Response to Environment Agency feedback (dated 17/09/2020) on the Port Clarence ESC

This document provides a response to feedback from the Environment Agency dated 17/09/2020 and entitled “Environmental safety case for disposal of low activity low level waste at the Port Clarence landfill sites: feedback from the Environment Agency”.

The structure mirrors Sections 1 to 15 of the Appendix entitled “Detailed Review Comments on the Environmental Safety Case for Disposal of Low Activity Low Level Waste at the Port Clarence Landfill Sites” that contain the detailed Schedule 5 review comments produced by the Environment Agency (a request for further information).

There has been subsequent correspondence with the Environment Agency on key issues and this is referenced appropriately as necessary. The feedback paragraph numbers are used where possible, and bullets are given sub-paragraph numbers. To avoid confusion, within document cross-referencing refers to “Item x” to locate response paragraphs that consider similar issues.

The main summary comments raised at the start of the Schedule (Environment Agency comments are highlighted in green in this document) are discussed under Section 0 below and cross referenced as appropriate to our detailed responses in subsequent sections. We note that the UK Health Security Agency (UKHSA) has assumed the duties of Public Health England (PHE) in April 2021 and this document therefore references both organisations.

Contents

0 Feedback statement and summary

The activity concentrations requested in the application are higher than those permitted for disposal at other low level waste (LLW) landfills, and reach the upper LLW activity concentration limit for small volumes of some radionuclides. The depth of the case presented in the ESC is equivalent to that we would expect for a low activity LLW disposal facility. We expect an ESC to be proportionate to the hazard presented by the waste. We have identified a number of areas in which further assessment is required to demonstrate the acceptability of Augean Plc's proposals.

In determining the activity concentrations proposed in the ESC, we have explicitly considered the hazard presented by the waste. Our proposal to include radionuclide specific activity concentrations in the permit was developed using a range of scenarios where an activity concentration could be meaningfully calculated. We also included the limits proposed by the NEA Paris Convention on Third Party Liability (again based on hazard) and the UK definition of LLW when determining the set of values. For each radionuclide we then used the minimum value from this set of values in order to assign each radionuclide to one of six bands ranging from a minimum of 100 Bq/g to 10,000 Bq/g on a greater than or equal to basis.

It needs to be stressed that the reason the activity concentrations for some radionuclides reach the upper activity concentration limit of LLW is because, fundamentally, they are less hazardous. The arbitrary UK definition of LLW is not proportionate to the hazard presented by different radionuclides, other than differentiating alpha emitting radionuclides from others.

The use of 200 Bq/g adopted at some landfill sites also bears no relationship to the relative hazard presented by different radionuclides and is not therefore proportionate to the hazard presented by the waste. Arbitrarily limiting all disposed concentrations to a single value bears very little relationship to relative hazards. We would also argue that the safety case presented in the ESC is considerably more detailed than has been accepted for sites operated by other companies that have been granted a 200 Bq/g activity limit. Nevertheless, the maximum consignment activity concentration for any radionuclide will be capped at 2,000 Bq/g in the updated version of the ESC (see Item 26).

The ESC makes the case that operations and operational doses at the Port Clarence landfills will be similar to those at the East Northants Resource Management Facility. However, this assumption is only valid in the situation of both landfills receiving similar inventories. The higher limits proposed for the Port Clarence landfills do not provide reassurance that this will be the case.

In the ESC this statement was made in the context of worker doses during site operations and is addressed below in Section 10.2. The statement is valid because the operational doses received by a worker on-site will be determined by the surface dose rate of waste packages and this dose rate is constrained to 10 µSv h^{-1} (2 µSv h^{-1} after burial) at both sites providing an upper bound to worker doses. Whilst the ESC proposed higher limiting activity concentrations for some radionuclides at Port Clarence compared to the ENRMF, the potential radiological capacity of some radionuclides is lower at Port Clarence than at the ENRMF. The hazard presented by the waste in this instance is limited by the surface dose rate acceptance criteria and not by the activity concentrations disposed or final inventory.

We note that the exposure of workers is controlled under the Ionising Radiation Regulations (2017) and that the cautious assessment calculations performed for the ESC ignore the ALARA precautions implemented on site (waste handling only using machines, workplace monitoring etc). Personal dosimetry of workers at the ENRMF has never recorded a dose above background levels.

The ESC presents insufficient evidence to support the assessment of future coastal change. Without a more detailed assessment of the evolution of the coast/estuary, we consider that it is not possible to make a case for erosion not occurring in the next few 100 years.

There has been considerable correspondence concerning this statement. External independent review of the feedback from the Environment Agency coastal and estuarine specialists made clear that the available estuarine modelling tools do not offer projections beyond 100 years with any certainty that could inform the radiological risk assessments and over that timescale the tools are generally used to consider the range of possible outcomes within an estuary rather than providing a best estimate. After discussions with the Environment Agency, it was agreed that although a date for erosion is unknown an inventory calculated at the end of the period of authorisation should be used, as this was the only date that would be accepted by the Environment Agency without further detailed specialist modelling of the evolution of the estuary. The final correspondence from the Environment Agency reported on a site visit by their coastal and estuarine specialists (16th December 2021).

For the radiological assessment we need to know the earliest date, and at what rate, the landfill mass is eroded. However, it has become clear that the approach of Environment Agency coastal and estuarine specialists to modelling is fundamentally different to that accepted for the assessment of radiological risk. We have therefore concluded that an acceptable answer to the question of when erosion could occur and at what rate is unlikely to be generated and the prospect of reaching a consensus based on coastal/estuarine modelling tools appears remote.

We have therefore agreed to adopt the extremely cautious assumption that the inventory that is eroded will be calculated at the end of the period of authorisation. We then considered some of the other very cautious assumptions used in the radiological assessment and this has led to changes in the value adopted for some of the assessment parameters as detailed in the responses below (see Section 6).

There remains the potential for flooding of the north-western part of the site in the event of extreme weather conditions / storm surge. The ESC does not consider the impacts of such an event in sufficient detail.

There has been further correspondence on the conceptual model for flooding and a new model produced that will be described in full in the revised ESC. Our approach is summarised in Appendix C.

We are concerned that the conceptualisation of the bathtubbing scenario is not conservative, and we consider that it is likely to occur during the post-closure period. The results of the post-closure bathtubbing scenario should be used to constrain the radiological capacity of the site.

There has been further correspondence on the conceptual model for bathtubbing/seepage and a new model produced that will be described in full in the revised ESC. The revised assessment considers multiple events and will be included as a candidate scenario for limiting radiological capacity. Our approach is summarised in Appendix D.

Augean Plc needs to carry out a more detailed assessment of impacts associated with C-14, in particular relating to its release from activated metallic waste, in order to justify the proposed C-14 activity concentrations and radiological capacity.

This was the approach taken in the ESC, see paragraph 635 of the ESC that references the LLWR work on this topic. Therefore, no further assessment will be performed.

Augean Plc should update its assumptions on inadvertent human intrusion to remove any reliance on future human actions to restrict intrusion after surrender of the environmental permit. It should also assess a new scenario involving intrusion into the eroding landfill.

This is a misunderstanding of our assessment: the inadvertent intrusion scenarios were not reliant on future human actions to restrict intrusion. The Environment Agency has provided further guidance on the type of intrusion scenario for the eroding landfill and these new scenarios will be included in the revised ESC (see Item 40.5).

The proposed discrete item activity concentration limits exceed the upper boundary of LLW for some radionuclides.

Augean will make an explicit statement in the revised ESC that no waste above LLW will be accepted for disposal and this is also part of the site procedures. The proposed limits are used in a sum of fractions approach for each radionuclide and the total activity concentration is then compared to the overall LLW limit. The use of constrained upper limits per nuclide introduces an arbitrary cap on disposals that is not consistent with a risk-based approach, hence the risk would be capped at a value lower than that stated in the NS-GRA for certain fingerprints. See Section 10.4 for further discussion.

Augean Plc proposes a complex method for the management of radiological capacity. We have concerns that consignors will struggle to understand the proposed waste acceptance criteria, leading to an increased chance of misconsignment. Augean Plc will need to demonstrate that it has the technical capability to manage capacity in an appropriate manner and to liaise with potential consigners to ensure that disposed waste meets the waste acceptance criteria and is consistent with the ESC.

The procedures that will apply to Port Clarence management of LLW are provided with this response. See Section 4 for further discussion.

We consider that Augean Plc has not demonstrated that the Port Clarence Landfill provides an optimised approach for the disposal of all LLW streams covered by the permit application, and that the landfill engineering and management procedures are optimised to ensure that impacts are as low as reasonably achievable. In addition, we do not consider that Augean Plc has suitably demonstrated that the proposed waste forms and packaging represents application of best available techniques.

This comment is more appropriate for a bespoke radwaste repository than a landfill since the landfill is engineered to meet Landfill Directive standards. Management procedures are ALARP under IRRs.

Augean's approach to the handling and disposal of LLW builds on the experience we have gained performing this work at our ENRMF site over the last decade. The processes for acceptance, checking and disposal of the waste have been optimised by taking the learning from ENRMF and applying this to the Port Clarence site and the small variations in waste types expected. These processes are captured in our Management Procedures.

Regarding the waste forms and packaging Augean work with our clients to ensure that the waste can be safely handled during disposal operations, but the waste producers have a requirement to show that Best Available Techniques (BAT) have been used in the generation and packaging of the waste. Augean request copies of BAT Assessments for all wastes.

Disposal is not generally considered BAT if a suitable reuse, recycling or treatment option is available. For example, surface contaminated metallic waste is decontaminated with the bulk of the metal being recycled and only the surface coatings and radioactive contamination being disposed at Augean sites. Whilst the exact composition of the waste that will be disposed of is unknown all waste generators are required to show that their chosen disposal option is BAT.

The packages used will typically have to meet the requirements of Class 7 Transport under ADR Regulations. Note that some lower activity waste may be Exempt from Class 7 due to the low activity. Waste packages that are suitable for road transport as Class 7 are robust and will have been loaded onto the vehicle using some form of fork-lift vehicle. Augean would replicate this process in reverse when offloading the waste for disposal. Waste packages that are suitable for transport on the public roads are suitable for transport the short distance on Augean landfill sites. Augean would review all proposed packages in the form of a Package Handling Assessment to ensure that they can be handled safely on our sites.

Optimisation is discussed further in Section 14.

Augean Plc should provide additional detail on its proposed environmental monitoring programme. This should include details of proposed levels that would trigger further investigation if exceeded.

Details will be provided in the revised ESC along with the approach used for further investigations. Four draft documents are provided separately for Port Clarence describing the monitoring and action plans for groundwater, leachate, landfill gas and particulates and asbestos (Port Clarence Groundwater MAP LLW 2022_draft.pdf, Port Clarence Landfill Gas MAP LLW 2022_draft.pdf, Port Clarence Leachate MAP LLW 2022_draft.pdf, Port Clarence Particulates Asbestos MAP LLW 2022_draft.pdf).

Augean Plc will need to submit an updated Leachate Management Plan should future off-site treatment of leachate be problematic due to its radioactivity, to demonstrate that it can effectively manage its leachate from LLW disposals.

Accepted. The Leachate Management Plan will be updated and submitted should the leachate monitoring demonstrate that off-site treatment of leachate will be problematic, evidence from ENRMF monitoring indicates that this will not be an issue.

The Environment Agency's National Permitting Service is reviewing the 2019 hydrogeological risk assessment (HRA) for the Port Clarence Landfill, and may make a separate further information request as part of that review. This is a key supporting reference to the ESC and we will be unable to make a determination on the ESC application until we are satisfied that the HRA meets our requirements. Should we identify any deficiencies in the HRA that affect the ESC then we will need to make an additional further information request.

Accepted. The HRA was submitted to the Agency as part of variations to the landfill permits that were approved in December 2020 (see Appendix H - HRA AU_PCg24423.pdf supplied with this submission).

We have identified a number of errors in the data and equations supporting the ESC assessments, which have lowered our confidence in the overall assessment. Augean Plc should carry out a thorough quality assurance check to avoid similar issues with resubmitted information.

A thorough check will be undertaken. Our assessment of the typographical errors identified indicate they do not impact our calculations. We have also updated some parameters values to achieve greater consistency between scenario assessments. All parameters will be re-checked before the ESC is re-issued.

1 Introduction

The detailed review comments are contained in an Appendix to the letter of 17/09/2020 and are sequentially numbered. For clarity where a paragraph provides an Environment Agency position statement, or statement of fact, that does not appear to require a response or does not impact the approach used in the ESC we state “Accepted”.

1. The ESC supports an application by the operator (Augean Plc) to the Environment Agency under the Environmental Permitting Regulations 2016 (EPR16) for a radioactive substance activity permit for the burial of low level waste (LLW) at the Port Clarence landfill sites. The ESC has been prepared by a contractor, Eden Nuclear and Environment, on behalf of Augean Plc.

Accepted.

2. The Port Clarence landfill sites comprise 2 adjacent, but separately engineered, landfills that are currently permitted for the disposal of hazardous waste and non-hazardous waste, and a waste treatment facility. The landfills currently accepts naturally occurring radioactive material (NORM) up to an activity concentration limit of 10 Bq/g under an exemption.

Accepted.

