CWW discharge, but the discharge rate and concentrations are so low that this is not expected to change the present assessment.

Total and un-ionised ammonia during construction and commissioning

Using the EA calculator, the EQS for un-ionised ammonia (21 µg l^{-1}) was exceeded in Case C_{max} and D_{max}, but only in the immediate vicinity of the discharge (within less than 10 m). Rapid dilution rates mean that the EQS was only exceeded when groundwater discharges and sewage discharges were at their maximum. The total area of EQS exceedance was 0.005 ha and, even during maximum discharges, the initial screening test was passed (Table 3). When combined construction and cold commissioning inputs of un-ionised ammonia are considered the area above the 21 ug l^{-1} threshold, when using the 95th percentile of ammoniacal nitrogen is small (Maximum 0.2 hectares). For the actual EQS when using the annual average there are no areas of exceedance and the un-ionised ammonia concentrations associated with *Corallina* and *Sabellaria* features are less than 25% of the EQS. An additional assessment of the in-combination effects of concurrent sewage discharges from the temporary jetty and HPB are considered below. Some small additional ammoniacal nitrogen inputs occur via the CWW discharge, but the discharge rate and concentrations are so low that this is not expected to change the present assessment.

For total ammonia, the modelling shows that at the 25m resolution of the model for the construction and commissioning phase there is no exceedance of either the mean 1100 ug l^{-1} or of the MAC 8000 ug l^{-1}.

Biological oxygen demand

The sewage treatment works is expected to achieve a maximum concentration of Biological Oxygen Demand (BOD) of 40 mg l^{-1} (i.e., draw down over 5 days) and the indicative Maximum Allowable Concentration (MAC) to be applied in the permit is therefore 40 mg l^{-1}. Using the 13.3 l s^{-1} discharge and a BOD of 40 mg l^{-1}, a daily BOD of 46 kg was calculated. This amount of oxygen would be transferred across 14364 m^2 of the water surface in a day. The tidal excursion (how far a particle is advected) at Hinkley Point, even on the weakest (neap) tides, is many kilometres, thus there is ample resupply of oxygen from the atmosphere so that no change in oxygen concentration would be observed.

Suspended solids

The background suspended solids concentration in the receiving water is relatively high (with a mean of 264 mg l^{-1} and a minimum of 33 mg l^{-1}). Commissioning activities such as hydrostatic testing and flushing will result in variable suspended solids loadings within resultant effluents. The primary objective of the Commissioning Effluent Treatment Plant (CETP) is to reduce the hydrazine concentration in the final effluent discharge. However, the CETP will also incorporate methods to reduce suspended solids to permitted levels prior to discharge.

Coliforms – bathing water standards and shell fisheries

The discharge point is not in designated bathing waters. Model predictions (which do not consider wave-driven mixing) indicate that treatment from the plant is sufficient to ensure that microbial concentrations in discharged waters comply with bathing water standards within a maximum of 2.8 km from the discharge point (without UV treatment) and within 10 m (with UV treatment). The nearest designated bathing waters are 12 km distant from the jetty discharge and the closest shell fishery is 32 km distant and so no effects on these features is predicted.

Potential in combination effects with the HPB discharge

This report has considered the potential interaction of the jetty discharges and the sewage discharge from HPB (2.4 km distant). There is no overlap of the plume mixing zone and the HPB discharge, and no interaction occurs because of the physical separation and the small discharge volume from the jetty.

During the main construction period the total annual loading of DIN has been considered for the two impacted Water Framework Directive designated waterbodies (Bridgwater Bay and River Parrett). The combined effect of HPC (construction discharge at the jetty) plus HPB is to uplift the DIN concentration in the Bridgwater Bay water body by 0.58 µmol l^{-1} and the Parrett waterbody by 2.52 µmol l^{-1} (when all the discharge goes into one body). There would therefore be no change of status: the present mean is 75 µmol l^{-1} and the 99th percentile concentration for Good status in turbid waters is 180 µmol l^{-1}. These results have also been confirmed including additional nutrient inputs during commissioning using a CPM model with no difference shown between the Bridgwater bay reference case or the HPC construction and cold commissioning run for either phytoplankton production or for macroalgae.

It is not known what the actual discharge concentration of microbial discharge is from Hinkley Point B, however assuming the same standard of secondary treatment as Hinkley Point C would imply an extent of exceedance of approximately 1.8km. This theoretical exceedance could only occur in very calm conditions. Under such calm conditions the plume would be long and thin and would not interact with the temporary jetty discharge, as the tidal stream lines are physically separate. In practice for most of the time, wave mixing will mix the discharge rapidly so that no interaction could occur.

If UV treatment is applied at HPC no microbial interaction with HPB is likely.

The thermal plume discharge from HPB has been considered and is expected to raise the mean background sea temperature at the jetty discharge location (where exceedance of the EQS's occurs) by approximately 1°C, this small temperature rise compared to the annual seasonal variation is considered unlikely to have any effect on the toxicity of any of the chemicals or metals considered.

Test for inclusion of habitats in the WFD assessment

The tests for inclusion of habitats in a WFD assessment are if the footprint of the FRR discharge is any of the following:

i. 0.5km² or larger
ii. 1% or more of the water body's area
iii. within 500m of any higher sensitivity habitat
iv. 1% or more of any lower sensitivity habitat

For tests i., ii. and iv there is no exceedance of these areas, but the jetty discharge is within 500 metres of *Sabellaria* and *Corallina* habitat.

Potential effects on WFD habitat

Higher sensitivity habitats:

The predicted plume discharge from the jetty is a fresh water source it is therefore very buoyant; the highest values will be associated with the surface. The highest areas of exceedance of standards for all parameters of relevance to a WFD assessment was for one of the tunnelling chemicals Condat CLB F5/M for which an area of 1 ha at the surface exceeds the relevant EQS. At the bed, the relevant concentration was predicted to be below EQS within 5 metres of the discharge. Neither mean bed concentrations nor 95th percentile concentrations exceed the EQS, and benthic features should therefore remain unaffected. There is a small area of exceedance at the surface near the point of discharge.

For the other discharges considered the area above EQS was much more limited. The assessment of the ammoniacal nitrogen discharge when at maximum levels with combined construction and cold commissioning inputs showed no areas of exceedance for total ammonia concentrations nor at the mean un-ionised ammonia EQS at the surface or bed and an area of only 0.2 ha at the surface for the un-ionised ammonia 95th percentile. More detailed time series analysis considering more extreme summer temperatures when the proportion of un-ionised ammonia is likely to be maximal confirmed that concentrations were less than 25% of the EQS at the locations where *Corallina* and *Sabellaria* features are located. The same assessment would also apply to any lower sensitivity habitat close to the jetty discharge.

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Appendix A Background values for Severn Estuary

Reference for background for dissolved zinc concentration included in suite of determinands analysed by National Laboratories Service for seawater collected from the shore at Berrow, Somerset (Lat 52.208587, Long 1.623361), 23rd February 2015.

Zinc data has been provided by the environment agency from sample point 60510019 at ST 19230 49247, dating back to 2012.

Table 20. Zinc data provided by EA (mean 2.62 µg l^{-1})

10-Jul-12	2IZZ	Zinc, Dissolved	µg l^{-1}	2.52
13-Aug-12	2IZZ	Zinc, Dissolved	µg l^{-1}	2.42
10-Sep-12	2IZZ	Zinc, Dissolved	µg l^{-1}	3.57
07-Oct-12	2IZZ	Zinc, Dissolved	µg l^{-1}	2.5
04-Nov-12	2HZZ	Zinc, Dissolved	µg l^{-1}	2.58
13-Jan-13	2HZZ	Zinc, Dissolved	µg l^{-1}	2.84
07-Feb-13	2IZZ	Zinc, Dissolved	µg l^{-1}	5.68
17-Mar-13	2IZZ	Zinc, Dissolved	µg l^{-1}	3.06
25-Apr-14	2IZZ	Zinc, Dissolved	µg l^{-1}	3.04
26-Jun-14	2IZZ	Zinc, Dissolved	µg l^{-1}	2.61
07-Jul-14	2IZZ	Zinc, Dissolved	µg l^{-1}	5.66
07-Aug-14	2IZZ	Zinc, Dissolved	µg l^{-1}	2.06
20-Sep-14	2IZZ	Zinc, Dissolved	µg l^{-1}	1.85
19-Jan-15	2IZZ	Zinc, Dissolved	µg l^{-1}	2.51
02-May-17	2IZZ	Zinc, Dissolved	µg l^{-1}	2.63

Table 21. Background values for contaminants in the Severn Estuary (from Amec 2009 report)

Analyte	**Units**	**Concentration**
Cyanide as CN	mg l^{-1}	<0.500
Ammoniacal Nitrogen as N	mg l^{-1}	<0.01
Nitrite as N	mg l^{-1}	<0.004
Nitrogen: Total Oxidised as N	mg l^{-1}	1.43
Orthophosphate, reactive as P	mg l^{-1}	0.08
Fluoride	mg l^{-1}	0.857
Sulphide as S	mg l^{-1}	<0.01
Solids, Dissolved at 105 C	mg l^{-1}	615
pH	pH Units	8.09
Bromide	mg l^{-1}	43.4
Arsenic	g l^{-1}	1.99
Selenium	µg l^{-1}	<1
Beryllium	µg l^{-1}	<10
Cobalt	µg l^{-1}	<10
Molybdenum	µg l^{-1}	<30
Silver	µg l^{-1}	<1
Cadmium	µg l^{-1}	0.08
Copper	µg l^{-1}	4.17
Lead	µg l^{-1}	0.5
Nickel	µg l^{-1}	0.974
Zinc	µg l^{-1}	4.94
Boron, Dissolved	µg l^{-1}	2980
Calcium, Dissolved	mg l^{-1}	299
Iron, Dissolved	µg l^{-1}	<100
Magnesium, Dissolved	mg l^{-1}	873
Manganese, Dissolved	µg l^{-1}	<20
Potassium, Dissolved	mg l^{-1}	265
Sodium, Dissolved	mg l^{-1}	6990
Strontium, Dissolved	µg l^{-1}	5060
Sulphate, Dissolved as SO4	mg l^{-1}	1800
Boron	µg l^{-1}	2940
Calcium	mg l^{-1}	292
Iron	µg l^{-1}	153
Magnesium	mg l^{-1}	841
Manganese	µg l^{-1}	<20
Potassium	mg l^{-1}	255
Sodium	mg l^{-1}	6810
Strontium	µg l^{-1}	5000
Sulphate as SO4	mg l^{-1}	1750
Mercury	µg l^{-1}	<0.01
Nitrate as N	mg l^{-1}	<1.43
Carbon, Organic: Total as C :- {TOC}	mg l^{-1}	2.3

Appendix B 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/1)*
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.