3. We have reviewed the ESC, focussing on whether the ESC meets the requirements of the Guidance on Requirements for Authorisation of near-surface disposal facilities for solid radioactive waste (GRA). Throughout our review, we have been mindful of the expectation that the developer should adopt “an approach to each requirement that is proportionate to the level of hazard presented by the inventory of waste for disposal in the facility”.

This is the approach that we expected the Environment Agency to follow. The comments provided by the Environment Agency that we respond to below indicate that there may be a disparity between the view of the developer and the Environment Agency concerning the proportionality of the assessment to the hazard presented by the concentration of different radionuclides in waste. Nevertheless, we have suggested capping the maximum activity concentration at 2000 Bq/g for some radionuclides (see Section 7).

4. We provide review comments on the ESC in the following sections. In our review, we have considered both the submitted ESC and responses to the public consultation on the application. In the following sections, we raise a number of issues on which we require additional information or assessment in order for us to make a decision on the permit application. We have used our best endeavours to provide comprehensive advice at this stage of the application process. However, due to the complexity of the proposals and the substantial further information request outlined in this notice, we may need to request additional information subsequently.

Accepted.

5. In the final section of this appendix, we provide detailed comments on some of the data and calculations used in the radiological assessment. These comments include feedback from Public Health England that we received during the consultation on the permit application.

Accepted.

2 Pre-application process

6. GRA Requirement R1 (Process by agreement) recognises the benefit of early dialogue between the developer and Environment Agency and notes that we expect the developer to set up a voluntary agreement with us to provide advice and assistance in the preapplication stage. Although Augean Plc has engaged with us in this manner during the preparation of the Port Clarence landfills permit application, we consider that having had a better understanding of the nature of the waste Augean Plc intended to apply for would have helped us plan our engagement better and to appropriately tailor our pre-application advice.

Accepted, noting that the nature of the waste was a direct outcome of the risk-based approach to the derivation of radionuclide activity limits based as discussed with the Environment Agency.

7. Augean Plc has communicated widely with a variety of stakeholders. However, it did leave some of the communications, mainly with members of the public and councillors, until after the permit application had been submitted. We suggest that earlier dialogue with the planning authority, local community, other interested parties and the general public on the developing ESC would have better met our expectations under GRA Requirement R2 (Dialogue with local communities and others).

A summary of the public and councillor engagement undertaken in relation to Port Clarence is provided in Appendix A. We believe this clearly demonstrates that early dialogue was undertaken with the relevant bodies at an appropriate time.

3 ESC document and structure

8. The ESC document covers the main issues that we would expect the ESC to consider, including the GRA Requirements. However, due to its length and level of detail, there are places where it could benefit from more clarity, for example:

The same structure has been used in the ENRMF ESC submitted in 2015 to the Environment Agency and the Port Clarence ESC is of a similar length and level of detail.

The following bullet points in the Environment Agency feedback are assigned a sub-level number for ease of further reference.

8.1 It would be advisable to add a few pages which summarise the case in nontechnical terms, including limitation of radioactivity by radiological capacity management and setting activity concentration limits. The current executive summary does not do this.

The current executive summary will be updated to provide a non-technical summary when the ESC is re-issued taking account of Environment Agency comments.

8.2 The executive summary concludes that the dose constraint from a single source used in the safety case is 0.3 mSv per annum for a member of the public. We assume that the source referred to is the entire Port Clarence landfill site as indicated in paragraph 189, however this is not explicitly stated, and reassurance is sought.

The Executive Summary stated that the disposal of LLW at Port Clarence would give rise to negligible impacts within the dose constraints specified by the Environment Agency. We can confirm that we have applied 0.3 mSv per annum to the entire landfill site (i.e., the non-hazardous and hazardous landfill sites are considered as a single source). This is evident from each of the ESC assessments where the value of the dose constraint applied is always stated explicitly.

Prior to paragraph 189 the ESC referred to the “landfills”. When the ESC is reissued, we will make it clear that the single source constraint relates to the combined landfills on the site.

A revised Executive Summary will present the safety arguments and detail how the site radiological capacity management and activity concentration limits ensure that disposals do not have an impact in the wider environment now or in the future.

8.3 The ESC would benefit from the presentation of clear safety arguments. In particular, the case would benefit from clearer presentation of the main safety claims, and supporting arguments and evidence, to make the case for environmental safety. In particular, this should cover how the landfill concept, including the barriers, along with site procedures, inventory control and optimisation, result in a system that provides environmental safety during both the operational and post-closure periods, and that impacts will be below regulatory criteria and are as low as reasonably achievable (ALARA). It should also consider significant uncertainties, and how they can be managed. This could also be used in a qualitative, non-technical summary of the ESC, which would have been useful to support stakeholder engagement. Conceptual illustrations would also help the presentation, in particular to illustrate concepts such as coastal erosion and bathtubbing.

The ESC already contains a concise and clear statement of the safety arguments. However, we will ensure each topic area listed above is addressed specifically and appropriately cross-referenced to evidence when the ESC is re-issued. Further explanation of the query was provided by the Environment Agency (C Lean; 7th July 2020):

"*However, the case would benefit from clearer presentation of the main safety claims, and supporting arguments and evidence, to make the case for environmental safety. In particular, this should cover how the landfill concept, including the barriers, along with site procedures, inventory control and optimisation, result in a system that provides environmental safety during both the operational and post-closure periods, and that impacts will be below regulatory criteria and are ALARA. It should also consider significant uncertainties, and how they can be managed. This could also be used in a qualitative, non-technical summary of the ESC, which would have been useful to support stakeholder engagement. Conceptual illustrations would also help the presentation, in particular to illustrate concepts such as coastal erosion and bathtubbing.*"

We have reviewed a number of conceptual illustrations and do not consider that they are beneficial in an ESC, largely because they do not assist a fundamental technical understanding and are not a requirement in our view. We disagree that they could have a place in a non-technical summary and believe conceptual illustrations have limited use in stakeholder engagement based on our experience. We will provide simple figures for bathtubbing and flooding of the type presented in Appendix D.

8.4 The main body of the ESC is difficult to digest in places without cross-reference to other parts of the ESC, in particular the detailed Appendix E. For example, the 'sum of fractions' approach is mentioned in numerous places in the ESC without further explanation before it is described in Section 7.4.2.1. An index for Appendix E would be useful for navigating the assessment sections.

The revised ESC will introduce the "sum of fractions" methodology in Section 1. To aid navigation of the ESC a table of contents will also be generated for Appendices B, D and E in the revised ESC. The glossary (Appendix A) and Augean policy statements (Appendix C) will not be provided with a table of contents.

8.5 The ESC would benefit from a clear summary of the proposed waste acceptance criteria relating to the management of the radioactive content (activity concentration / radiological capacity) of the proposed disposals and a clearer explanation of how they are to be used and applied in practice. The proposed limits are given in Tables 33, 34 and 35. Suggested capacities for the hazardous and non-hazardous landfills are provided but the supporting text does not make it easy for an informed reader to understand how they are to be used; for example, unlike ENFMF, a single limiting capacity is not being defined for each radionuclide. Requirement R13 of the GRA states that "the developer/operator of a disposal facility for solid radioactive waste should establish waste acceptance criteria consistent with the assumptions made in the environmental safety case and with the requirements for transport and handling, and demonstrate that these can be applied during operations at the facility."

The exact details of waste acceptance criteria would normally be prepared after issue of the permit or draft permit when it is clear what the Environment Agency accepts for disposal at the site. To clarify, the proposed limits for activity concentrations in packaged waste are presented in Table 32 and in loose tipped waste in Table 33 of the ESC. The proposed radiological capacities for the hazardous landfill are presented in Table 34 and for the non-hazardous landfill in Table 35 of the ESC.

Early discussions with the Environment Agency determined that the two landfills would operate under the same permit for LLW disposal. However, the conditions and types of waste accepted at the two landfills are different and therefore a single limiting radiological capacity for each radionuclide is not appropriate: each nuclide has two radiological capacities, one for each landfill. For example, landfill gas generated in the non-hazardous landfill is collected and used on site for power generation releasing carbon and hydrogen to atmosphere and representing a future pathway for the release of C-14 and H-3. There is also a low risk of waste catching fire in the non-hazardous landfill due to higher organic matter content that will not be disposed to the hazardous waste landfill due to the restrictions placed on disposal of waste organic matter content. These two scenarios are relevant for the non-hazardous site but not relevant to the hazardous site. It is therefore appropriate to calculate the sum of fractions separately for each landfill before combining them into a total sum of fractions for the two landfills together.

For the other scenarios used to limit radiological capacity in the ESC there is little difference between the impact of the scenario for the two landfills. For example, the radiological capacity determined for an excavator 60 years after closure is not sensitive to the type of landfill and it can be assumed that the radiological capacity for this scenario applies to the site. We have therefore used a radiological capacity for each landfill and stipulated that the sum of fractions for a specific scenario when added together for both landfills must not exceed 1.

We have chosen to limit the LLW disposals by specifying radiological capacities for a set of scenarios for each nuclide, rather than a single capacity for each nuclide. This is because we have 2 landfills and different scenarios produce limits for different timescales: for example, C-14 might be limited by exposure immediately after site closure, and Th-230 by erosion of the site when sea level rise impacts disposed waste. In this way we avoid over-conservatism and optimise use of the site. For example: using a single set of radiological capacities, the sum of fractions for a 1 TBq disposal each of C-14 and Th-230 is 0.7, whereas applying the scenarios separately the sum of fractions immediately after closure is 0.19 and at the time of erosion it is 0.51. The scheme is straightforward to apply using a spreadsheet.

We provide a spreadsheet for review (Monitoring Tool Blank +examples (draft).xlsx), it is very similar to that used at the ENRMF to monitor the sum of fractions for cumulative disposals. We will explain more clearly in sections 7.4 and 1.5 of the revised ESC how the scenario limits are used in practice. The site procedures are provided (with this feedback) that cover pre-acceptance review of waste consignments and conditions for acceptance of consignments at the site (see Item 9).

We believe our approach is consistent with the environmental safety case and with the requirements for transport and handling of waste.

8.6 The ESC discusses management of parameter and scenario uncertainty in the dose and risk assessment in Appendix E. Augean Plc does not consider conceptual model uncertainty explicitly, stating that this is addressed by adopting a generally conservative approach to defining pathways and uptake routes (paragraph 1250). It does not systematically identify the major sources of uncertainty in the ESC, and their potential implications. This is contrary to our expectations as set out in the GRA, requiring the developer/operator to identify all uncertainties that have a significant effect on the ESC and establishing and maintaining a clear forward strategy for managing them (paragraph 7.3.10).

We have now systematically considered the major sources of uncertainty in the ESC, have noted their potential implications and provide our strategy for managing the significant uncertainties. A structured list of these major uncertainties and proposed treatment is presented in Appendix B and this will be included in the revised ESC.

The list of the major sources of uncertainty is divided into four themes: landfill engineering; properties of the waste; pathways and receptors; and, site evolution.

8.7 The use of precise dates, for example, the year 4560 for the earliest onset of coastal erosion, may give the reader a false impression about the accuracy of the estimate. When stating dates, Augean Plc should clearly state whether they are AD or after present / site closure.

For any analysis involving radioactivity a date is always required and, in all cases, we round to tens of years which seemed appropriate for the range of timescales considered. We will add text concerning the uncertainty of projected dates for the onset of significant events.

We will adopt the Common Era (CE) notation for all years used in the ESC and relate all elapsed time periods to a reference point (e.g., after present, after site closure, after capping, after restoration, after the POA). For month year (October 2000) or day month year (12^{th} October 2000) references the CE notation will be omitted.

8.8 Augean Plc does not discuss how it will manage the ESC. We expect the ESC to be kept as a 'live' document. In order to do this, Augean Plc will need to review the effect of changes in operations or site information on the ESC and determine when significant changes will trigger an update to the ESC.

Paragraph 496 of the ESC briefly addresses this by stating *"The ESC will be subject to periodic review. It is suggested that this is undertaken every 10 years. However, should any new information arise that affects the assumptions supporting the ESC, or monitoring results indicate that the assessments could be challenged, a review would be initiated."*

A section will be added to describe how corporate governance works at the Augean landfill sites. Any operational procedure changes and monitoring reports require sign off by the Corporate Stewardship Director, this ensures that any changes in procedure, new information and monitoring results that may affect the conclusions of the ESC are reviewed.

Some of the key aspects that may trigger an update of the Port Clarence ESC are:

- new climate change predictions;
- a change in commercial waste availability;
- a change to landfill design during construction and operation of the facility; or,
- changes to parameter recommendations.

4 Site management

Management and procedures

9. Management requirements are described in Section 5 of the ESC. Augean proposes to implement 9 new procedures plus a radiation protection plan and risk assessment, and an emergency plan for LLW disposal operations (paragraphs 176-7). Although Augean Plc has experience managing radioactive waste disposal at the East Northants Resource Management Facility (ENRMF), procedures would be more complex at the Port Clarence landfills due to the greater range of waste packages proposed, plus loose tipped waste, and a more complex approach to capacity management due to differing capacities for the hazardous and non-hazardous parts of the landfill and for packaged and loose tipped waste, as well as the need to account for NORM. We will wish to review updated procedures that relate to the disposal of LLW prior to any permit issue to make sure that they are fit-for purpose and clear and transparent and that Augean Plc has suitably qualified and experienced technical support in order to assess the disposability of candidate waste streams and to manage radioactive waste disposals.

The site management and procedures reflect the wide range of activities that the company undertakes and many relate to very specific activities and are relevant to only a few members of staff. This is normal and established practice. The draft procedures for LLW management at Port Clarence have been prepared, cover the different types of waste to be received and are provided in the following documents accompanying this response:

- Conditions for acceptance of solid low level radioactive waste (PC LLW01);
- Pre-acceptance of low level radioactive waste (PC LLW02);
- Acceptance of low level waste to landfill (PC LLW03);
- Quarantine of low level radioactive waste – landfill (PC LLW04);
- Use of Personal Dosemeters (PC LLW05).
- Local Rules – Ionising Radiations Regulations (PC LLW07);
- Return of empty radioactive waste containers (PC LLW08); and,
- Emergency plan – Port Clarence (PC01).

Comments on competency are provided in response to Item 10 below.

A draft spreadsheet (Monitoring Tool Blank +examples (draft).xlsx) is also provided with this response that will be used to manage the radiological capacity of the Port Clarence site. This spreadsheet checks the cumulative inventory against the capacity constraining scenarios relating to each landfill at the site, i.e., taking account of the hazardous and non-hazardous parts of the landfill. The spreadsheet is similar to that used at the ENRMF over the last 10 years. The Port Clarence version also provides a check on the activity concentrations of each radionuclide in a consignment. Further checks on activity concentrations in a consignment (loose or comprising packages) and constituent packages would be undertaken as part of the pre-acceptance review undertaken before wastes are delivered to the site.

The capacity and activity concentrations will be finalised when the permit is issued.

10. Paragraph 176 states that Augean Plc employs a qualified Radioactive Waste Advisor (RWA) and a specialist Technical Assessor qualified as a Radiation Protection Supervisor (RPS), who are supported by consultants. While this is not uncommon practice, we expect Augean Plc to provide assurance as to how it will maintain an 'Intelligent Customer' role for the site, for example relating to succession planning and availability of advice when key staff members are unavailable, given that the RWA and RPS capability appear to be held by singletons.

The intelligent customer role is maintained through a team with defined roles and responsibilities, and each role has a nominated deputy. Technical support and expertise are provided by Corporate Stewardship specifically the Health Safety and Environment Managers (HSEQ Managers) who deal with Permitting issues and legislative compliance, the monitoring team that monitors the environmental impact of the site in all media and the site chemists who provide laboratory facilities and determine the suitability of waste for acceptance at the site. The HSEQ Managers undertake regular inspections of the site including compliance with Environmental and Radiological Permits. Periodic audits of procedures are undertaken in accordance with the IMS the frequency of which is determined on a risk basis. The HSEQ Managers report all inspections to the Director of Corporate Stewardship who is a member of the Management Board and advises the Board on health and safety and environment issues. All HSEQ Managers have received radiological training relevant to the operation of the Augean sites and are qualified RPSs. The ENRMF Site employs four RPS on site who ensure that all operations are in line with the Local Rules as written by our Radiation Protection Advisor.

Augean employs a dedicated Technical Assessment Team providing a centralised service to the business. The team currently comprises three experienced professionals and one graduate trainee. The purpose of this team is to assess waste streams, determine how the waste can be managed in accordance with the waste hierarchy and the suitability of the waste for acceptance at a specified site. The team tracks and monitors waste inputs, including radiological capacity, to site through computer software. The role of Technical Assessor is to collate waste characterisation information and undertake the initial chemical and radiological evaluation of the suitability of waste for disposal at the site. The assessment team is independent of the operational team and is based at the Company Headquarters at Wetherby. The final approval for booking of the waste to the site is given by the Site Manager. The process for acceptance of waste is set out in the Pre-acceptance and Acceptance procedures.

Paragraphs 175 and 176 of the ESC indicate that HSEQ Managers and Technical Assessors are not roles occupied by singletons.

We would actually prefer not to specify within the ESC the exact number of staff involved in these roles, instead stating that all roles have nominated deputies and the teams are capable of undertaking the "Intelligent Customer" role. Defined roles and responsibilities include the following:

- Radiation Protection Advisor (UKHSA),
- Radioactive Waste Advisor (UKHSA),
- Radiation Protection Supervisor (HSEQ Managers), and,
- Dangerous Goods Safety Advisor (Class 7).

11. The ESC assumes 50 years of disposal operations followed by a 60 year period of post-operation active management. We understand that the existing financial provisions for the landfill will not be altered as a result of this application. We will not allow surrender of the RSR disposal permit until we are satisfied that the landfill is passively safe and that, where future generations could be affected, they are afforded the same level of protection as that applied at the time of surrender. This may require a substantially longer period than 60 years. Augean Plc should make sure that it has the finances and procedures in place for management of the site over these timescales.

Accepted.

12. The ESC does not provide any information about enhanced security procedures for receipt of LLW. We expect this to be considered by Augean. For example, the site is not fully fenced around its entire perimeter and we have heard anecdotal evidence of trespassing (for example, the use of the landfill as a bike track). Landfill sector guidance states that operators should provide perimeter fencing and gates to prevent unauthorised access as far as practicable. We expect the perimeter fencing to be extended around the entire site, and adequate security monitoring and maintenance regimes put in place to prevent any uncontrolled access to the site or the disposed wastes.

Augean has not been requested by the Environment Agency to fence the boundary of the site. Security is managed on a risk-based approach which has been accepted historically.

Unless LLW is quarantined, at no point in the handling of LLW on site is the material left without a member of Augean staff or a driver. The material is immediately covered following disposal. Critical areas where LLW is managed such as the quarantine area will be suitably secured.

The revised activity concentration limits that will be proposed in the revised ESC are now less than 2000 Bq g^{-1} and many waste fingerprints will results in maximum disposals of less than 200 Bq g^{-1}. Augean do not therefore propose using enhanced security arrangements.

We note that question 12 was split over a page in the PDF file provided and included paragraph number 13 mid-question. The numbering below continues to follow the sequence used by the Environment Agency and therefore starts at 14.

Management of disposals

14. Radioactive waste will not be segregated from non-radioactive waste, however, radioactive waste containing hazardous waste will not be disposed in the non-hazardous waste landfill (paragraph 33). As radioactive waste is not subject to routine leachate testing, how will Augean Plc determine the hazardous content of the radioactive waste, or will it rely on consigners to appropriately determine the best route? In the case of the latter, how will Augean Plc check and assure itself of consigner assumptions? Similarly, how will Augean Plc monitor the total organic carbon content of disposals to make sure wastes are consistent with ESC assumptions and are disposed of to the appropriate part of the landfill? Augean Plc should clarify these points.

Augean requires full characterisation and waste acceptance assessment in accordance with the Environmental Permitting Regulations (UK Government SI, 2016) and waste classification technical guidance (Environment Agencies, 2021) for all radioactive wastes accepted for landfill.

The Conditions for Acceptance (CFA) that will apply at Port Clarence will specify that the consignor must discuss with Augean the requirement for leaching tests and other tests to demonstrate compliance with waste acceptance criteria, prior to preparing the consignment for shipment. The characterisation methodology of the waste and the results must be provided in a Waste Characterisation Document/Report. The leaching test must be undertaken in accordance with BS EN 12457-2. Testing for organic matter content may use either Loss on Ignition (LOI) or Total Organic Carbon (TOC). Therefore, Augean will have a full analysis as with any other hazardous waste (including organic content).

A complete set of Port Clarence LLW draft procedures has been provided to the Environment Agency along with this response (see list under Item 9).

15. Augean Plc proposes an emplacement strategy to require wastes containing “significant radium contamination” (> 5 Bq/g of Ra-226) to be disposed of below 5 m of the restored landfill surface to mitigate against impacts associated with radon gas prior to erosion of the site. We accept this strategy, which is in line with that used at the ENRMF, but need Augean Plc to demonstrate that appropriate operational procedures are in place to allow this emplacement strategy to be carried out.

Included in the procedure Acceptance of Low Level Waste to Landfill (see Item 9 above).

5 Understanding of site characteristics

16. Site characteristics are described in Section 2 of the ESC, including the landfill history, the local environment, geology and hydrogeology. The landfill is located approximately 280 m from the northern bank of the River Tees, which is tidal at this location, and about 3 km west of the tidal flats at Seal Sands. It is constructed as a landraise on former marshland that has been reclaimed by the historical tipping of blast furnace slag. Groundwater underlying the site flows towards the River Tees, with groundwater in boreholes nearest the river (100 m from the river) exhibiting tidal influence.

Accepted.

17. The ESC provides a brief summary of the site geology and hydrogeology, referring out to the 2019 hydrogeological risk assessment (HRA) for more detail.

Accepted.

18. We note that data from the HRA LandSim model is used to parameterise the radiological risk assessment GoldSim model. We have compared some of the data in the HRA (Table HRA 3) with data presented in the ESC and make the following comments:

18.1 We struggle to correlate some values presented in the ESC with values sourced from the HRA. For example, the clay hydraulic conductivity of 5.95 x 10^{-11} m/s (Table 107) correlates with the mean of CQA data post-2010 from Table HRA 3 rather than the value used in the 2019 HRA. The hazardous waste cell aquifer width is 689 m in the ESC (Table 13) but the HRA value is 808 m. We seek clarification of these data.

There are some parameter differences between the HRA and the ESC. These were due to the timing of the two submissions. The ESC models will be updated to be consistent with the approved HRA when the revised ESC is issued. The following clarifications are also offered:

> The parts of the landfills considered for LLW disposal are not the same as the landfills assessed for the HRA's. This is because existing filled cells, in both landfills, will not contain LLW at closure and the internal cell bunds are assumed to maintain their structural integrity after closure thereby reducing the aquifer width that radionuclides can enter. A narrower width is also more cautious in terms of the radiological assessment.
>
> Table HRA 3 presents both values of hydraulic conductivity. The values used in the 2019 HRA is 5.91 10^{-11} m/s and the CQA data provides a mean value of 5.95 10^{-11} m/s. The actual values obtained in practice are considered most appropriate for use in the radiological assessment implemented in a GoldSim model. The difference between the values is small but the slightly larger adopted value means the radiological assessment is cautious and considers the clay more permeable than is assumed in the HRA.

A copy of the Port Clarence HRA is provided with this submission (Appendix H - HRA AU_PCg24423.pdf).

18.2 The ESC quotes a single data point for a number of parameters that are defined in the HRA in terms of a probability density function (pdf) (for example, hydraulic conductivities). Augean Plc should clarify how it has determined deterministic parameters from sources that are defined as a pdf. For example, the ESC assumes a basal clay hydraulic conductivity of no greater than I x 10^{-9} m/s. The HRA assumes a pdf with min / most likely / max values of 4.72 x 10^{-11} / 5.91 x 10^{-11} / 9.27 x 10^{-10} m/s respectively. The ESC data may be conservative for assessing impacts via the groundwater pathway. However, lower hydraulic conductivities could make bathtubbing more likely.

As stated in the point above the ESC does not assume a value of 10^{-9} m/s for the basal clay hydraulic conductivity, this is referenced in paragraph 28 in relation to the Landfill Directive as implemented in EPR2016 and is a minimum requirement for a clay barrier. We will make this clearer in the revised ESC. The hydraulic conductivity achieved at the site and used is stated in Table 107 as 5.95 10^{-11} m/s. The ESC uses deterministic models and applies mean or most likely values, this applies to the groundwater pathway parameters whereas Landsim uses a probability density function.

The likelihood of bathtubbing relates to the relative conductivity of the basal barrier to the cap, if the value for the basal layer always exceeds the cap, bathtubbing is unlikely to occur. If more water enters the landfill than can drain, bathtubbing is more likely to occur.

18.3 The landfill basal areas summarised in Table 108 do not correlate with the basal areas used in the LandSim input from the 2019 HRA. This could be because the HRA includes the entire landfill while the ESC just includes the areas that would be used for LLW disposal (that is, the ‘future phases’ outlined in Table 61). However, Augean Plc should clarify this.

The basal area shown in Table 108 is for cells that will receive LLW whereas the Landsim model considers both the landfill cells as constructed and future cells. This will be clarified in the revised ESC.

19. The 2019 HRA for the Port Clarence Landfill has been submitted to the Environment Agency as part of the 2019 disposal permit variation submission. The Environment Agency’s National Permitting Service is reviewing the 2019 HRA and has requested some updates to the assessment. As the 2019 HRA is a key supporting reference to the ESC, we will be unable to make a determination on the ESC application until we are satisfied that the HRA meets our requirements. Should we identify any deficiencies in the HRA that affect the ESC then we will need to make an additional further information request.

Accepted. The 2019 HRA was approved in December 2020.

20. Most of the site lies in flood zone 1 (<1 in 1,000 annual probability of flooding). However, the north-west part of the landfill (in the permitted area for future non-hazardous waste disposal) is partially in flood zone 2 (<1 in 100 annual probability of flooding) and partially in flood zone 3 (>1 in 100 annual probability of flooding from rivers or >1 in 200 annual probability of flooding from the sea). The highest recorded storm surge to date is 4.09 m in 2013 and we have heard anecdotal evidence of on-site flooding at that time. However, improved tidal defences now provide protection to 4.4 m. We consider that there remains the potential for flooding of part of the site in the event of extreme weather conditions / storm surge, which Augean Plc should consider further (see Section 10.1).