Appendix C Calculations for discharge concentrations and Effective Volume Flux

Table 22. Groundwater contaminants and concentrations likely to be present in the construction dewatering discharge and comparison to EQS for three cases. AA refers annual average concentration and MAC refers to the maximum allowable concentration. EVF ($m^3 s^{-1}$) has been derived using 95th percentile discharge concentrations and the AA EQS (except for mercury where the MAC EQS has been used). The shaded values indicate those used in the screening test assessment.

Contaminant	Assessed discharge concentration $\mu g\ l^{-1}$ 95th percentile (used in EA Screening test)	Saltwater AA EQS ($\mu g\ l^{-1}$)	Background concentration ($\mu g\ l^{-1}$)	EVF Case A and Case D [(EFR x RC)/(EQS-BC) m^3]	EVF Case C [(EFR x RC)/(EQS-BC) m^3]	TraC Water test 5 EVF< 3.0 Pass/Fail
Un-ionised ammonia (N)	123.5	21	4.6[4]	(123.5 x 0.02) / (21 – 4.6) = 0.15	(123.5 x 0.0467) / (21 – 4.6) = 0.352	Pass
DIN	4073	2520[5]	1050	(4073 x 0.02) / (2520 -1050) = 0.06	(4073 x 0.0467) / (2520 -1050) = 0.129	Pass
Cyanide	50	1	0	(50 x 0.02) / (1- 0) = 1	(50 x 0.0467) / (1- 0) = 2.3	Pass
Total cadmium	0.46	0.2	0	(0.46 x 0.02) / (0.2 – 0.0) = 0.05	(0.46 x 0.0467) / (0.2 – 0.0) = 0.12	Pass
Total chromium	24	0.61	0.02	(24 x 0.02) / (0.6 – 0.02) = 0.83	(24 x 00467) / (0.6 -0.02) = 1.93	Pass
Total lead	3	1.3	0.02	(3 x 0.02) / (1.3 – 0.02) = 0.05	(3 x 0.0467) / (1.3 – 0.02) = 0.11	Pass
Total copper	199.5	4.76	3.95	(199.5 x 0.02) / (4.76 – 3.95) = 5.46	(199.5 x 0.0467) / (4.76 – 3.95) = 12.74	Fail
Total zinc	1642.15	6.8	3.035	(1642.15 x 0.02) / (6.8 – 3.035) = 8.72	(1642.15 x 0.0467) / (6.8 – 3.035) = 20.37	Fail
Total mercury	0.49	0.07	0.02	(0.49*0.02) / (0.07-0.02) = 0.2	(0.49*0.0467) / (0.07-0.02) = 0.46	Pass
Sewage DIN (max value)	20,000	2520	1050	(20,000*0.014) / (2520-1050) = 0.19	(20,000*0.030) / (2520-1050) = 0.41	Pass

EFR = Effluent discharge rate which is 0.02 m^3/sec for case A and D and 0.047 m^3/sec for case C. In the case of the sewage it is 0.014 m^3/sec and 0.030 m^3/sec as max flow case.

Table 23. Example products for use in ground conditioning, their properties and percentage of key component substances and associated Predicted No Effect Concentrations for each substance or surrogate value for a group of similar substances

Chemical function	**Product**	**Main active substance(s)**	**Active concentration per day assuming 100% use for 1 intake tunnel and 1 outfall tunnel. Mass (kg)**	**Predicted no effect concentration for aquatic environment (µg l^{-1})**
Anti-clogging agent	BASF Rheosoil 143	Sodium lauryl ether sulfate (<30%)	(16 rings x 64 l sec^{-1} + 24 rings x 48 l sec^{-1}) x (30% in formulation, 0.3 x 0.1, 10% total residual from spoil x product density 1.05) = 68.5 kg[1]	40[2]
Soil conditioning-additive	CLB F5 M	2,4-Pentanediol, 2-methyl- (≤10%)	(16 rings x 64 l sec^{-1} + 24 rings x 48 l sec^{-1}) x (10% in formulation, 0.1 x 0.1, 10% total residual from spoil x product density 1.05) = 22.8kg[1] total	4300[3]
		Alcohols, C10-16, ethoxylated, sulfates, sodium salts – (≤10%)		35[2]
		Mono-C10-16-alkyl, Sodium sulfate (≤10%)		4.5[4]

[1] This value takes account of substance density (1.05), % active substance, and assumes 90% associated to spoil (see later discussion); [2]see Table 15 HERA; [3]see SIDS, 2001, [4]see Table 13 HERA, 2002

Table 24. Environment Agency screening assessment of surfactant components of products. Example chemicals for use in ground conditioning, their properties and fate

Conditioning product	Estimated Discharge concentration mg l^{-1} of active substance. Case D	Saltwater AA EQS[1] µg l^{-1}	Background concentration µg l^{-1}	Effective volume flux (Case D) (concentration in discharge (µg l^{-1}) x discharge volume (m^3 s^{-1})) / EQS or equivalent (µg l^{-1}) - background (µg l^{-1})	TraC Water test 5 EVF< 3.0 (Pass/Fail)
BASF Rheosoil 143	19.8	40	0	(19800 x 0.040) / (40 x 0) = 19.80	Fail
CLB F5 M Ethoxylated sulphates	6.6	35	0	(6600 x 0.040) / (35 x 0) = 7.54	Fail
CLB F5 M Mono- alkyl sodium sulphate	6.6	4.5	0	(6600 x 0.040) / (4.5 x 0) = 58.67	Fail

Table 25: H1 Test 1 and 5 for discharges of commissioning chemicals and construction inputs.

Substance	**Estimated discharge concentration μgl^{-1}**	**Saltwater AA EQS μgl^{-1}**	**Background concentration μgl^{-1}**	**Effective volume flux Total flow 70 l/s**	**TraC Water test 5 EVF < 3.0 (Pass/Fail)**
Ethanolamine	4000	160	-	1.75	Pass
Total ammonia from commissioning including Case D inputs	281240[1]	1100	124	21	Fail
Unionised ammonia - from construction wastewater and commissioning inputs including chemical breakdown products converted to un-ionised ammonia assuming commissioning wastewater pH 10 and mean temperature 12.5	187682	21	0.2	977	Fail
Hydrazine	10	0.0004	0.00015	2800	Fail

[1] Total ammonia includes 271206 μgl^{-1} from commissioning + 10034 μgl^{-1} from Case Dmax construction (see Table 8). Note that for modelling the construction discharges is modelled as a separate continuous input and the commissioning as a pulse discharge see section 4.10.2

Table 26. Groundwater and sewage contributions of ammoniacal nitrogen, nitrogen, and phosphorus for Case D1max

Case Dmax	NH_4-N µg l^{-1}	Discharge rate litres/ second	Total mass NH_4-N µg	DIN µg l^{-1}	Discharge rate litres/second	Total mass DIN µg	PO_4-P µg l^{-1}	Discharge rate litres/second	Total mass phosphate PO_4-P µg
Sewage	20000[1]	13.3	266000	20000	13.3	266000	10000[3]	13.3	133000
Groundwater	4732[1]	25	118300	2951[2]	25	73775	48[4]	25	1200
Total concentration in discharge		**38.3 (l/second)**	(total sewage + groundwater/ discharge rate) = **10034** (µg l^{-1})		**38.3 (l/second)**	(total sewage + groundwater/ discharge rate) = **8871** (µg l^{-1})		**38.3 (l/second)**	(total sewage + groundwater/ discharge rate) = **3504**(µg l^{-1})
Loading (kg/year)						**10713.44**[5]			**4227.40**[6]

[1] see section 4.6 for derivation of source values – these are 95 percentiles to assess most conservative case for toxicity.

[2] This is the mean dissolved inorganic nitrogen input level from groundwater to be used in support of annual assessment.

[3] A concentration 10mg l^{-1} as P was derived for treated sewage from package units based on Natural England, 2016; 4: For groundwater a 50th percentile value of 0.048mg l^{-1} as TP was derived for Wessex groundwater by Stuart and Lapworth, 2016 and is used here as a substitute prior to full site data becoming available. 5: ((38.3 x 60 x 60 x24) x(0.000008871) x 365 =10713.44 kg; 6: ((38.3 x 60 x 60 x24) x(0.000003504) x 365 =4227.40 kg. (Following Environment Agency recalculation of groundwater nitrogen inputs total sewage and groundwater inputs are 8160 (µg l^{-1}) and total loading kg/yr is 9855.9 (µg l^{-1}

Table 27. Potential ammonia, nitrogen, and phosphorus contributions from cold commissioning chemical breakdown products

Conditioning product	**Estimated conditioning concentration µg l^{-1}**	**Contribution as un-ionised ammonia (NH_3-N) µg l^{-1}**	**Nitrogen contribution (kg)**	**Phosphorus contribution (kg)**
Hydrazine	400000	175000[1]	3271	-
Un-ionised ammonia	12000	12000	505	-
Ethanolamine	1180	636.5	85.88	-
Total un-ionised ammonia	-	187637	-	-
Total equivalent proportion ammonia (NH4-N)[2]	-	**271206**[2]	-	-
Total nitrogen (cold commissioning)			**3862**	**-**
Total PO4-P (cold commissioning)				**201.85**[3]
Total nitrogen construction Case D and cold commissioning (kg/year)			10713.44 + 3862= **14575**[4]	
Total phosphorus construction Case D and cold commissioning (kg/year)				4227.40 + 201.92= **4429**

[1] Hydrazine breakdown pathway assumed $2N_2H_4 + 0.5\ O_2 > N_2 + 2NH_3 + H_2O$; 2: This value is derived using the un-ionised ammonia calculator assuming conditioning solution parameters of pH of 10, salinity of 1 and annual average temperature at Hinkley Point 12.5 C.[2] This value was rounded up to 272 mg/l for GETM modelling.

[3] The total phosphorus contribution is based on maximum dose rate of 500ppm trisodium phosphate resulting in a maximum annual loading of 1068.35 kg trisodium phosphate which is equivalent to the PO_4-P loading shown.

[4] Following Environment Agency recalculation of groundwater nitrogen a value of 9,855.9 kg/y is added to the input for commissioning 3862 kg/y and results in an overall reduced loading of 13,717.9 kg/y

Table 28. Cumulative annual loading nitrogen based on variable groundwater discharge

Case	Calculation of DIN concentration
C	3.76 mg/l = (27.46 $l\ s^{-1}$ x 2.951^1 mg/l N + 30 $l\ s^{-1}$ x 5^2 mg/l N) / (27.46^3 + 30^4 + 4 $l\ s^{-1}$) a value of 4 litres is added to volume as tunnelling chemical make-up water with no DIN contribution (substituting the EA recalculated groundwater mean of 1.861 for 2.951 Case C =3.27
C1 max	13.2 mg/l = (27.46 $l\ s^{-1}$ x 7.685 mg/l N + 30 $l\ s^{-1}$ x 20 mg/l N)^1/ (27.46^3 + 30^4 + 4^5 $l\ s^{-1}$) based on average dewatering volume Case C and maximum DIN in dewatering and maximum sewage flow and concentration (substituting the EA recalculated groundwater mean of 1.861 for 2.951 Case C1 max =11.58
D	3.5 mg/l =(based on average dewatering volume Case D and average DIN in dewatering and average sewage flow and average concentration (25 $l\ s^{-1}$ x 2.951 mg/l N+13.3 $l\ s^{-1}$ x 20 mg/l N / 40 $l\ s^{-1}$) (substituting the EA recalculated groundwater mean of 1.861 for 2.951 Case D =2.82
Dmax	11.45 mg/l = (25 $l\ s^{-1}$ x 7.685 mg/l N + 13.3 $l\ s^{-1}$ x 20 mg/l N)^1/ (40 $l\ s^{-1}$) based on average dewatering volume and maximum DIN in dewatering and average sewage flow and maximum concentration (substituting the EA recalculated groundwater mean of 1.861 for 2.951 Case D =9.19

Notes: ^{1} average dewatering nitrogen value; ^{2}average sewage ammoniacal nitrogen

^{3}average groundwater (l sec^{-1}); ^{4} maximum sewage (l sec^{-1}); ^{5} average tunnelling chemical makeup water volume (l sec^{-1});

Table 29. Cumulative annual loading nitrogen based on variable groundwater discharge

Year	Calculation of annual loading
Year 1	(365 x 24 x 3600)[1] x (2951[2] x 30.5[3] + 5000[4] x 13.3[5]) / (1000 x 1000000)[6] =4934 kg N (following Environment Agency recalculation of the groundwater nitrogen input a mean dewatering concentration of 1861 is substituted for 2951= total loading of 3886.8 kg N
Year 2	365 x 24 x 3600 x (2951 x 27.5 + 5000 x 13.3) / (1000 x 1000000) =4655 kg N (Updated loading 3710.6 kg N)
Year 3	365 x 24 x 3600 x (2951 x 23.8 + 5000 x 13.3) / (1000 x 1000000) =4316 kg N (Updated loading 3497.2 kg N)

Notes: [1] days, hours, minutes, seconds;

[2] mean dewatering concentration nitrogen ($\mu g\ l^{-1}$); [3] groundwater ($l\ sec^{-1}$);

[4] ammoniacal nitrogen as a proxy for total nitrogen from sewage treatment ($\mu g\ l^{-1}$) as other contributions e.g. NO_2, NO_3 are small ; [5] discharge rate ($l\ sec^{-1}$);

[6] conversion of units to kilograms.

Appendix D CORMIX modelling dilution rates.

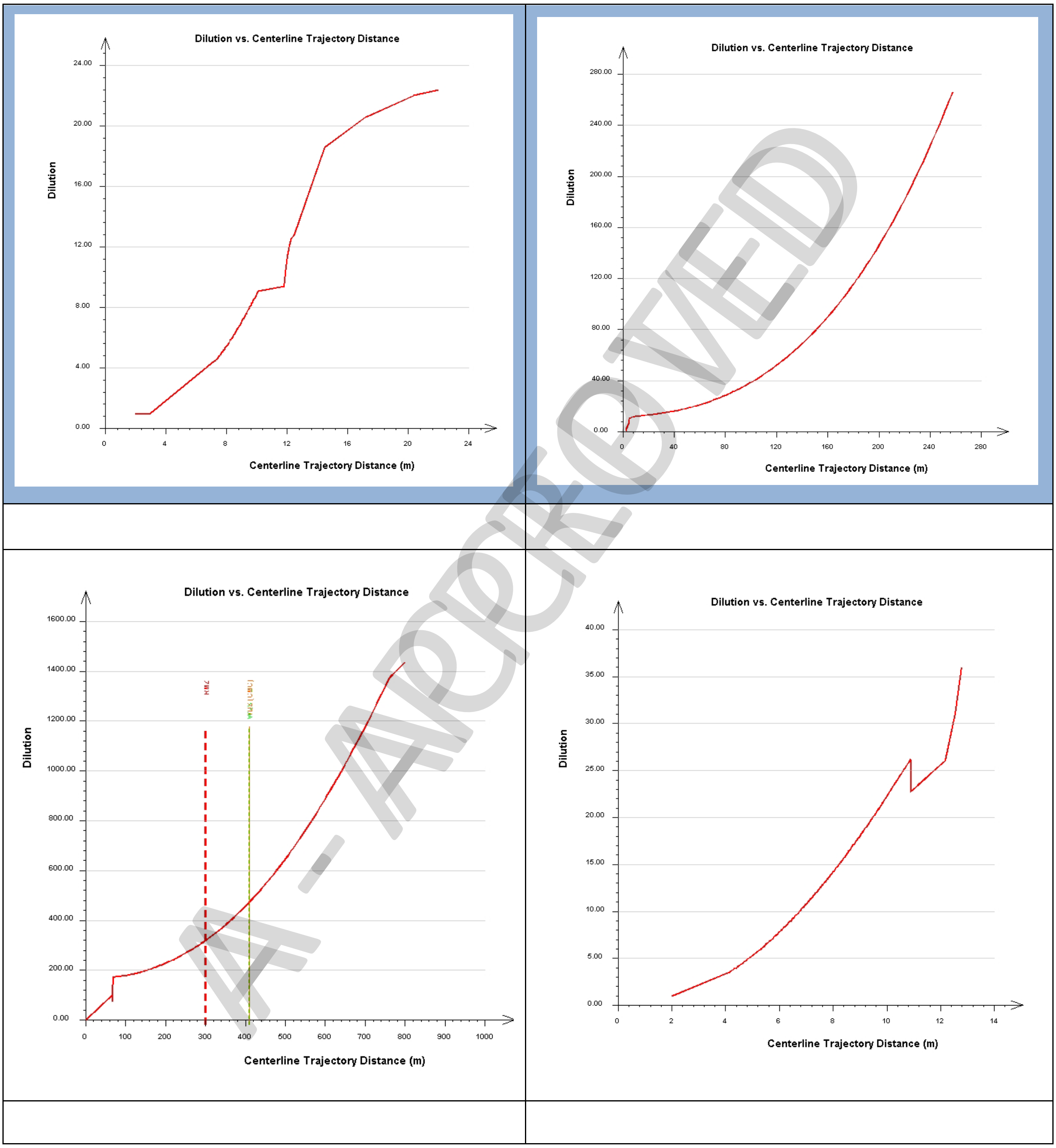
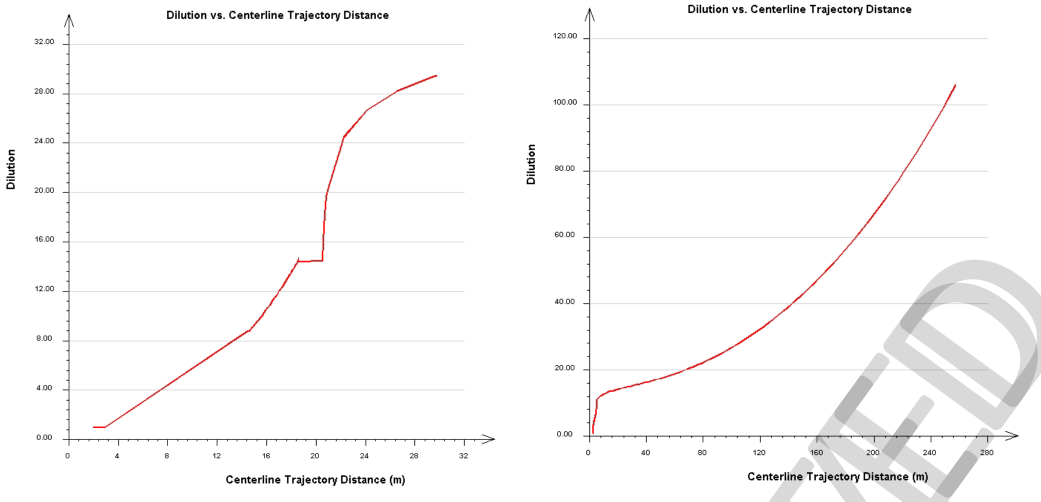
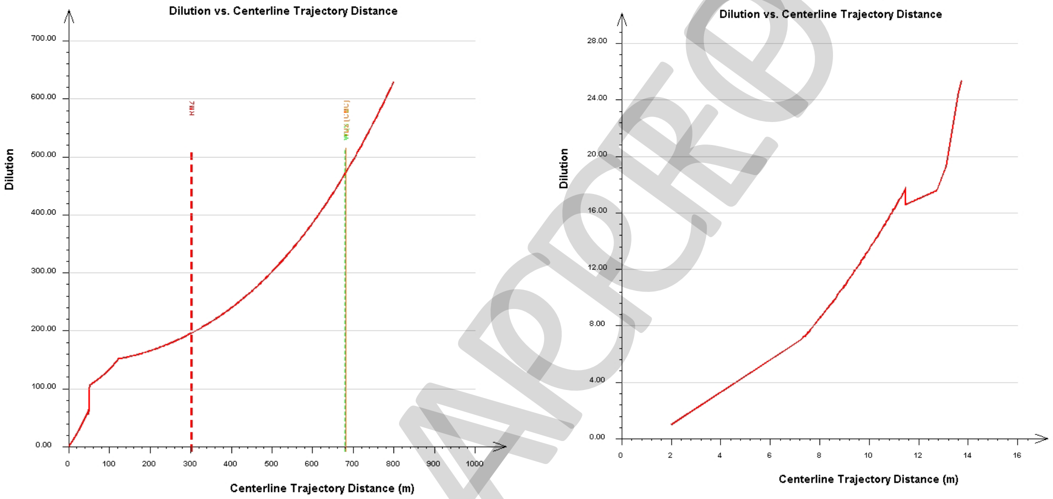


Figure 27. Dilution from low tide to high tide for a 45 l s^{-1} discharge at the jetty. Relevant for Case D.



Low Tide

Low Tide 1 hr



Mid Tide

High Tide

Figure 28. Dilution from low tide to high tide for a 90 l s-1 discharge at the jetty. Relevant for case C.