The site manager, [redacted], has been employed at the site since the start of operations in 1999 and states there has been no flooding of any part of the site during this period. The anecdotal evidence must therefore apply to other areas that may be close to the site.

On 5th December 2013, a flood bank on the Southern side of Greatham Creek, downstream of the A178 failed during an extreme tidal event (water level peak of 4.09 m AOD, a 1.24 m storm surge), leading to a very significant breach in the defences. The breach point is about 3 km directly to the north of the landfill. [redacted] visited the Port Clarence Landfill site that night and can confirm that the site did not flood. We recognise the potential risk in respect of flooding events and have therefore considered this further.

The projections for sea level rise used to support the ESC are based on climate change scenario RCP8.5 (Stocker, et al., 2013) described as the business-as-usual scenario but based on very high baseline emissions and featuring a dramatic expansion of coal use. This is considered an extreme scenario and assumes there is no action to curtail global carbon emissions. It is therefore a very cautious basis for radiological assessments.

The EA requirements ask that we assess what could occur with no reliance on human intervention. Site evolution will clearly be impacted by both local and global interventions in the future and there are many alternative management options that could be considered for the estuary. None of the radiological assessments in the ESC rely on human intervention after the period of authorisation.

Appendix C provides a description of the model for flooding of the landfill that will be used in the revised ESC.

6 Coastal erosion

21. Augean Plc reviews factors affecting the natural evolution of the site in Section 2.9 of the ESC and concludes that future erosion is unlikely and will not occur before the year 4560 AD at the latest (that is, 2480 years after site closure). This is based on an erosion rate of 10 cm/y, which is considered a 'worst case' by Augean.

The feedback in Item 21 partly summarises the position adopted in the ESC which also focussed on the location and elevation of the site. There has been further correspondence discussing coastal erosion and Augean have consulted with an independent expert to further understanding of the key issues being raised by the Environment Agency.

For the radiological assessment of site erosion, two of the key uncertainties are the timing (the earliest erosion starts) and the rate of erosion at the site (how much is lost to the estuary per annum). These impact the inventory remaining when erosion starts and the rate of export from the site into the marine environment.

We have therefore adopted an extremely cautious approach where we assume that at the (unknowable) date when erosion starts to occur, the inventory in the landfill is the same as the inventory at the end of the period of authorisation (60 years). Hence, radioactive decay of the inventory before erosion is ignored. Our approach is summarised in Appendix E.

22. We have reviewed the Shoreline Management Plan (SMP) for the Tyne to Flamborough Head (which includes the Tees Estuary). It was prepared in 2007 and does not reflect the most recent climate projections, including those of the UK Climate Impacts Programme 2018, which indicate greater levels of potential sea level rise than projected in previous iterations. The Tees estuary at the moment is primarily a sediment sink, but this could change with sea level rise. In the absence of manmade defences there would be a significant change in the geomorphology of the coast, including a general loss of the sand dunes to the north and east of the Tees (including the natural flood defence for the inland area which includes the landfill). The SMP states that baseline erosion rates are 20-40 cm/y. These rates would be expected to increase with sea level rise (that is, these rates may not be conservative in the light of more recent sea level rise projections). Therefore, we do not consider the erosion rate of 10 cm/y, and hence the projected date of earliest erosion, suitably conservative.

The Environment Agency states that erosion rates are 20-40 cm/y in this region of the coast, taken from the most recent shoreline management plan (Guthrie & Lane, 2007), specifically these are 0.4 m/y for Seaton Sands to the north and 0.2 m/y for Coatham Sands to the south of Tees Mouth. These rates relate to a projected coastline erosion and are not applicable within the estuary (where the landfill is located) for which there is no equivalent statement or modelling. The earliest records show that the estuary accumulates sediment and evidence demonstrates that the estuary has accumulated sediments continuously since dredging started in 1853 (Le Guillou, 1978). This accumulation continued after construction of the North and South Gares and the upstream tidal barrier.

Whilst the sediment balance within the estuary may change with sea level rise, and this will determine whether sediment accumulates in or is removed from the estuary by tides, it does not provide an indicator to the rate of estuary bank erosion that may occur. We now assume a very cautious erosion rate of 1.0 m per year (0.4 m/y x 2.5). At this rate it would take at least

200 years for wave action to remove the non-radioactive waste between the coastline and LLW that would need to occur before LLW is exposed from the seaward direction. The factor of 2.5 is used in the shoreline management plan to account for a likely increase in erosion rate due to sea level rise (Guthrie & Lane, 2007). We have applied this rate to erosion of LLW using an inventory calculated 60 years after closure.

The first paragraph above explains our calculations in the ESC. The revised ESC will take the very cautious approach discussed in the second paragraph.

23. The preferred management strategy for the Tees Estuary involves maintaining defences to Seaton Carew in the long-term but allowing more natural roll back of the beach to the south. The dunes associated with this beach effectively protect the landfill. The SMP does not give us confidence that there will be maintenance of defences that could protect the landfill beyond the end of institutional control (c. 2130 AD): “Because of the control imposed at the mouth of the Tees, by the Gares, the semi-natural dune frontages can be allowed to retreat in a manageable manner.”

The ESC does not assume there is, or relies on, protection from the Gares in the future. The ESC has considered sea level rise and the erosion of materials only from land that is under the control of Augean Ltd. The cautious land erosion rates suggested above (Item 22 response) are not reliant on the presence of either the Gares or the raised areas of industrial land and ports infrastructure that lie between the landfill and the sea. Whilst the erosion rate will be impacted by the factors listed below (Item 24) we believe the adopted erosion rate applied to a small area of land relative to the size and elevation of the reclaimed estuary is now sufficiently cautious that these other factors do not need to be considered further.

Nevertheless, following discussions with the Environment Agency, the revised ESC will now adopt the very cautious approach described in Appendix E.

24. While recognising the difficulties in forecasting the evolution of the landscape local to the landfill over the timescales of relevance to the ESC, we are concerned about the lack of consideration of the wider coastal area and how changes to the open coastline will affect the estuary over the timeframes of interest. We have the following comments:

- The current flood risk assessments do not appear to consider the impacts of several metres worth of sea level rise on wave energy and internal hydrodynamics within the estuary. We think it probable that shear stress generated by waves and currents could reasonably be expected to increase given greater water depths and larger tidal prism in future.
- We would expect greater exploration of the logic behind the assumption that the Tees will remain a depositional environment in the future. The current depositional trend may be indicative of a system recovering from historic reclamation of its intertidal area (reducing the tidal prism) and further stabilised by defences (particularly the breakwaters). One could reasonably assume that sea level rise and other pressures affecting tidal prism (for example, changes to management regime and/or removal of the barrage or breakwaters) might affect this trend, which would present the possibility that the system might become less depositional or shift to net erosion.
- The reason that the estuary has been static in recent times is because it’s managed and there are defences in place. However, erosion would be expected along with sea level rise. For example, for every 1 mm of sea level rise, a very rough rule of thumb is that one could expect a corresponding erosion of 1 m of a barrier beach such as the one by the estuary.

• Over timescales in excess of 100 years, we expect some consideration of possible changes to the open coastline (particularly Seaton Sands and Coatham Sands) which effectively shelters the estuary and partially controls the tidal prism by maintaining the inlet dimensions. This is currently missing from the assessment. The barrier beaches either side of the inlet are currently stable as a result of the breakwaters, but a breach during a storm or the removal / failure of the breakwaters would considerably impact on their stability, and thus on estuarine processes across the whole tidal Tees.

• Although the landfill is currently protected by flood defences, it is likely that the landfill will be subject to erosion or flood risk challenges over the lifetime of the radioactive elements it will contain in the situation of significant sea level rise (> 6 m within the next few hundred to thousand years), a major storm surge and lack of maintenance of the current sea defences. As stated in the GRA, we would not accept an ESC that relies on human actions for more than a few hundred years at most to control risks from a disposal facility for solid radioactive waste (paragraph 4.6.6).

There has been further correspondence on these issues between Augean Ltd and the Environment Agency. Further clarifications were provided and Augean Ltd consulted further with Peter Robins (Bangor University) who has responded to the points raised and outlined what further work could be undertaken to provide an improved understanding of the potential evolution of the coastline and estuary. It became clear from the work done by Bangor University that further detailed assessments would be disproportionate to the radiological risk involved, costly and uncertainty would remain concerning erosion rates within the estuary. Therefore, we are adopting the cautious approach in the revised ESC that is presented in Appendix E.

25. In summary, we consider that there is insufficient evidence presented in the ESC to support the assessment of future coastal change. Without a more detailed assessment of the evolution of the coast/estuary, including consideration of the points raised above, we consider that it is not possible to make a case for erosion not occurring in the next few 100 years. We realise that addressing the comments above would involve a lot of work, potentially disproportionate to the application. One way forward would be assume that erosion of the landfill could occur immediately after the end of the period of institutional control.

Radiological assessments require methods to estimate the dose to people who may come into contact with radioactivity released into the environment. Without exception the assessment methodologies used simplify the complex environmental processes and behaviours that lead to these exposures. The methodologies used in the Port Clarence ESC are based on cautious assumptions ensuring that doses are not underestimated.

We are concerned the Environment Agency are being overly cautious about the assumptions concerning erosion at the site, that this will restrict disposals unnecessarily and that LLW disposal is being divorced from the risks involved. The suggested approach of assuming erosion of the site at the end of the period of authorisation is overly cautious. Bringing the timing of erosion forward to such an early time has a substantial impact on the activity concentrations that can be buried and on the radiological capacity of the landfills.

We subsequently suggested erosion after 250 years but this was not accepted. We have therefore assessed a scenario assuming erosion occurs (with no specified time of erosion), but with a very conservative inventory in the landfill (decay only up to the end of the period of authorisation). To offset the bias due to the conservative inventory estimate we suggested refining the radiological assessment by considering the physical situation that will arise at a time when the water level is sufficiently high that erosion of the waste could take place. We therefore suggested reducing the daily access to the site to monthly visits given that the site is very likely to be surrounded by water at the time erosion occurs given the relative height of surrounding land and the lowest elevation at which LLW will be emplaced. This argument was not accepted.

The Environment Agency (16th December 2021) presented pictures of bank cliffing along with degradation of an exposed bundle (of unknown material), as evidence of current erosion of the estuary bank adjacent to the landfill and suggested this was evidence that erosion could occur from the south undercutting the waste mass before the surrounding area was inundated. We do not think that this is a convincing argument. It is difficult to conceive how the low lying land to the north and northwest of the site (maximum elevation of 2 to 3 m AOD running from Port Clarence village to Greatham Creek) would not be permanently inundated before LLW at >8.5 m is undercut on the inner curve of the estuary (with a height difference of over 5 m between the low-lying land and the LLW).

Historic maps of the estuary are available online (National Library of Scotland, n.d.) and these clearly show the development of the estuary since the late 1850's when slag from the local smelting industry was used to train the estuary to its current path. The mapping survey of 1853 shows that the site of the landfill is in the tide washed area of the estuary. Maps produced towards the end of the 1890's show a line of material has been placed along the mean low water mark. This material is still evident now at low water in the estuary, indicating the reclamation materials are durable. The high water mark at that time ran beside the railway line to the west of the site. A map of 1920 shows that the high water mark has moved closer to the main estuary channel and follows a line that is still clearly visible on aerial photographs (running south from the intersection of Huntsman Drive and Riverside Road to the east of the site). The current limits of the high water mark next to the site were established between 1947 and 1952 and run parallel to the low water mark from a point to the south of the landfills eastern boundary. There is a mudflat between high and low water marks adjacent to the landfill site.

The landfill therefore sits over an area that was progressively reclaimed after the Second World War and was completed in 1953. The mud bank in the estuary adjacent to the site shows on all the maps since the estuary was trained (1850's) and is a feature that can occur in slower moving water on the inner curve of a channel.

Based on the available mapping evidence we conclude there has been no active erosion of the established banks of the estuary since they were formed.

7 Waste characteristics

26. Waste characteristics are described in Section 3 of the ESC. The activity concentrations requested in the application are higher than those permitted for disposal at other LLW landfills, and reach the upper LLW activity concentration limit for small volumes of some short- and longer-lived radionuclides, including H-3, C-14 and I-129. Activities of candidate waste streams for disposal are much lower than the maximum activity concentration limits applied for.

There has been further discussion with the Environment Agency in relation to this issue to clarify the concerns raised. During our pre-application discussions with the Environment Agency, we explained the application would be for activity concentrations based on the relative risk associated with each radionuclide and we took this approach in our development of the ESC. The application was not based on a comparison with activities permitted for disposal at other landfills and we capped the average concentrations proposed at values below the upper LLW activity concentration limit.

The ESC indicates that it is not possible to determine at this time what waste streams will be accepted for disposal because the contracts have not yet been awarded and in many cases the waste has not yet been generated. The ESC lists the types of waste that are likely to be disposed at the site but the list is not exhaustive or inclusive of all waste descriptions that could be accepted over the operational life of the landfill.