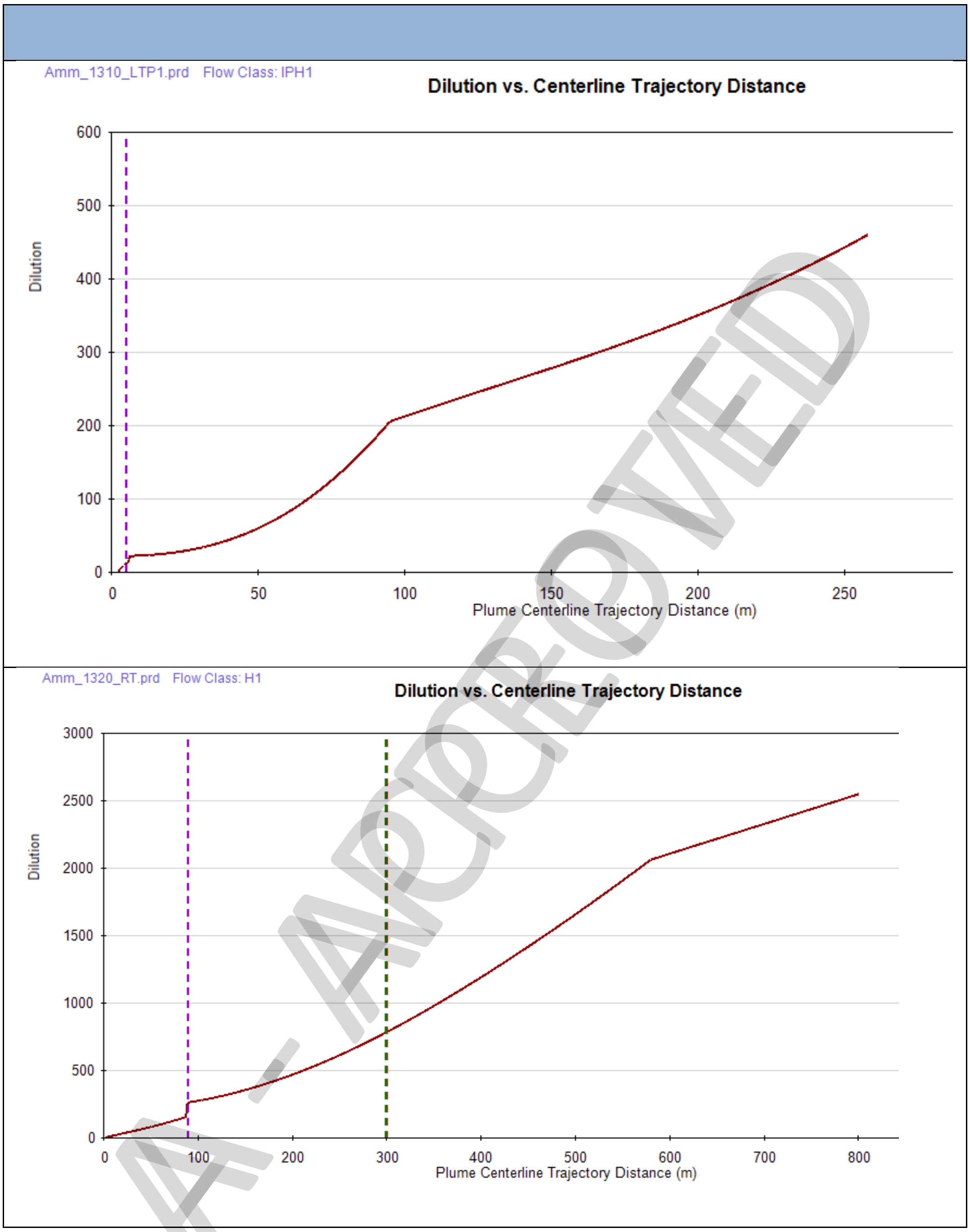


Figure 29. Dilution rates for 13.3 l s^{-1} simulation for 1hr after low tide (top) and mid tide (bottom).

It is evident from the figures above that it is the shape of the plume around the low tide simulation that is a potential concern as this is when high concentrations at the seabed are most likely to occur.

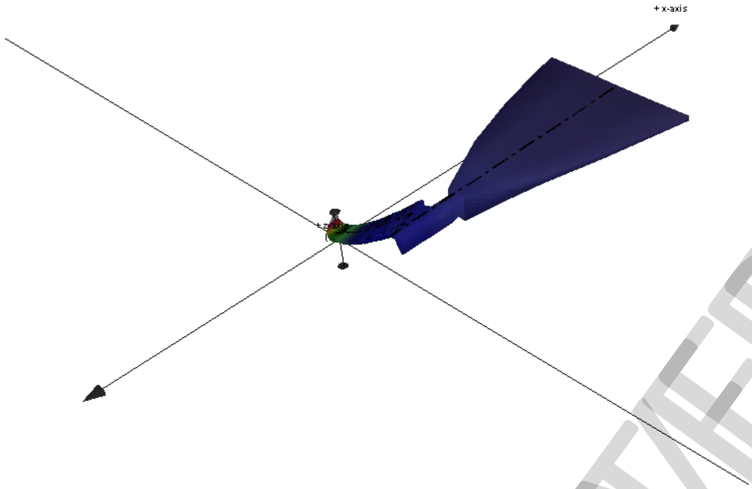


Figure 30. CORMIX output near low water slack, showing the buoyant nature of the plume for 45 l s^{-1} discharge.

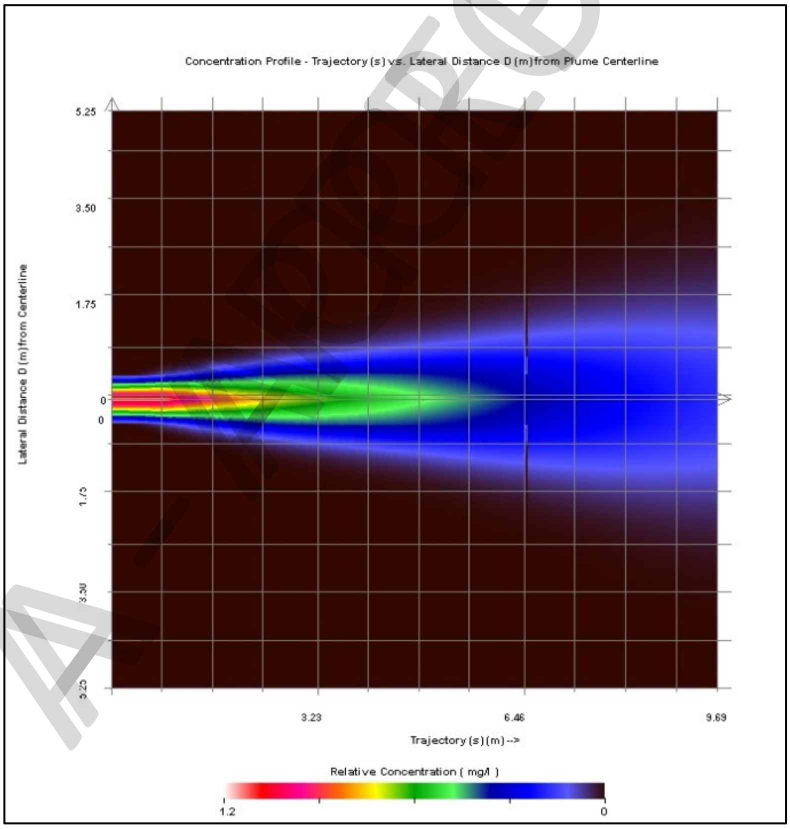


Figure 31. CORMIX outputs showing the dilution of the plume at higher spatial resolution than the GETM 25 m Hinkley Point model can achieve.

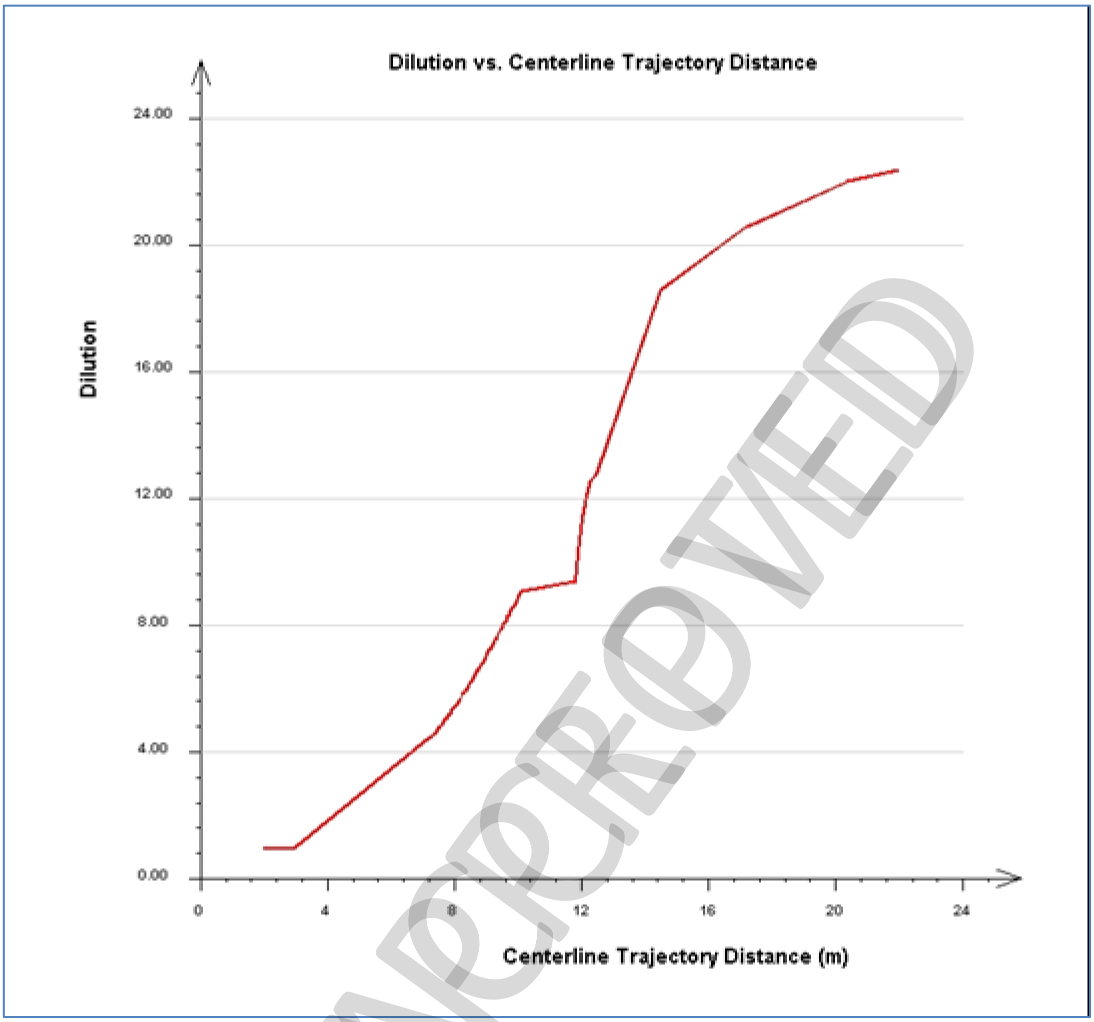


Figure 32. CORMIX outputs showing the dilution of the plume along the centreline 45 l s^{-1} simulation at low water. The size of GETM grid cells used in the Hinkley Point model was 25m. CORMIX predicted dilution is approximately 22-fold at 25 m from the discharge i.e. by the edge of the 1st GETM grid cell.