We assessed a range of waste streams in terms of their disposal at Port Clarence and their associated activity concentrations. Appendix D of the ESC shows the potential impact of disposal of LLW at Port Clarence using 3 derived inventories (total activity for defined fingerprints) and representative consignments, these were: cumulative disposals that have been recorded at the ENRMF; disposal of waste using the specific activity of wastes disposed at the ENRMF; disposal of waste based on the proportions of radionuclides in the national LLW inventory; and, actual LLW waste streams. We also showed that LLW concentrations extrapolated from the National Inventory are not suitable for disposal at the site. We then gave example calculations to show how disposals would be assessed against the limiting scenarios.

With RSR permits that consider discharges to atmosphere or to aquatic systems the permitted release considers the process and discharge points involved. The permit provides a little headroom (subject to BAT etc) so that permits are not breached and permit revision requirements minimised. In the case of disposal to landfill this approach is only appropriate where the disposal inventory is fully characterised and already determined.

We set out below the rationale behind the approach that will be adopted in the revised ESC to determine the limiting activity concentrations for each radionuclide listed in the permit. The EPR2016 (as amended 2/5/2018) lists the out of scope activity concentrations above which a material is considered radioactive material or radioactive waste. The relevant values are presented in Part 2 Table 2 and concentrations range from 0.01 Bq/g to 10,000 Bq/g. This range is indicative of the relative risk associated with specific radionuclides. Whilst this suggested to us that consignment average values of 10,000 Bq/g might be acceptable for some radionuclides, we will now cap the upper limit at 2,000 Bq/g averaged over a 10 t load, with a corresponding package limit of 4,000 Bq/g. The lowest limit used will be 10 Bq/g averaged over a 10 t load, with a corresponding package limit of 50 Bq/g. The latest table is presented in the draft CFA provided with this submission (PC LLW01).

Radionuclide specific activity concentrations are first calculated using the minimum value from the following scenarios:

- borehole excavator at 60 years after closure;
- trial pit excavator at 60 years after closure;
- site worker emplacing waste;
- site worker handling waste packages;
- public exposure from a dropped load;
- dog walker with daily access to LLW following erosion of site at an unknown time (with an inventory at 60 years after closure); and,
- activity limits specified in the Paris convention.

A scenario that considers informal scavenging will also be used to calculate the final values presented in the revised ESC.

These calculated values are then assigned to a band (e.g., 10, 20, 50, 100, 200, 500, 1000 or 2000 Bq/g) using an equal to or greater than basis (for a radionuclide with a calculated value between =20 and <50, the radionuclide is assigned a maximum of 20 Bq/g for disposals). This introduces an additional element of caution to that already used in the selection of scenario parameters. Inclusion of the daily dog walker erosion scenario in the group used to calculate limiting concentration values has a major impact, markedly reducing the maximum concentration in waste that can be disposed for many radionuclides. The calculated concentrations of Ra-226 (2.1 Bq/g), Pa-231 (4.6 Bq/g) and Th-232 (3.6 Bq/g) in particular, are impacted by this erosion scenario.

The disposal records for the ENRMF were used to investigate the proposed concentration bands and determine the impact of real waste fingerprints on disposal. Based on the bands outlined above, 170 consignments received at the ENRMF would be rejected at Port Clarence because the sum of fractions for concentrations would exceed 1 (a maximum value of 18.1) mainly as a result of their Ra-226 content.

The fingerprints of all ENRMF consignments have also been used to estimate the maximum potential activity concentration for a consignment with that fingerprint that would be accepted based on the proposed activity bands. This analysis shows the following distribution:

Range Max Bq/g		Count
	<=10	211
>10	<=20	62
>20	<=50	69
>50	<=100	756
>100	<=200	1672
>200	<=500	700
>500	<=1000	140
>1000	<=2000	148

Based on the fingerprints of consignments disposed at the ENRMF the maximum activity that could be disposed is less than 200 Bq/g for 74% of potential consignments. Hence, although the activity concentration for individual nuclides is >200 Bq/g, the mixture of radionuclides in the fingerprint means that the vast majority of the wastes that could be accepted would be below 200 Bq/g. Obviously, the actual activity concentration would depend on the level of contamination in the waste so these theoretical maximum concentrations may not be present in actual wastes proposed for disposal at the site. Note also that the actual total activity disposed at the ENRMF is less than 10 Bq/g in 80% of consignments.

27. We note that 305,400 tonnes of NORM have been disposed of in the non-hazardous landfill at Port Clarence. This takes place under an exemption from the Environmental Permitting Regulations which allows disposal of NORM with activity concentrations below 10 Bq/g. We discuss the implications of co-disposal of NORM and LLW later in this notice. Paragraph 515 states that this NORM waste contains an average of 1.8 Bq/g Th-232 and 0.4 Bq/g U238. However, the activity concentrations of NORM waste disposed of up to July 2019 that are used to assess the impacts associated with NORM disposals to date are slightly different (Table 51). Augean Plc should clarify the activity concentration of NORM disposals to date.

The total disposal of NORM at the end of quarter two (Q2) 2020 was 397,126 tonnes. The statements in Paragraph 515 and Table 51 concerning the activity concentrations of NORM are slightly different representing different averaging periods and selection of values for the assessment. We can confirm that by the end of Q2 2020, NORM waste disposed contains an average of 1.41 Bq/g Th-232 and 0.44 Bq/g U-238 whereas current disposals in 2020 contain an average of 1.10 Bq/g Th-232 and 0.43 Bq/g U-238.

The assessments reported in Table 51 are provided below using updated models and the average concentrations for waste disposed since 2016 to quarter 3 2020.

NORM head of chains	Disposed (MBq)	Bq g-1	Intrusion - Smallholder (60y) All ages	Intrusion - Borehole excavator (60y) - worker	Gas + Ext. (Recreational 0y) All ages	Erosion to coast (2540y) All ages (PC-Cream)	Erosion - Dog walker (2540y) All ages	Leachate spillage (0y) All ages	Fire in non-hazardous cell (all ages)
Th-232	$5.28\ 10^{5}$	1.4	$1.83\ 10^{-6}$	$5.30\ 10^{-6}$	$1.28\ 10^{-15}$	$3.92\ 10^{-7}$	$2.84\ 10^{-6}$	$1.50\ 10^{-8}$	$4.95\ 10^{-6}$
U-238	$1.66\ 10^{5}$	0.4	$4.44\ 10^{-8}$	$1.22\ 10^{-7}$	$1.06\ 10^{-23}$	$1.44\ 10^{-9}$	$1.39\ 10^{-8}$	$2.01\ 10^{-9}$	$2.34\ 10^{-7}$
U-234	$1.66\ 10^{5}$	0.4	$4.01\ 10^{-8}$	$1.43\ 10^{-7}$	$2.92\ 10^{-45}$	$1.38\ 10^{-7}$	$1.83\ 10^{-8}$	$1.88\ 10^{-9}$	$2.74\ 10^{-7}$
Th-230	$1.66\ 10^{5}$	0.4	$1.94\ 10^{-6}$	$1.60\ 10^{-6}$	$2.85\ 10^{-38}$	$1.01\ 10^{-5}$	$3.36\ 10^{-6}$	$1.12\ 10^{-9}$	$2.92\ 10^{-6}$
Ra-226	$1.66\ 10^{5}$	0.4	$1.27\ 10^{-4}$	$5.55\ 10^{-6}$	$7.66\ 10^{-11}$	$5.14\ 10^{-6}$	$1.66\ 10^{-6}$	$2.50\ 10^{-8}$	$5.70\ 10^{-7}$
µSv y-1			$2.24\ 10^{1}$	$4.03\ 10^{0}$	$1.27\ 10^{-5}$	$2.77\ 10^{0}$	$2.34\ 10^{0}$	$1.29\ 10^{-2}$	$3.28\ 10^{0}$

28. The assessment assumes that radioactive waste comprises a maximum of 20% by weight of total disposals (paragraph 185). If the percentage of LLW in disposals was greater than 20% then the basis of the ESC and the radiological capacity limitation would become invalid. We think that this is a real possibility, given the government targets of 10% municipal waste to landfill by 2035 and of zero avoidable waste by 2050. In the situation of a permit being granted, Augean Plc will need a system in place to monitor the mass of LLW disposed as a fraction of total disposals. If the total mass of LLW disposals could exceed 20% then a trigger should be set to reassess the basis of the ESC or to cease disposals.

Our response considers both the projected disposals of non-radioactive wastes to landfill and then considers the scenarios impacted by the 20% LLW assumption.

There is no routine municipal waste disposal at the Port Clarence site. Disposals are largely commercial and industrial waste types that may share some characteristics with municipal waste but are not the subject of the key objectives/milestones outlined in the papers supporting the Circular Economy Package policy statement that achieves the government's targets you refer to. We do not therefore agree with your assertion that the assumption concerning LLW waste as a proportion of total waste disposals will be under threat from reducing municipal waste disposal.

The government targets are not therefore relevant to the waste streams accepted at Port Clarence which comprise largely industrial wastes, contaminated soils, dredging wastes and

APCR. The arisings of these waste streams, notably APCR are increasing. Nevertheless, If the Environment Agency wishes a regular review to be undertaken, Augean would accept a permit condition to that effect.

The scenarios where 20% is used as a parameter in the assessment are presented under Item 77. The radiological capacity limit for a radionuclide is only affected if one of these scenarios is the scenario that limits the radiological capacity for that radionuclide. It would be unaffected if other scenarios were the limiting scenario.

29. The ESC is based on Augean Plc's proposed updated landfill design. If these changes are not adopted then Augean Plc will have to update the ESC as the relative volumes of the hazardous and non-hazardous parts of the landfill affect radionuclide capacities.

Accepted. The revised landfill design was approved in December 2020.

8 Leachate management

30. The ESC states: "Under normal circumstances leachate generated in the landfill is treated on site through the waste stabilisation plant (about 20,000 m^3 y^{-1}). This process binds the leachate in the stabilisation matrix. The stabilised material is then disposed of in the landfill. In the event that the capacity of the stabilisation plant is insufficient to accommodate the amount of leachate that must be removed from the landfill (for example during plant maintenance) the excess leachate is sent to a suitable treatment works which currently is the Billingham Reed Beds (Scott Bros. Ltd) but could also be sent to Bran Sands Industrial Effluent Treatment Works (Northumbrian Water Limited). Under normal operating circumstances it is necessary to send approximately 2,600 m^3 y^{-1} of leachate for off-site treatment." (paragraph 220).

Since the ESC was drafted and submitted there have been changes that affect leachate management at the site. 5 ha of the landfill is now capped with further capping proposed that will reduce the amount of leachate generated. Furthermore, a third stabilisation plant has been installed at the Waste Recovery Park (WRP) and this has increased demand for processing liquid. As a result, there is a shortfall in processing liquid for the stabilisation process and Augean has been importing leachate from its Mark's Quarry site and is currently considering ways of harvesting rainfall or accessing a mains supply. In the unlikely event that there is excess leachate generated at the site, such as during periods of maintenance the leachate can be stored in tanks at the WRP. Therefore, going forward Augean has no need to export leachate from the site.

We confirm that we recognise that the Reed Beds are not the subject of an RSR permit hence the facility would only be used if the leachate quality was suitable for treatment and subject to appropriate permitting.

Similarly, leachate will only be disposed of at Brans Sands if the leachate quality and radionuclide content meet the terms of their permit. The likelihood that leachate will be unsuitable for disposal at the above facilities is very low. The radiological capacity of the site is lower than the ENRMF, for a larger volume and area of landfill site. To date the radionuclide concentrations recorded in leachate at the ENRMF site (RPA/RWA review of 2019 results of the ENRMF Environmental Monitoring Programme, PHE June 2020) are considered to be out of scope of EPR 2016 as amended 2018, i.e., LLW inputs to the ENRMF site have not resulted in leachate contamination of regulatory concern.

The primary limitation on processing capacity at the WRP will be availability of APCR which is used as a reagent (a substitute for cement) in the stabilisation process. In the unlikely event that excess leachate is generated and is not suitable for disposal at the Reed Beds or Bran Sands, Augean has the option to use cement, lime or other stabilising medium and if necessary Augean can also increase operating hours taking advantage of the 24 h operating consent under planning. As cement and lime are readily available to purchase this removes any constraint on our ability to treat the leachate.

31. We note that if the Scott Bros. Reed Beds are to be used for disposal of any in-scope radioactive materials, then they would need to have an RSR permit for the disposal of Radioactive Waste. As part of an application, disposal from the Reed Beds to Billingham Beck would have to provide a risk assessment, for example using the Environment Agency's Initial Radiological Assessment Methodology (IRAM), in support of an application to receive such a permit. Augean Plc should provide an agreement in principal from both Northumbrian Water Ltd and Scott Bros. and must ensure that the leachate meets the permit limits and is suitable for treatment at these facilities.

This is addressed in Item 30 above.

32. Bran Sands Effluent Treatment Works already has an RSR permit. However, it currently only allows for NORM chains and would need to be varied to accommodate the range of radionuclides in the leachate (if in-scope).

This is addressed in Item 30 above.

33. The ESC does not discuss the implications on leachate management at the landfill if off-site treatment of leachate ceases due to its radionuclide content. It would be useful to understand the capacity of each radionuclide that could result in the leachate coming into scope of the Radioactive Substances Regulations, and resultant doses to exposed groups, to determine whether the lack of a permit for the receiving sites could cause a problem. Augean Plc will need to submit an updated Leachate Management Plan should future offsite treatment of leachate be likely to be problematic to demonstrate that it can effectively manage its leachate from LLW disposals, either by demonstrating that it will not be in scope of RSR or by demonstrating that it has the capacity and route(s) to manage it.