Appendix E Simulation of ponded water when high concentrations of Zinc could occur.

The purpose of this appendix is to demonstrate that the model accurately replicates potentially high concentrations of zinc which could be formed around periods of slack water. These periods are mostly likely to occur around neap tide, and so this period has been investigated.

The purpose of this appendix is to demonstrate that the model accurately replicates potentially high concentrations of zinc which could be formed around periods of slack water. These periods are mostly likely to occur around neap tide, and so this period has been investigated.

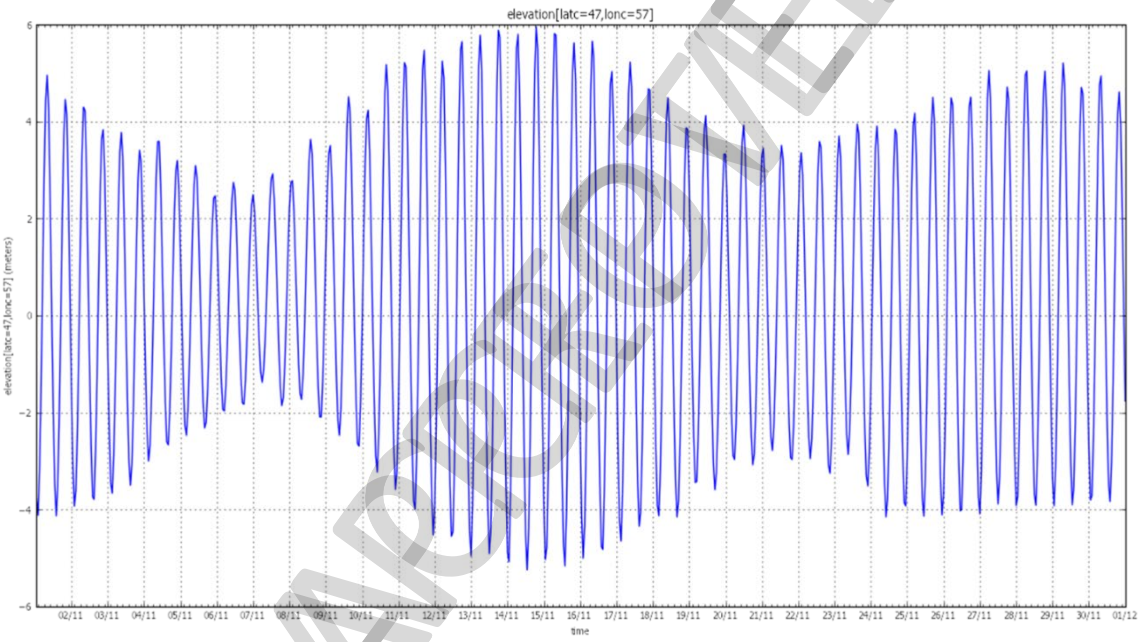


Figure 33. Spring Neap cycle (mean sea level) from model. Note the neap tides on 6th - 7th November, when it is most likely that water from the discharge will temporarily form a static pond.

As can be seen from the plots below, high concentrations above 0.06 mg l^{-1} (in fact up to 0.18 mg l^{-1}) are simulated at neap tides. This is consistent with a peak discharge of 1.2 mg l^{-1} and an expected dilution of approximately 20 m by 25 m distance from the discharge. At other tidal state dilution occurs much quicker, and the area of high values is confined to the discharge.

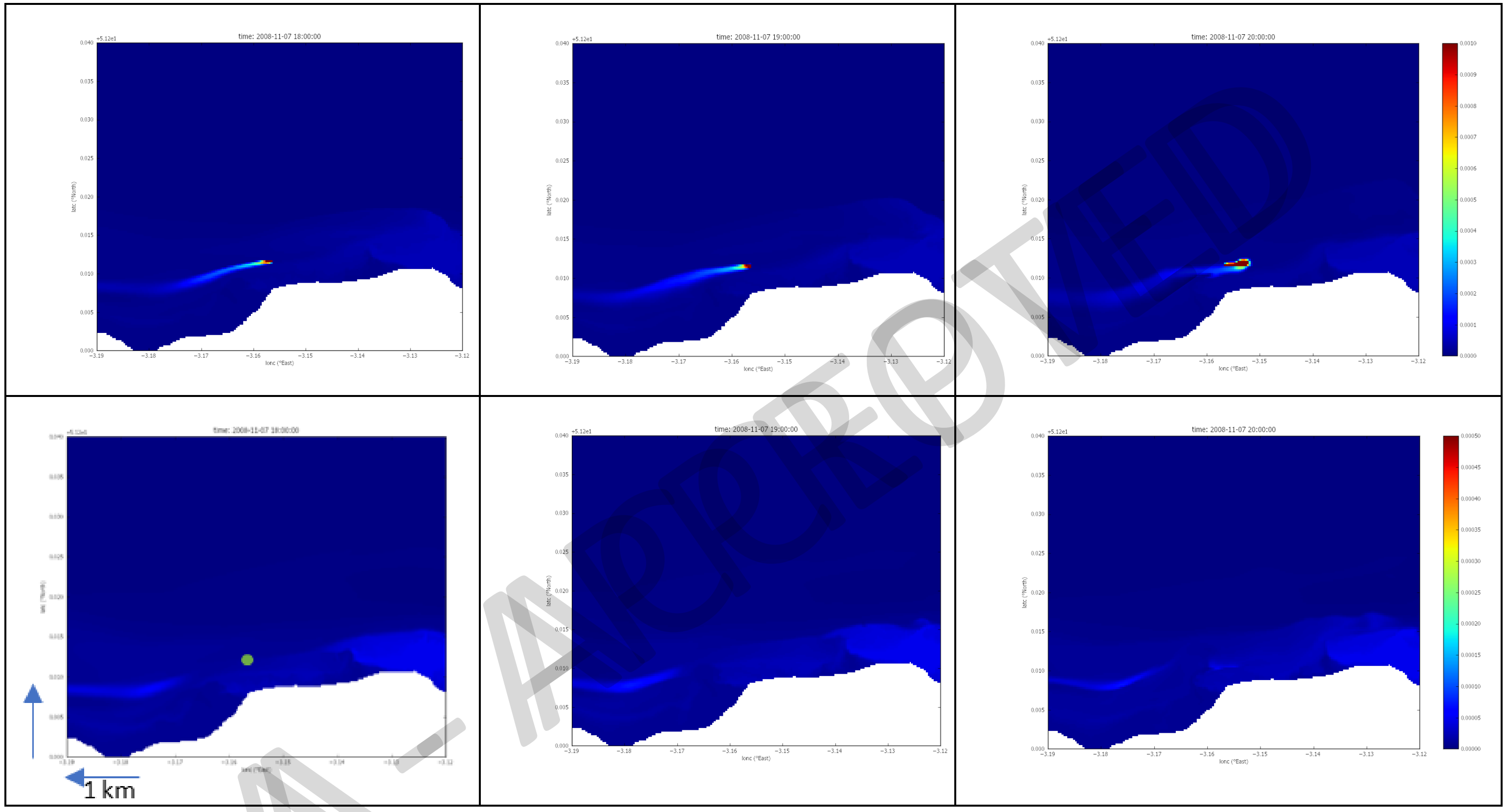


Figure 34. Top panel surface, bottom panel near bed (mg l^{-1}). EQS is 0.0038 mg l^{-1}. Green dot marks approximate position of the buoyant discharge. Note that the top panel concentrations are on different scale to the bottom panel concentrations, surface concentrations are approximately double those of the bottom. Tide is ebbing until 19:00 with low water slack at 19:30, the tide then changes to the flood tide, so that at 20:00 ponded water is in the same position at 18:00. Plots are not geographically projected thus the arrows indicate length of 1 km.

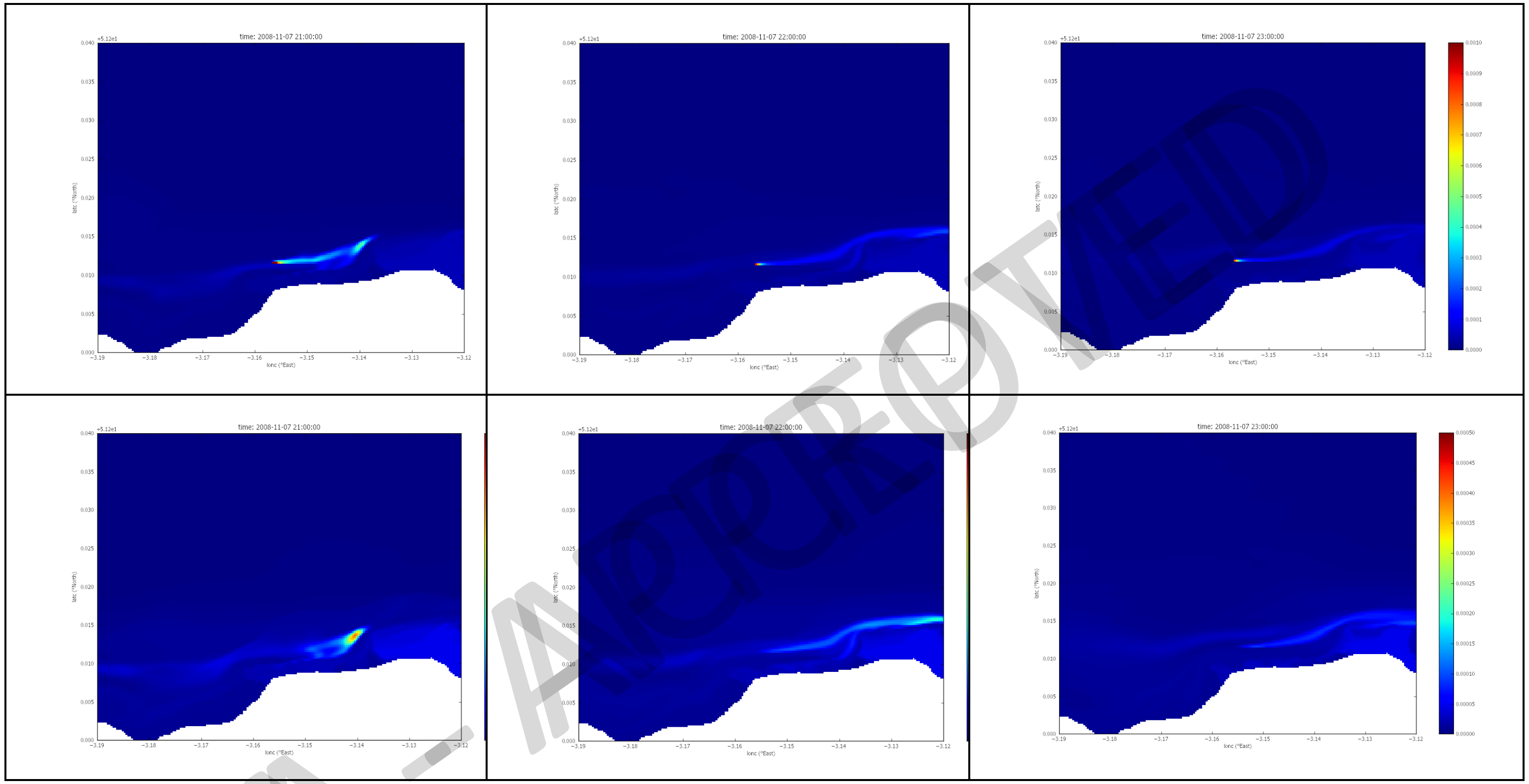


Figure 35. Top panel surface (mg l^{-1}), bottom panel near bed (mg l^{-1}). EQS is 0.0038 mg l^{-1}. Green dot marks approximate position of the buoyant discharge. Note that the top panel concentrations are on different scale to the bottom panel concentrations, surface concentrations are approximately double those of the bottom. 21:00 is during the flood tide, not the passage of the peak to the East, with high water at 24:00.

Appendix F Phytoplankton Modelling at Hinkley

F.1 Background and observational data relating to phytoplankton.

The Severn Estuary is a highly turbid estuary and has been known as such (Underwood 2010) production in the water column is likely to be very low and it is unclear if measurements of chlorophyll in the water column come from direct production, advection from elsewhere, or from chlorophyll derived from production occurring on the sediment mixed off the mudflat areas or broken up macroalgal material.

F.1.1 Observations of chlorophyll in Bridgwater Bay

As shown below, the mean concentrations of chlorophyll in Bridgwater bay are low and there is not a particular strong seasonal signal in phytoplankton concentration in the area; there are generally higher values in the summer months when primary production would be expected to occur, but only a couple of mg/l above the background winter levels. It is not clear if winter background levels come from advection from the wider environment or direct from the mudflat areas.

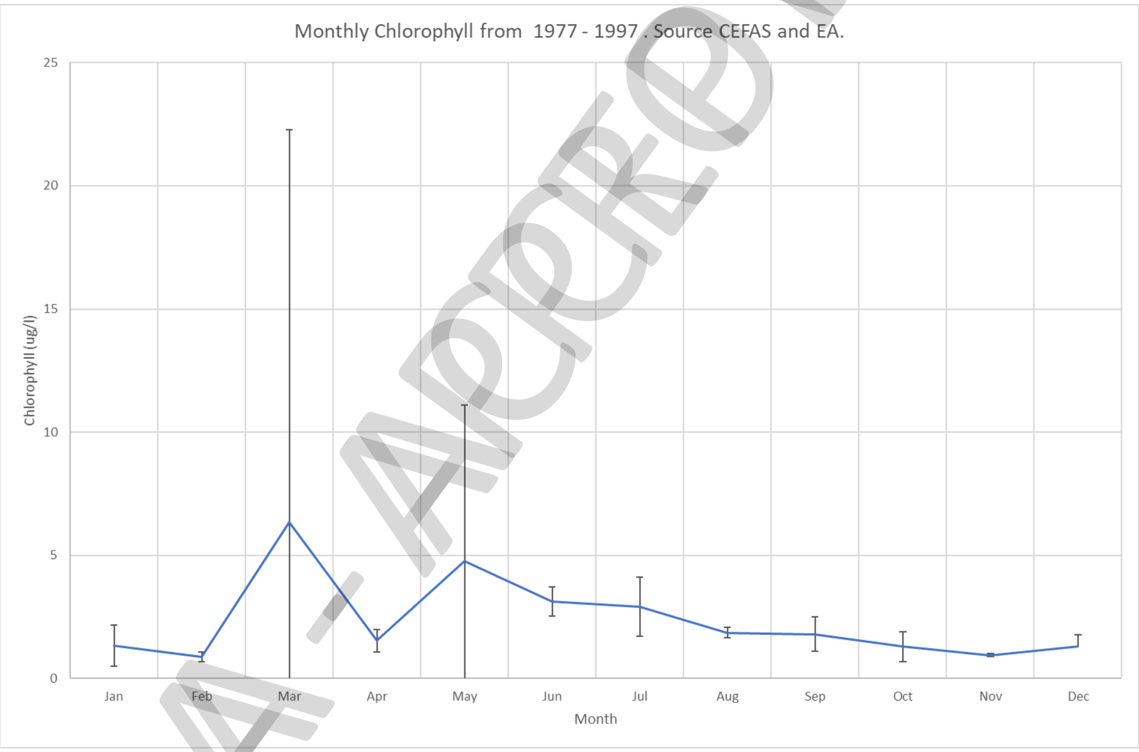


Figure 36: Observations of Chl-a, in Bridgwater bay per month from Cefas database 1977 – 1997. The March data has one data point at 48 μg l-1 which skews March datasets.

F.2 Model setup

F.2.1 Model description

We used the Combined Phytoplankton and Macroalgae (CPM) model to predict the effect of the discharge on phytoplankton community biomass. This model simulates the dynamics of phytoplankton biomass using data on known environmental drivers such as nutrients and light.

The original CPM model combined two earlier models developed for the Environment Agency (EA): one for phytoplankton, based on the UK Comprehensive Studies Task Team (CSTT) (CSTT, 1994, 1997; Painting *et al.*, 2003, 2007) and one for macroalgae (Cefas, 2003; Aldridge and Trimmer, 2009). The first version of the CPM model (Aldridge *et al.*, 2008) was developed as a static equilibrium model based on summer or annual average values, the subsequent version (used here) implements a dynamic model that does not rely on equilibrium assumptions and permits daily estimates of phytoplankton growth.

F.3 Basic concepts ('how the model works')

A detailed presentation of the physical, biological, and mathematical structure of the model is given by Aldridge and Tett, 2011. A schematic summary of the main features of the model is shown in Figure 37. Several kinds of primary producers are found in coastal environments. Microalgae are found in the water column, as the phytoplankton, and in or on the seabed, as the microphytobenthos. Associated larger producers include seaweeds (macroalgae) and aquatic macrophytes (seagrasses and saltmarsh). The current CPM model simulates phytoplankton and macroalgae. It does not simulate seagrasses or saltmarsh, but this is of no import for the current application because there are no seagrass or saltmarsh habitats in the vicinity of the HPC discharge.

At any instant the total biomass of producers is controlled by the least available, or limiting, resource. This can be a nutrient (nitrogen or phosphorous), or light. If nutrients control biomass, then the total biomass of primary producers stops increasing when the rate of nutrient input equals the rate of consumption. However, the limiting resource changes with time and the dynamic model solves the underlying equations for the rate of change of phytoplankton biomass without requiring assumptions of equilibrium. The version of the dynamic CPM model represented here is a single box with an exchange rate with outside waters.

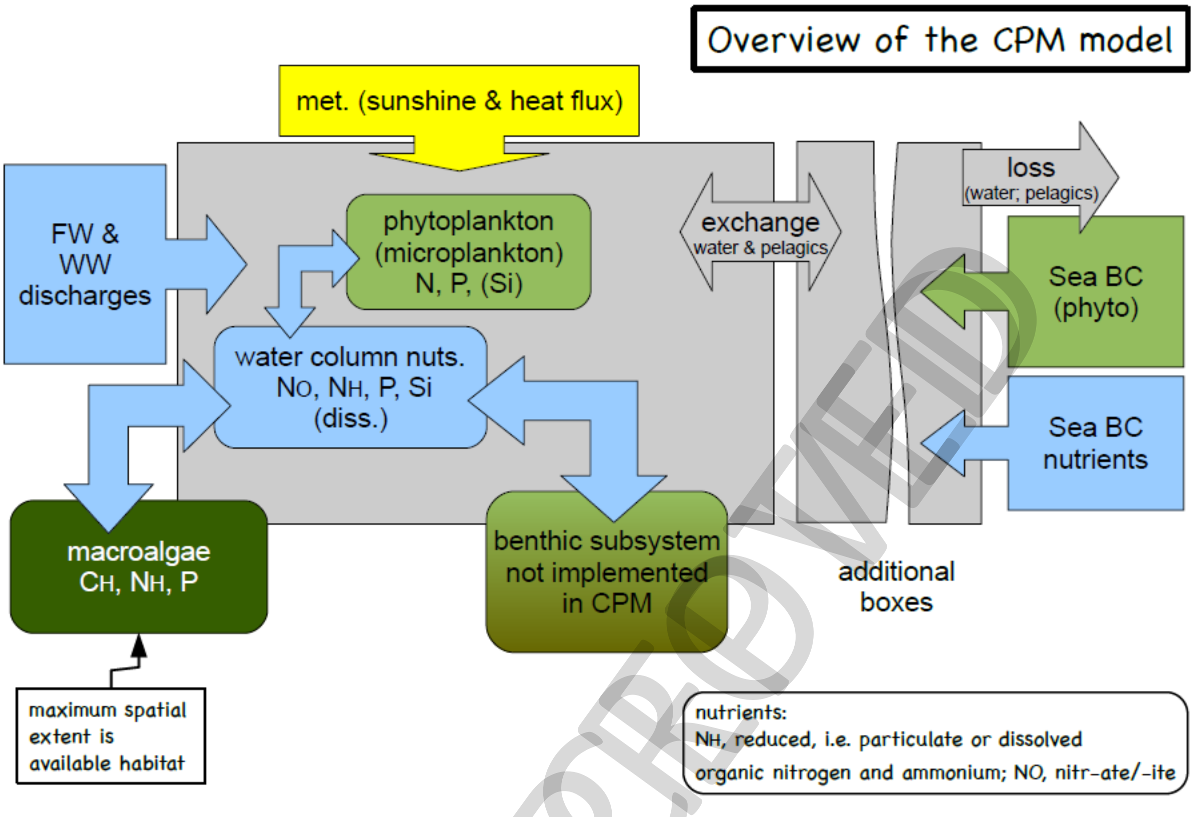


Figure 37: Schematic of CPM model components and processes (Aldridge et al., 2011)