Accepted and this is also addressed in Item 30 above.

9 Landfill design and geotechnical implications

34. The design of the Port Clarence landfills is consistent with our expectations for hazardous and non-hazardous landfills. We have accepted that this is appropriate for the disposal of low activity LLW at other landfills. However, Augean has not demonstrated that the engineering is appropriate for the disposal of higher activity LLW as proposed at Port Clarence. We make the following comments:

34.1 Augean Plc should substantiate the assumed date of onset of cap degradation, taking into account the fact that the site will be progressively capped as the individual cells are completed so that the cap age over the first and last LLW disposals could differ by up to 50 years. Although the ESC states that any damage to the cap will be detected and repaired during the period of authorisation, we assume that this will only relate to large scale faults and that gradual degradation of the cap performance will take place during this time. This should be considered.

A geosynthetic clay liner (GCL) is to be used for capping (paragraph 70). The design cap assumptions are described (MJCA B1; J Congo 29/6/2020) and will incorporate a GCL. A key principle is that as the GCL incorporates low permeability geological materials which do not degrade it is not necessary to simulate degradation of the material in the LandSim modelling of the long term performance of the capping system. This principle has been accepted by the Environment Agency for the Thornhaugh Landfill Site.

A cautious view of cap integrity was used for the ESC, where it was assumed the cap would degrade over time after the final closure of the site. These assumptions have been revised and the models considering water balance of the landfills all now use a non-degrading GCL.

As part of our consideration of design optimisation the impact of the GCL verses a degrading cap is considered.

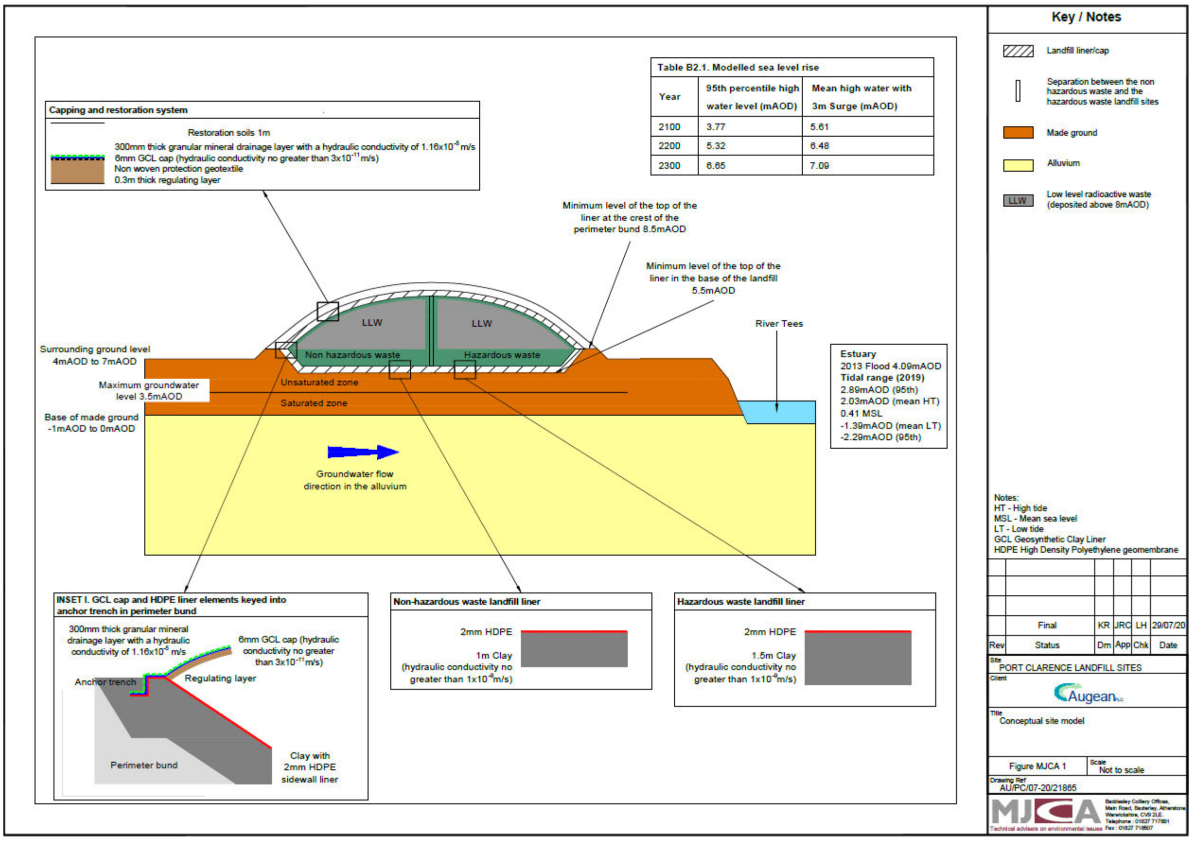
For comparative purposes, we have also estimated infiltration rates for a scenario in which it is assumed that the capping system will incorporate a dedicated cap drainage layer and for a scenario in which it is assumed that no dedicated cap drainage layer will be present. Where present it is assumed that the cap drainage layer will comprise a 300 mm thick layer of sand overlying the GCL cap with a hydraulic conductivity of 1.16 10^{-5} m/s (Kruseman & de Ridder, 2000). For the purpose of the calculations, lateral drainage in the other soil layers overlying the cap is ignored. Where no dedicated drainage layer is present it is assumed that the restoration soils overlying the GCL cap will be 500mm thick and comprise loam with a hydraulic conductivity of 1.16 10^{-7} m/s (Appelo & Postma, 1999).

Parts of the site have been capped already but these will not contain LLW. It is understood that a 1mm thick flexible membrane liner (FML) cap has been constructed in Phase 3 and Phase 4 of the hazardous waste landfill and that construction of a 1mm FML cap is ongoing in Phase 1 of the non-hazardous waste landfill. The potential implications of these capped areas for the site water balance are discussed in Appendix D.

34.2 The ESC should clarify the materials used in the capping and basal layers. For example, paragraph 741 provides the first mention of an LLDPE geomembrane. The main body of the report discusses a high density polyethylene membrane. Augean Plc should clarify this. In addition, there is no mention of a geosynthetic clay liner in the main body of the ESC. It would be good practice to include a reasonable description and conceptual drawing of the engineering in the ESC rather than refer to a supporting document.

The discussion in the main body of the text refers to the basal liner comprising a geomembrane and a mineral clay layer (paragraph 66) and then refers to a geosynthetic clay liner (GCL) to be used for capping (paragraph 70). Later at paragraph 741, there is a discussion about the degradation of capping materials where the resilience of a GCL is expected to be greater than an LLDPE geomembrane cap (undefined in the text but referring to a linear low density polyethylene capping material).

To clarify the materials used we presented a conceptual drawing of stylised waste cells highlighting the engineered barriers and the various features of the two landfills (provided to the Environment Agency on 30/7/2020) and reproduced below.



34.3 Figure 4 shows that the expected post-settlement levels of the top of waste and cap surface are about 9 m lower than the pre-settlement levels. Augean Plc should consider the implications of differential settlement, in particular associated with the different properties of the hazardous and non-hazardous waste and the engineered bund that separates them. Given that the cap is much thinner than the expected amount of settlement, Augean Plc should consider the potential for differential settlement to increase infiltration into the landfill through, for example, thinning of the cap or ponding on its surface.

This issue is addressed in the Stability Risk Assessment (MJCA, 2019) that has been provided to the Environment Agency covering the site. Environment Agency guidance in 'How to comply with your environmental permit. Additional guidance for: Landfill (EPR 5.02)' dated March 2009 states that:

> *"An accurate prediction of settlement is difficult because time-related settlement data are rarely available from surface measurements. The data that is available indicates long-term settlement of biodegradable waste can be approximated to an exponential curve which could result in most settlement taking place over 30 years with the majority occurring in an initial five year period".*

Biodegradable waste is deposited only in the non-hazardous waste landfill site; the waste acceptance criteria for the landfill of hazardous waste has a total organic carbon limit of 6% therefore only materials with no or very limited biodegradability are deposited. While some settlement is to be expected for the non-hazardous waste landfill, limited or no settlement is likely for the hazardous waste landfill site. Any significant settlement of the waste mass at the site should therefore occur within the first five to ten years of waste placement with the majority of all settlement taking place within the 60 year management control and aftercare period of the site. In the unlikely event that settlement has a detrimental impact on the integrity of the capping and restoration system these would be remediated within the 60 year management control and aftercare period of the landfill. Settlement of the landfill following the 60 year management control and aftercare period will be minimal and the site is designed to be physically stable.

A copy of the Strategic Risk Assessment is provided with this submission (see Appendix I - SRA AU_PCe24438.pdf).

34.4 The ESC should justify the statement that leachate levels will be maintained at 1 m above the landfill base throughout the operational period.

The maintenance of the leachate level at 1 m is a landfill permit requirement which must be maintained throughout the active management period of the site.

34.5 As it is a landraise, the ESC should consider slope failure as a potential waste exposure mechanism.

The Stability Risk Assessment (MJCA, 2019) makes clear that this is not a credible scenario for the maximum slope (1v:7.7h) of the restored site that will cover the LLW.

34.6 An engineering performance assessment, comprising an evaluation of engineered system degradation and associated failure mechanisms (of which a stability assessment would be a part), would add confidence to the claims that the landfill engineering is suitable for the proposed LLW disposals.

A Stability Risk Assessment (SRA) is an application requirement of the landfill permits and this will be referenced in the revised ESC. The Port Clarence Stability Risk Assessment was provided to the Environment Agency on 9th June 2020 (MJCA, 2019) and demonstrates that the ENRMF emplacement strategy is appropriate for use at the Port Clarence landfills. The SRA was submitted with the permit variation application for the hazardous and non-hazardous landfills. The SRA has been accepted by the Environment Agency. No further slope stability work has been carried out.

35 Augean Plc believes that the landfill and engineering design will not be compromised by disposal of the proposed LLW waste forms, which include half height International Standards Organization (ISO) containers and drums. It has told us that the landfill stability and the integrity of the post-closure engineering will not be compromised by the presence of these waste forms and any preferential settlement caused by hard spots or voidage, citing evidence from the ENRMF (Meeting between Environment Agency, Augean Plc and Eden Nuclear and Environment, 19 September 2019).

Accepted. A site specific report is in preparation which will specify the precautions necessary to ensure that disposal of iso-containers does not compromise the landfill engineering design.

36 We have reviewed the ENRMF stability assessment (TerraConsult. Kingscliffe settlement. Report 1764. Final version 17/6/13.). This provides evidence that the formation of voids of up to 2.5 m in depth caused by the collapse of steel containers (for example ISO containers) are not likely to cause significant tensile strains in the clay capping materials used at ENRMF, thereby causing cracking of the cap. The assessment further makes a number of recommendations for site operations:

36.1 Containers should be placed on a minimum thickness of 1 m of mixed fill above the base.

36.2 Containers should be spaced at least 4 m apart in plan so as to allow for placement of the mixed fill and nominal compaction by tracking in by plant.

36.3 Containers should be placed such that the top of any container is a minimum distance of 2 m below the clay capping.

Accepted and this has been included in the Waste Acceptance procedure PC LLW03 presented with this submission.

37. We expect Augean Plc to demonstrate that the ENRMF assessment is valid for the Port Clarence landfill. We also expect Augean Plc to clarify whether it proposes additional emplacement strategies for ISO containers, similar to those recommended for ENRMF.

Addressed in responses to Items 35 and 36.

10 Radiological assessment

38. Our comments on the radiological assessments in the sub-sections below relate to information supplied in Section 6 and Appendix E of the ESC. The assessment considers impacts for the period of authorisation and the post-closure period (that is, the time after surrender of the permit, which is anticipated to be about 2130 AD) separately.

Accepted.

10.1 Scenarios

39. The period of authorisation considers 6 scenarios that are deemed 'likely to occur' and a further 6 scenarios that are deemed 'unlikely to occur'. Four of each are assessed quantitatively. Exposed groups considered include workers on the site and treatment plants, members of the public, anglers and farming families (adults, children and infants). The postclosure assessment includes 3 scenarios that are deemed 'likely to occur' and a further 5 scenarios that are deemed 'unlikely to occur', of which 3 of each are assessed quantitatively. Exposed groups considered include members of the public, construction workers, residents and fishing/farming families (adults, children and infants). In addition, the assessment considers impacts associated with inadvertent human intrusion, large/discrete items and particles, and impacts to non-human biota.

We will provide a similar summary in the revised ESC to indicate likely and unlikely scenarios and the quantitative and qualitative assessments.

40. We consider that an appropriate range of assessment scenarios and exposed groups has been considered in the radiological assessment, with the following exceptions:

40.1 We have anecdotal evidence that the northwest part of the site has been subject to flooding, and this part of the site is in flood zone 2/3. Paragraph 47 acknowledges this but notes that flood waters will not overlap with the cell liner under current projections to 2115. However, we consider that there is a potential for floodwaters to be in direct contact with the waste in the non-hazardous part of the landfill, in particular before completion of the engineered sides of the landfill. Augean Plc should explore impacts associated with flooding/bathtubbing during the period of authorisation, which includes assessment of non-human biota inhabiting surface water bodies that could be affected, as an event that is unlikely to occur.