Where FW is fresh water, WW wastewater, N nitrogen, P phosphorous, Si silicate, BC boundary conditions, No nitrate and nitrite, N_H organic ammonium and Nitrogen, C_H Carbon,

Table 30 Selective input parameters for model

Area (km2)	Avg. depth (m)	Light attenuation coefficient (Kd)	Winter back-ground N (µmol)	Winter back-ground P (µmol)	Summer back-ground N (µmol)	Summer back-ground P (µmol)	Tidal Range (m)	% Intertidal habitat for Macro Algal	Loss of micro-plankton (L), (d-1)
91.84	10.6	1	75	1.9	50	1.9	11.5	20	0.125

The value for the light attenuation coefficient or Kd of 10, is consistent with an SPM of about 160 mg l^{-1} using the equation of Devlin 2008. Values in the surface waters around Bridgwater bay are generally in the range of 100 – 800 mg l^{-1} (Underwood 2010). It is theoretically possible that in periods of neap tide, with little winds, that suspended sediment could be less than typically observed, a Kd of 1 consistent with an SPM of 10 mg l^{-1} has been used as an extreme worst case (i.e., for which light penetration with depth would be higher and hence potential for algal growth increased).

F.3.1 Incorporation of nutrients.

The model runs are a baseline run, with no additional nutrients, and a HPC construction and commissioning discharge run including the nutrients due to the discharge from conditioning chemicals, treated sewage, groundwater discharge, and due to the breakdown products of the hydrazine and other commissioning chemicals.

Table 31 Nutrient inputs to model

Waterbody Name	Nutrient addition per year kg	Phosphate per year kg
Bridgwater Bay Reference	No additional input	No additional input.
HPC Construction nutrients.	14575[1]	4429

[1] Based on updated calculation by the Environment Agency of groundwater nitrogen inputs an adjusted total loading of nitrogen from groundwater+ sewage+ commissioning inputs is calculated as 13,717.9 kg/year

Model Results - production

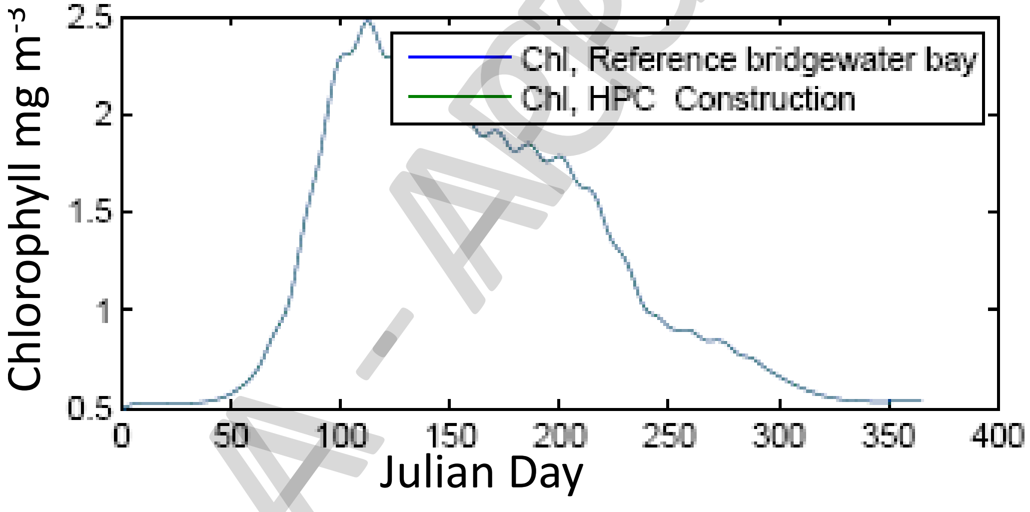


Figure 38: Instantaneous phytoplankton levels (mg Chlorophyll m^{-3}), for Bridgwater Bay with no power station discharge, HPC construction, Note there is no discernible difference, construction and reference lines are the same.

Table 32 Phytoplankton and Macro Algae production

Scenario kd (1)	Phyto Annual Gross Production, (g C m^{-2} y^{-1})	Macro Annual Gross Production, (g C m^{-2} y^{-1})
Bridgwater Bay	11.05	18.43
HPC Construction	11.05	18.43

Evident from above is that there is no difference between the simulations, which is entirely consistent with the known understanding of this high turbidity environment where nutrients are never limiting. Model results using Kd of 1 give estimates of 18 g C m^{-2} y^{-1} for macroalgal production which is broadly similar to values as estimated by Underwood (2010) of 33 g C m^{-2} y^{-1}, which applies to a wider geographic context.

F.3.2 Limiting factors that control phytoplankton growth.

The model shows which factors are limiting, during the annual cycle, as demonstrated below. Light is the limiting factor throughout the entire year. Therefore, additional nutrient input makes no difference to the output production.

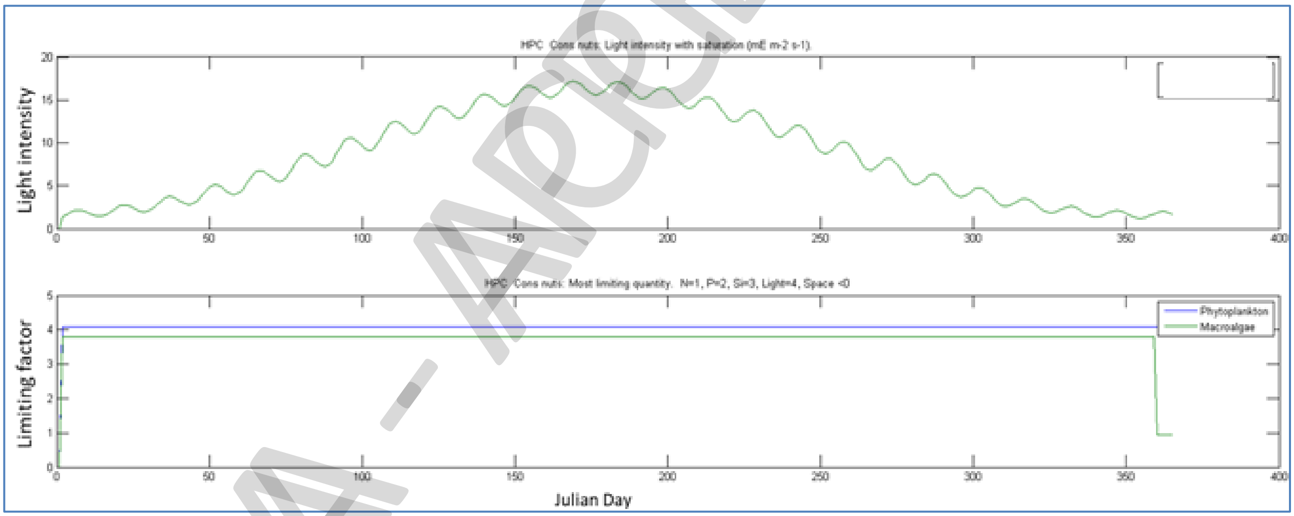


Figure 39: Limiting factors controlling phytoplankton growth, top figure is light intensity, bottom figure is the limiting parameter. Factor 4 'light' is the limiting factor for both phytoplankton and macroalgae.

F.4 Summary

The area of Bridgwater bay is severely light limited, and the available nutrients are not utilised. Therefore, the addition of more nutrients from the power-station has no effect on water column Phytoplankton production in the Bridgwater Bay area. Similarly, there is no predicted effect on the macroalgal production.

F.5 References

Aldridge, J.N., Trimmer, M. 2009. Modelling the distribution and growth of ‘problem’ green seaweed in the Medway Estuary, UK. Hydrobiologia. 629: 107-122.

Aldridge, J.N., Painting, S.J., Mills, D.K., Tett, P., Foden, J. and Winpenny. K. 2008. The Combined Phytoplankton and Macroalgae (CPM) Model: predicting the biological response to nutrient inputs in different types of estuaries in England and Wales. Report to the Environment Agency. CEFAS Contract C1882.

Devlin, M.J., Barry, J., Mills, D.K., Gowen, R.J., Foden, J., Sivyer, D., Tett, P. 2008. Estuarine, Coastal and Shelf Science 79, 429-439.

Cefas. 2003. Investigation of Factors Controlling the Presence of Macroalgae in some Estuaries of South East England. Cefas contract C1642 contract for the Environment Agency.

CSTT. 1994. Comprehensive studies for the purposes of Article 6 of DIR 91/271 EEC, the Urban Waste Water Treatment Directive. Published for the Comprehensive Studies Task Team of Group Coordinating Sea Disposal Monitoring by the Forth River Purification Board, Edinburgh.