Our interpretation of the risk of the site flooding is different to that presented above. The site manager, Terry Blanchard has been employed at the site since the start of operations in 1999 and states there has been no flooding of any part of the site during this period. On 5th December 2013, a flood bank on the Southern side of Greatham Creek, downstream of the A178 failed during an extreme tidal event (a peak of 4.09m AOD including a 1.24 m storm surge), leading to a very significant breach in the defences. The low lying tract of land to the west of the site running from Port Clarence village to Greatham Creek has an elevation of 2 to 3 m AOD and was subject to flooding. Terry Blanchard visited the landfill site that night and can confirm that the site did not flood. We recognise the potential risk in respect of flooding events and have therefore considered this further to show quantitatively that there is no potential for flood water to be in direct contact with LLW in either landfill for the foreseeable future.

The projected sea level rise and the potential for a storm surge of 3 m on top of a 95th percentile high tide (UKCP18 RCP8.5 Marine) has been considered. In December 2013 the local maximum for the storm surge was 1.24 m over a spring tide of 3.85 m AOD whereas we have applied an estimated inshore storm surge maximum value of 3 m (Spencer, et al., 2015) based on the 1953 benchmark storm surge event. On this basis the earliest date when a flood could overtop the bund that supports the basal liner of either landfill (8.5 m AOD) and flood water enter and mix with leachate is 2210 CE. We note that at this date when flooding becomes possible, it will be an unlikely event (reliant on an extreme tide coinciding with a storm surge) and will therefore occur at very low frequency (60 years and previously 30 years between the most recent comparable events), however as sea level rises after this date the storm surge height required to overtop the bund will reduce until a smaller surge above a less extreme high tide will rise above the top of the bund more frequently. It is not possible for floods to enter waste filled cells before at an elevation lower than 8.5 m AOD.

In order for a significant volume of flood water to then enter the landfill, the cap or the seal between cap and basal liner will also need to have degraded. Should the first flooding occur in 2210 CE, the mean sea level will have risen to about 1.95 m AOD with a high tide of about 3.57 m AOD and at this time the 95th percentile tides (5.5 m AOD) will exceed the height of current sea defences. We conclude that by the time there is the potential for flood water to enter the landfill, there will also be regular tidal inundation of the surrounding land that lies at 2 to 3 m AOD. Such land will be unsuitable for agricultural use or regular access for recreational purposes and the main pathway to receptors is considered to occur through the transfer of draining leachate to the marine environment.

We do not agree with the conclusion made under Item 40.1 that the bund surrounding the non-hazardous landfill can be overtopped by floodwaters before completion of the engineered sides of the landfill. As outlined above the relative physical height of a 95th percentile tide, storm surge event and bund height protect the waste from floodwaters until 2210 CE. We have considered a floodwater depth of 1 m at this time to illustrate the potential impact which could occur at this time if a spring tide coincided with the storm surge. This scenario is detailed in Appendix C.

40.2 The ESC does not explore impacts associated with the disposal of stabilised leachate in the landfill. Augean Plc should demonstrate that appropriate processes will be in place to monitor activity concentrations in the leachate and assess resultant doses to workers.

The stabilisation process is controlled under the WRP permit. The ESC assesses doses that result to workers who may be involved in leachate treatment and this assessment is considered cautious for the process using leachate at the WRP. Leachate used in the stabilisation process is introduced to an enclosed and abated mixing system, after treatment the resultant materials are technically assessed and then disposed of to landfill. The leachate utilised in the treatment process will be monitored in accordance with the permit conditions prior to use in the stabilisation process, therefore any leachate with higher activity concentrations would be detected prior to removal from the cell and therefore would not be used in the treatment process.

Stabilised material is then placed in the landfill. Any impacts associated with the disposal of stabilised material in the landfill will be limited by the initial disposal because there is no additional radioactivity introduced to the landfill or increase in chemical availability. There is therefore no new radioactivity, no enhanced transfer within the environment and no impact on radiological capacity.

The stabilised material will be loose tipped and the approach used ensures that this material will have radionuclide concentrations below the limits proposed for loose tipping of waste.

Augean will demonstrate that appropriate processes will be in place to monitor activity concentrations in the leachate and the disposal process (see Port Clarence Leachate MAP LLW 2022_draft.pdf).

40.3 The ESC does not consider impacts associated with flooding or storm surges postclosure: “With sea level rise the area surrounding the landfill is likely in due course to be subject to periodic flooding. At some stage the peak flood height will begin to overlap the basal liner and water may enter the base of the landfill. However, the bathtubbing and the groundwater scenarios are both assumed to occur earlier and would have similar or greater effects than inundation. This pathway has not therefore been considered further” (paragraph 261). We disagree with the statement that the bathtubbing scenario may be considered analogous to flooding as only a single bathtubbing event is considered. Likewise, impacts via the groundwater pathway may not be considered analogous to flooding since the former will affect groundwater underling the landfill and receptors down hydraulic gradient while the latter may provide a fast pathway to surface soils and water bodies. In addition, neither the bathtubbing nor groundwater scenarios are used to constrain radiological capacity. Augean Plc should consider impacts associated with flooding of the landfill, and its impacts on radiological capacity.

A scenario that considers the impact of post-closure floodwater is included in the revised ESC and is presented in Appendix C, and a revised seepage/bathtubbing scenario is presented in Appendix D. These scenarios are now in the group that is used to limit radiological capacity.

40.4 The ESC should consider whether there is a potential or the creation of perched leachate in the landfill, which could result in releases to the surface environment via the sides of the landfill.

Perched leachate occurs where infiltration is unable to percolate to the base of the site due to low permeability layers within the landfill. As waste is relatively heterogeneous, any discrete low permeability layers are generally small areas within the landfill mass. Significant volumes are unlikely to perch in modern landfills as low permeability materials such as clays are avoided for use as daily cover. It is common practice if lower permeability layers are used as cover material, for the layers to be disturbed and mixed with other waste before further waste is placed above. This practice is also implemented to remove any low permeability temporary capping that may be placed. At Port Clarence soils and filter cakes are typically used for daily cover which do not have inherently low permeability.

In the event that perched leachate occurs near the side of the landfill, it will drain down the drainage layer constructed inside the side liner system or through the regulating layer placed immediately below the capping material. In the unlikely event that there were issues associated with low permeability layers in the waste and perching they would be detected during the operational or active management phase of the site and addressed by interceptor drains or perforating the low permeability layers by drilling. Phases of the landfill have been operational for over 10 years and are in excess of 20 m in height but there has been no experience to date of leachate breakout at the sides of the site in the absence of a cap.

40.5 There are no inadvertent human intrusion scenarios that consider intrusion events into the eroding landfill. Augean Plc should consider scenarios for intrusion into undiluted radioactive waste in an eroding cliff line, for example informal scavenging and local organised material recovery as base case intrusion scenarios. These should be activity concentration limiting scenarios.

The Port Clarence landfill is close to the coast and making use of brownfield land that was previously reclaimed using industrial wastes and estuary dredgings. There is the potential for sea-level rise to lead to erosion of the landfill after a few hundred to a few thousand years. Erosion of the landfill could expose undiluted radioactive waste. Possible intrusion scenarios involving exposure to the undiluted radioactive waste, based on work to support the ESC's for LLWR and Clifton Marsh but considered in the context of the Port Clarence site are:

- **Informal scavenging**. Individuals or small groups of people scavenging items using hand tools. This could involve a dig into the side of a bank with hand tools or simple scavenging from tide washed land. The exposure pathways would include: external doses from being close to exposed waste (both whilst excavating and at home, if any objects are taken home), inhalation of contaminated dusts and inadvertent ingestion of contaminated material.
- **Material recovery by local small contractor or group**. Small groups of local people or contractors may excavate the waste using hand tools, portable mechanical equipment or small diggers. People handling the recovered items could be exposed to radioactivity as per the informal scavenging case. Material recovered may be suitable for use as hardcore (e.g., for construction), although this is anticipated to be mixed with other materials prior to use. Occupants of spaces or houses in which such material is used may be exposed to radioactivity. However, it is considered that in most cases exposures are bounded by the smallholder and resident intrusion scenarios, where a house is located directly on materials excavated from the landfill.

- **Commercial Excavation**. A larger-scale, planned excavation would be preceded by site investigation works, which would likely reveal the presence of hazardous waste. If excavation proceeded after such a discovery, this would be informed intrusion and is not assessed. If the hazardous nature of the waste was not discovered, doses would be bound by the material recovery scenario, as workers would carry out a similar role. As such, we do not intend to assess this scenario.
- **Technical or archaeological investigation**. Exposed waste may be investigated by technical experts or archaeologists at the request of a governing agency (e.g., local authority). More precautions are expected to be taken in such an investigation compared to the previous scavenging and excavation scenarios. The presence of hazardous waste would likely be discovered, either via on-site investigation or by searching records. Controls or planned (intentional) remediation may then be put in place. We include a Trial pit scenario and given the similarities we do not intend to assess this scenario.

The Informal Scavenger scenario is similar to the excavation scenarios for trial pits that is included in the ESC. Exposure would be calculated for:

- Inhalation - based on the concentration of radionuclides in air;
- Ingestion - based on waste concentration; and,
- Irradiation - based on semi-infinite slab adjusted for a bank when outside and sphere when object taken home.

The same exposure pathways apply to the Material Recovery scenario as well, this scenario allows for taking something home for use as building material. An Informal Scavenger scenario and a Material Recovery scenario will be included in the revised ESC and used in the assessment of activity concentrations.

41. Landfill dimensions, including plan areas of the future phases, are summarised in Table 61 of the ESC. However, assessment calculations tend to use the basal areas instead (see for example, Table 108). This may be appropriate for some calculations, for example for the groundwater pathway. However, other scenarios such as gas pathway should be based on the surface area. We query whether this has been done, for example, although the equation under paragraph 622 states that the radon calculations are based on surface area, the supporting area data summarised in Table 72 are for basal areas. Augean Plc should confirm whether the correct data have been used in the calculation and, if not, update the results accordingly.

The height of each cell and their exact location has not been determined at this time. Approximate dimensions are provided that are used to estimate volume and area. The gradient of the restored site has a maximum of 1v:7.7h pre-settlement.

We note that the plan basal area will be less than the surface area of the restored landfill and calculations are therefore conservative, the ratio of basal area to slope area at this gradient is 0.992. The following amendment will be made at paragraph 662 to clarify the text:

- $AREA$ is the plan basal area containing radioactive waste, this is a cautious assumption for a restored site with a 1v:7.7h maximum pre-settlement slope;

42. The groundwater pathway calculations used in the ESC are based on a GoldSim model. However, it does not provide sufficient information for us to validate the output of the GoldSim model for the groundwater pathway. Augean Plc should outline to us the steps it has taken to verify and validate the GoldSim model. We suggest that a comparison of output from the LandSim HRA model could be used to add confidence that the 2 models are consistent.

We have considered comparing the output from the GoldSim model with the output from the LandSim HRA model. There are two significant differences between the two models that make a direct comparison impossible:

- The LandSim model considers different contaminants. The parameterisation is different and pre-processing would be required for the data to be suitable for the GoldSim model.
- The GoldSim Model includes a dynamic leachate level, which was created to respond to queries related to bathtubbing and sea level rise. LandSim uses a fixed leachate level.

We have checked that the input data of the GoldSim model are consistent with the input data of the LandSim model. This includes the site geometry, the generic material parameters for geological materials (e.g., clay).

For a selection of radionuclides, we have compared the output from the GoldSim model to the results of a bespoke calculation developed in GNU Octave, an open-source multi-purpose mathematical simulation programme. These show close agreement.

43. The description of the radiological assessment in the main body of the report does not provide a comprehensive summary of the assumptions, for example a qualitative description of the exposed groups and exposure pathways/routes. For example, paragraph 319 does not make it clear whether the doses from ingestion and external irradiation are treated separately or are summed together, nor whether inhalation of particles is considered. These are significant assumptions that should be summarised for the reader without having to refer to the detailed appendix.

We have added details for paragraph 319 as below but maintain that if technical detail is required the reader should refer to Appendix E of the ESC. We consider the level of detail in the main body of the report adequate for the intended broad readership.