APPENDIX C AMMONIACAL NITROGEN AND DIN DATA FOR OUTLET 12 EFFLUENTS

C.1 Groundwater and Tunnel Effluent data

	Ammoniacal Nitrogen as N (mg/l)			Sum of Dissolved Inorganic Nitrogen (mg/l)		
Date	**Outlet 1 - GW**	**Outlet 12-GW**	**Outlet 12-TE**	**Outlet 1 - GW**	**Outlet 12-GW**	**Outlet 12-TE**
23/03/2017	0.09			2.23		
24/03/2017	0.02			0.43		
25/03/2017	0.03			0.45		
26/03/2017	0.03			0.55		
27/03/2017	0.12			0.86		
28/03/2017	1.06			4.58		
01/04/2017	0.23			3.42		
02/04/2017	0.03			0.66		
03/04/2017	0.17			1.03		
04/04/2017	0.08			0.31		
05/04/2017	0.02			0.33		
06/04/2017	0.16			1.01		
07/04/2017	0.09			0.42		
08/04/2017	0.1			0.43		
09/04/2017	0.08			0.41		
10/04/2017	0.09			0.62		
11/04/2017	0.12			0.56		
12/04/2017	0.1			0.43		
13/04/2017	0.08			0.4		
19/04/2017	0.11			0.34		
26/04/2017	0.17			0.42		
27/04/2017	0.12			0.46		
03/05/2017	0.13			0.37		
10/05/2017	0.03			0.25		
12/05/2017	0.13			0.13		
18/05/2017	0.3			0.57		
24/05/2017	0.19			0.64		
25/05/2017	0.16			0.6		

	Ammoniacal Nitrogen as N (mg/l)			Sum of Dissolved Inorganic Nitrogen (mg/l)		
Date	Outlet 1 - GW	Outlet 12-GW	Outlet 12-TE	Outlet 1 - GW	Outlet 12-GW	Outlet 12-TE
01/06/2017	0.11			0.3		
08/06/2017	0.13			0.56		
15/06/2017	0.07			0.69		
29/06/2017	0.17			0.42		
13/07/2017	1.3			2.25		
27/07/2017	0.4			0.71		
10/08/2017	0.8			1.4		
24/08/2017	0.4			0.8		
14/09/2017	0.6			1.14		
28/09/2017	1.5			2.03		
12/10/2017	0.5			1.05		
26/10/2017	0.9			1.62		
09/11/2017	0.7			1.27		
24/11/2017	0.4			0.8		
07/12/2017	0.5			0.83		
14/12/2017	0.5			1		
21/12/2017	0.5			0.86		
11/01/2018	0.6			1.15		
25/01/2018	0.3			0.58		
08/02/2018	0.5			1.02		
22/02/2018	0.4			0.7		
08/03/2018	1.1			1.67		
09/03/2018	1.4			2.04		
22/03/2018	0.6			0.94		
12/04/2018	0.8			2.12		
26/04/2018	0.3			0.57		
10/05/2018	0.2			0.45		
11/05/2018	0.2			0.45		
24/05/2018	0.3			0.57		
14/06/2018	0.41			0.91		

	Ammoniacal Nitrogen as N (mg/l)			Sum of Dissolved Inorganic Nitrogen (mg/l)		
Date	**Outlet 1 - GW**	**Outlet 12-GW**	**Outlet 12-TE**	**Outlet 1 - GW**	**Outlet 12-GW**	**Outlet 12-TE**
28/06/2018	0.7			1.08		
12/07/2018	1.6			2.39		
26/07/2018	0.6			0.97		
09/08/2018	1.1			1.82		
23/08/2018	0.6			0.97		
13/09/2018	1.1			1.89		
27/09/2018	0.4			0.84		
11/10/2018	0.8			1.46		
25/10/2018	0.3			0.67		
08/11/2018	0.8			1.84		
21/11/2018		0.3			0.57	
13/12/2018		0.5			0.94	
10/01/2019		0.5			0.83	
26/01/2019		0.4			0.71	
27/01/2019		0.5			0.83	
28/01/2019		0.4			0.72	
29/01/2019		0.5			1.63	
30/01/2019		0.9			1.54	
31/01/2019		0.6			1.05	
01/02/2019		0.6			0.95	
02/02/2019		0.5			0.84	
03/02/2019		0.7			1.08	
04/02/2019		0.8			1.19	
05/02/2019		1			1.44	
06/02/2019		1.3			1.82	
07/02/2019		1.2			1.69	
08/02/2019		1.3			1.81	
09/02/2019		1.4			1.94	
10/02/2019		1.3			1.81	
11/02/2019		1.2			1.69	

	Ammoniacal Nitrogen as N (mg/l)			Sum of Dissolved Inorganic Nitrogen (mg/l)		
Date	**Outlet 1 - GW**	**Outlet 12-GW**	**Outlet 12-TE**	**Outlet 1 - GW**	**Outlet 12-GW**	**Outlet 12-TE**
12/02/2019		0.9			1.32	
14/02/2019		1			1.43	
14/03/2019		0.7			1.51	
11/04/2019		0.7			1.07	
09/05/2019		1.2			1.5	
13/06/2019		0.8			1.69	
11/07/2019		1			1.42	
18/07/2019		0.4			0.61	
25/07/2019		0.6			0.82	
01/08/2019		0.5			0.71	
08/08/2019		1.2			1.69	
15/08/2019		4			4.5	
22/08/2019		0.93			1.6	
29/08/2019		2.3			2.4	
05/09/2019		0.76			0.8	
12/09/2019		1.79			1.8	
19/09/2019		0.72			0.8	
26/09/2019		2.3			2.7	
03/10/2019		3.8			3.8	
10/10/2019		1.05			2.8	
17/10/2019		0.66			0.8	
24/10/2019		0.58			0.8	
31/10/2019		0.78			1.8	
07/11/2019		1.12			2.7	
14/11/2019		1.21			1.8	
21/11/2019		0.58			0.9	
28/11/2019		1.2			1.4	
05/12/2019		0.62			0.6	
12/12/2019		1.13			1.2	
19/12/2019		0.52			0.7	

	Ammoniacal Nitrogen as N (mg/l)			**Sum of Dissolved Inorganic Nitrogen (mg/l)**		
Date	**Outlet 1 - GW**	**Outlet 12-GW**	**Outlet 12-TE**	**Outlet 1 - GW**	**Outlet 12-GW**	**Outlet 12-TE**
27/12/2019		0.37			0.7	
02/01/2020		0.54			0.7	
09/01/2020		0.93			1.6	
16/01/2020		4.3			4.4	
23/01/2020		0.51			0.8	
30/01/2020		0.66			2.4	
13/02/2020		0.4	0.51		0.5	1.4
12/03/2020		0.53			0.7	
09/04/2020		0.54			0.6	
23/04/2020		0.5			0.6	
14/05/2020		0.55	1.2		0.7	2
11/06/2020		0.46			0.5	
18/06/2020			1			1.6
09/07/2020		0.44	1.2		0.4	1.2
16/07/2020			1.4			2.1
24/07/2020			0.36			1
30/07/2020			1			1.8
07/08/2020			0.61			0.6
13/08/2020		1.7	0.86		1.7	1.2
20/08/2020			1.9			2.1
27/08/2020			3			3
07/09/2020			1.2			1.7
10/09/2020		0.54			0.7	
11/09/2020			1.4			2
22/09/2020			1.2			1.6
01/10/2020			1.4			1.9
08/10/2020		0.42			0.5	
12/11/2020		0.59	0.75		0.6	1.1
01/12/2020		0.77	4.3		0.9	4.4
05/01/2021		0.48			0.6	

	Ammoniacal Nitrogen as N (mg/l)			Sum of Dissolved Inorganic Nitrogen (mg/l)		
Date	**Outlet 1 - GW**	**Outlet 12-GW**	**Outlet 12-TE**	**Outlet 1 - GW**	**Outlet 12-GW**	**Outlet 12-TE**
21/01/2021			0.47			1.4
02/02/2021		0.44			0.4	
16/02/2021			1.4			2.6
02/03/2021		1.3			1.3	
03/03/2021			1.7			2.8
24/03/2021			1.2			0
29/03/2021			0.12			0
06/04/2021		1	1.2		1	2.4
04/05/2021		0.57			0.6	
11/05/2021			1.2			2.4
18/05/2021			0.16			0
01/06/2021		0.59	1.8		0.8	2.1
15/06/2021		14.51			17.5	
29/06/2021		0.78			0.8	
06/07/2021		0.58	0.93		0.6	1.3
08/07/2021		0.45			0.7	
13/07/2021		0.51			0.5	
20/07/2021		0.594750563			0.5	
03/08/2021		1.4			1.4	
19/08/2021			0.12			1.1
07/09/2021		0.44	0.56		0.4	0.6
14/09/2021		0.45			0.5	
05/10/2021		1.5	0.16		1.5	1
02/11/2021		1.12	0.8		1.4	2.6
07/12/2021		0.6			0.8	
08/12/2021			1.1			1.8
04/01/2022		0.4	1.3		0.6	2.4
01/02/2022		0.4			0.4	
03/02/2022			2.3			2.5
01/03/2022		0.4			0.6	

	Ammoniacal Nitrogen as N (mg/l)			Sum of Dissolved Inorganic Nitrogen (mg/l)		
Date	**Outlet 1 - GW**	**Outlet 12-GW**	**Outlet 12-TE**	**Outlet 1 - GW**	**Outlet 12-GW**	**Outlet 12-TE**
09/03/2022			1.2			2.3
04/04/2022		0.3			0.5	
07/04/2022			0.09			0.89
03/05/2022		0.3			0.5	
11/05/2022			16.5			17.1
07/06/2022		0.4			0.6	
08/06/2022			0.6			2
05/07/2022		0.6	5.2		0.5	2.8
01/08/2022		0.4			0.9	
02/08/2022			1.4			1.9
06/09/2022		0.3			0.6	
07/09/2022			6			6.8
04/10/2022		0.8	14		1.6	15.6
01/11/2022		0.3	5.4		0.5	6.3
06/12/2022		0.6	13.2		1	17.8
03/01/2023		0.3			0.5	
04/01/2023			4.3			9.3
17/01/2023			4.8			8.4
24/01/2023			2.9			11.5
01/02/2023			5.5			9.7
07/02/2023		0.4	2.8		0.6	10.8
14/02/2023			0.3			0.5
21/02/2023			1.7			2
28/02/2023			1.8			11.1
07/03/2023		0.3	1.5		0.5	10.7
14/03/2023			3.2			10.4
22/03/2023			1.4			10.8
28/03/2023			3.1			11.3
04/04/2023		0.3	1.5		0.7	10.3
02/05/2023		0.3	0.8		0.5	10

C.2 CSTP data

Date Sampled	Ammoniacal nitrogen mg/l N
06/09/2022 11:34	7.85
20/09/2022 08:40	<0.2
27/09/2022 10:06	<0.200
04/11/2022 09:36	10.93
09/11/2022 10:24	16.83
11/11/2022 08:07	14.37
15/11/2022 11:28	0.25
17/11/2022 07:58	9.99
21/11/2022 08:10	<0.2
24/11/2022 11:33	16.63
28/11/2022 11:04	<0.2
02/12/2022 09:25	31.78
09/12/2022 11:05	25.10
12/12/2022 11:24	0.36
14/12/2022 12:12	9.38
19/12/2022 10:23	<0.2
21/12/2022 09:12	<0.2
23/12/2022 07:33	<0.2
19/01/2023 10:32	15.63
01/02/2023 10:22	21.97
14/02/2023 11:11	1.04
27/02/2023 09:33	<0.2
07/03/2023 11:15	12.28
11/04/2023 11:44	<0.2
22/04/2023 09:08	12.79

APPENDIX D MODELLING AND CALCUATION FILES

(Provided sepearately)