319. *Decisions regarding acceptance for waste containing high activity particles can be made by comparison of the results of dose calculations for the activity on the particle with the NS-GRA intrusion dose guidance level. The ingestion dose and external (whole body) dose are therefore compared separately to the annual dose guidance level of 3 to 20 mSv. The doses from these pathways are not considered to be additive, i.e., it is unlikely that a particle giving a whole body dose is then ingested. The exposure is regarded as a 'one-off' event and hence the appropriate dose guidance value would lie towards the upper end of the range cited. The dose from contact with the skin is compared with the 50 mSv annual dose limit for the equivalent dose to skin for members of the public, as specified in the NS-GRA. Inhalation of particles is not considered as it is not relevant for particles of 1 mm in size and inhalation of particles up to 10 μm in size was found not to be an important pathway in other assessments of particles* (Sumerling, 2013; HPA, 2005; HPA, 2011). *Wastes that do not meet these dose guidance levels are not accepted without specific approval from the Environment Agency. Demonstration that the disposal route adopted represents BAT would also be required.*

10.2 Operational period radiological assessment

44. The assessment includes workers at the Augean Plc landfill and at the Augean Plc offsite leachate treatment facility. These workers will be employed by Augean Plc which will hold the permit to dispose of radioactive waste. Therefore, Augean Plc is responsible for their worker's exposure and the workers are protected under Health and Safety at work legislation including the Ionising Radiation Regulations 2017 (IRR17). Because of this, we have not formally reviewed the Augean Plc workers exposure assessment. However, we note that the ESC claims that, because operations at the ENRMF are similar to those proposed for the Port Clarence landfills, then doses are anticipated to be similar (see, for example, paragraph 585). The ESC does not discuss the implications of the higher activity concentration values proposed for the Port Clarence landfills on worker doses, and the external doses to workers presented in Table 65 are based on 200 Bq/g. The ESC notes that total doses from Co-60, Ag-110m, Sn-126, Ra-228 and U-232 slightly exceed 1 mSv/y. If the maximum activity concentrations applied for were assessed, then doses from Sb-125, Eu-152 and Eu-154 would also exceed 1 mSv/y.

Augean Ltd look after the welfare and protect the safety of their employees and the management systems in place ensure that all legal requirements are satisfied.

Notwithstanding the range of activity limits proposed at Port Clarence a key criterion for waste acceptance is the surface dose rate of waste packages. It is stated at paragraphs 197 and 198 (and Section 7.3.1) in the ESC that one of the waste acceptance criteria is that wastes accepted at the landfill will not have a surface dose rate exceeding 10 µSv/h at 1 m (PC LLW01) and for emplaced waste the maximum dose rate above covered waste should be less than 2 µSv/h at 1 m (PC LLW03). This is consistent with practice at the ENRMF and maximum doses from waste packages will therefore be similar. This will limit the exposure of operatives under normal conditions accordingly.

45. The calculation of external dose to members of the public during the period of operation considers that a member of the public stands 50 m from waste with a dose rate of 10 µSv/h at 1 m for 8 hours per day. The daily dose that this person would receive is 12 µSv. These habits do not seem probable. A more likely scenario would involve a person, for example a dog walker, passing the site on a daily basis and receiving dose for a short period each day. With reference to present day habits of the local population, Augean Plc should consider whether a more probable exposure scenario could result in a significant annual dose. We also note that there is also an error in the definition of equation parameters on p224 and that the calculations are based on an activity concentration limit of 200 Bq/g. Augean Plc should clarify the calculation used and demonstrate that this scenario remains appropriate at the maximum activity concentrations proposed for all radionuclides.

The assumed habits are extreme and serve to demonstrate that doses to a member of the public at the site boundary would be extremely low (12 µSv/y; not as stated above 12 µSv/d).

It is made clear in paragraph 197 that a limiting dose rate criterion of 10 µSv h^{-1} at 1 m from the LLW package applies to a package on delivery, and further in paragraph 201 that a dose rate criterion of 2 µSv h^{-1} at 1 metre above the covered LLW waste will be applied at Port Clarence. No waste on site will therefore exceed these criteria.

The scenario was cautiously based on Co-60, it uses an improbable short distance and applies extreme habits that are unlikely to occur. The calculated dose is very cautious and is used to demonstrate that a very small annual dose could occur only under extreme circumstances that are unlikely to ever occur. Paragraph 198 describes the assessment that leads to an annual dose of 12 µSv/y. The text will be clarified to state:

> The dose to a member of the public standing at a distance in direct line of sight of a waste package/shipment is calculated. The maximum dose rate at 50 metres is estimated to be 4 10^{-3} µSv/h for a package with a surface dose rate of 10 µSv/h. If the person stands in that location for 8 hours per day and there is waste at the maximum surface dose rate in that location every day, then the person would receive 12 µSv/y; the corresponding dose at a distance of 100 m would be 3 µSv/y. These are very low doses from calculations that are very conservative.

A more realistic scenario, dogwalker, could spend 0.5h/day, walking past the perimeter of the site. The exposure time is therefore lower, hence a lower dose.

We note the typographical error in the standard inverse square law equation where distances X are described as doses. The text will be amended as follows.

$$D_1 = D_2 \cdot \frac{{X_2}^2}{{X_1}^2}$$

where:

- D_1 and D_2 are dose rate at positions 1 and 2 (µSv h^{-1}); and,
- X_1 and X_2 are the distances for the dose rate measured at positions 1 and 2 (µSv h^{-1}).

This calculation as described is based on a surface dose rate limit of 10 µSv/h that is applied to delivered waste consignments/packages. We acknowledge that elsewhere in the ESC a standardised calculation is sometimes based on a specific activity of 200 Bq/g (e.g., the dropped load) but also note that this is then used to derive maximum activity limits.

46. Maximum activity concentrations calculated for radionuclides in loose tipped waste are shown in Table 68, indicating worker doses to be limiting. Augean Plc uses these to define limiting activity concentrations for loose tipped waste (Table 33). We note that the maximum activity concentrations for Ac-227, Th-229 and Cm-248 are lower than their defined limiting activity concentrations. Therefore, loose tipped waste containing these radionuclides at the defined maximum activity concentrations could result in workers receiving dose in excess of 1 mSv/y. Augean Plc should reconsider the limits for these radionuclides in loose tipped waste.

The loose tipping scenario considers the inhalation pathway of dust released to atmosphere for workers and members of the public. The worker doses limit the concentration of loose tipped waste. In deriving the limiting concentrations, we cautiously assumed that a worker might spend an extended period of time supervising tipping but considered this overly cautious for the small amount of Ac-227, Th-229 and Cm-248 recorded (UK RWI) as present in LLW or VLLW (i.e., these waste streams are unlikely to be present in concentrations above 1 Bq/g based on ENRMF consignments).

A factor was applied to the dose a worker could receive from loose tipping to account for the possibility that the projected number of loads accepted could be greater than the 80 used in the assessment. This factor was based on the assumption that 10% of a worker’s time is spent supervising the loose tipping of waste. Application of this adjustment was not clear from the scenario description given in the ESC and this will be clarified when the ESC is reissued. This adjustment reduced the limiting activity concentration for loose tipped waste by a factor of about 4.4 (to produce the maximum activity concentration shown in Table 68) and it is these concentrations that were used to determine the limiting bands containing specific radionuclides in Table 33.

The un-factored activity concentrations relating to the doses shown in Table 68 for Ac-227 (9.2 Bq/g), Th-229 (20.3 Bq/g) and Cm-248 (14.5 Bq/g) are substantially above 5 Bq/g and given the low probability of these radionuclides arising in wastes, the lowest band for loose tipped waste (5 Bq/g) was adopted. It is therefore very unlikely that the site constraint of 1 mSv for workers will be exceeded by loose tipping waste containing these radionuclides.

47. As discussed in Section 8, the majority of leachate generated in the landfill is treated on site through the waste stabilisation plant (about 20,000 $m^3\ y^{-1}$). Currently about 2,600 $m^3\ y^{-1}$ of leachate is sent off site. The ESC calculates dose per unit release for worker and public exposed groups associated with off-site treatment of leachate, which are based on projected leachate activity concentrations per MBq input to the landfill (Table 79). Off-site leachate treatment is not used to limit capacity because leachate disposal is directly controlled by Augean Plc and a discharge permit would be required to transfer the leachate. We concur with this.

Accepted.

48. The dropped load assessment is based on an activity concentration of 200 Bq/g in a 1 t load. In this assessment, paragraph 691 states that the worker inhalation rate is used for both the worker and the public in the assessment. However, the parameters summarised in Table 93 include different inhalation rates for workers and adult members of the public. Augean Plc should clarify what data it used. With the exception of inhalation rates for members of the public, parameters and calculations appear identical to those used in the equivalent assessment in the 2015 ENRMF ESC[8]. However, the calculated doses differ slightly for all radionuclides for both workers (generally at the 3rd significant figure) and members of the public (by about 20%). Augean Plc should explain the reasons for the differences.

The statement in paragraph 691 is incorrect and the adult inhalation rate was used for all members of the public. The inhalation rates used in the assessment models for different members of the public will be reviewed and set consistently across all scenarios in the revised ESC. The estimated doses to a child and an infant will therefore be lower in the revised ESC calculations.

The dose coefficients used for Port Clarence were transcribed directly from the original reference sources cited whereas the ENRMF largely used the SNIFFER dataset in order to avoid any inconsistency between the 2009 radiological assessments and the 2015 ESC for the ENRMF. There are therefore differences between a small number of the inhalation dose coefficients but these are not apparent at 3 significant figures.

The minor difference between the worker doses (at 3 significant figures) is due to the rounding down of the worker inhalation rate to 3.3 $10^{-4}\ m^3\ s^{-1}$ for the ENRMF whereas the rate at Port Clarence is calculated from an hourly rate (1.2 $m^3\ h^{-1}$/3600 s) and the parameter therefore has a recurring 3 in the value used and this accounts for the difference. This will be corrected when the ESC is revised. The 20% difference referred to above is the ratio of worker and adult inhalation rates.

49. The dropped load assessment is not used to constrain radiological capacity because the resultant dose relates to activity concentrations at a package scale rather than total capacity. However, doses for Ac-227 and Cm-248 exceed the site worker dose criterion. The ESC notes that the probability of Ac-227 and Cm-248 being in a bag at this activity concentration limit is very low given the total activities of both radionuclides in the 2016 UK Radioactive Waste Inventory (UKRWI) (1.1 MBq). Augean Plc proposes to limit activity concentrations of both radionuclides to 5 Bq/g in loose tipped waste. We query why it has asked for an activity concentration limit of 500 Bq/g for Cm-248 and 2000 Bq/g for Ac-227 in packaged waste? In addition, Augean Plc proposes higher activity concentration limits for other radionuclides. Augean Plc should demonstrate that this scenario remains appropriate at the maximum activity concentrations proposed for all radionuclides.

The revised ESC has activity concentration limits of 10 Bq/g for Cm-248 and 20 Bq/g for Ac-227 in packaged waste. These are now constrained by the revised erosion scenarios.

The dropped load assessment is one of the scenarios used to determine the limiting activity concentrations (see ESC paragraph 408) in waste consignments. We also test that the activity concentration per package, that is part of a consignment (a factor of 2 to 5 above the consignment activity limit), remains appropriate, this demonstrates that the maximum average and peak activity concentrations are appropriate for members of the public. In three cases (Th-228, Cm-243 and Cm-244), the worker dose from the higher activity packages exceeds the site worker criterion, but local rules for dealing with a spillage will ensure that workers are protected.

50. Augean Plc should clarify the calculation of doses from a tipper truck load spillage (paragraph 701). We think that the doses in Table 95 have been calculated by scaling up the doses from Table 94 by a factor of 40, however, this is not clear in the text.

The doses are calculated from first principles. The parameters used for the tipper truck load result in a greater release of the inventory by a factor of 40 (the load is x20 greater and the fraction released is double).

51. We note the potential for high doses to be received by site workers associated with wound exposure to thorium, plutonium and americium isotopes (Section E3.9). Management of the health and safety aspects of working with radioactive substances falls under the remit of the Ionising Radiation Regulations 2017 and is enforced by the Health and Safety Executive. We will not comment on these aspects in the context of the ESC.

Augean is conscious of its Health and Safety responsibilities as outlined in the Health, Safety, Quality and Environment Policy provided in Appendix C of the ESC. This was provided for information and as evidence of the Environmental Safety Culture and Management System in place within the company.

52. Table 77 lists parameters used in calculation of doses from fires. C_{TIAC} is given as 2.8 x 10^{-7} Bq h m^{-3} Bq^{-1} (from Clarke, 1979[9]). We have not found the data in the source document but note that Public Health England (PHE) in its 2014 NORM assessment for the Port Clarence landfills quote this parameter as 1.6 10^{-6} Bq h m^{-3} Bq^{-1} from the same source document. Can Augean Plc explain the difference? We note that this scenario has the potential to limit the radiological capacity of the non-hazardous part of the landfill.

Table 8 from the PHE 2014 NORM assessment quotes a figure of 2.8 x 10^{-7} Bq h m^{-3} Bq^{-1} and this is the same value that was used in the Port Clarence ESC (Table 77), to ensure consistency with the NORM assessment. We are unable to locate the source of the value 1.6 10^{-6} cited above in the PHE document. The referenced source document (Clarke, 1979) contains a series of graphs for different stability categories for dispersion at different release heights. The most probable source of the PHE value is from Figure 18 for Pasquill stability category F with dispersion over 30 minutes from a source at zero stack elevation and at a distance of 250 m downwind (noting that the units presented in these graphs are Bq s m^{-3} for a unit release). The R91 scheme covers categories from A to G representing increasing atmospheric stability – where G is the most stable (radiological assessments often use category D as default). These are therefore very cautious assumptions for a coastal location (see Figure 11 of Clarke, 1979, that shows coastal impact on stability category distribution), i.e., we have used an assumption of stable conditions in an area unlikely to experience stable conditions.

10.3 Post-closure radiological assessment

Erosion scenarios

53. Paragraph 742 states that “a loss of a significant depth of cover materials through rainfall induced erosion is unlikely where a restored landform is vegetated and subject to periodic inspections and maintenance activities as appropriate”. We accept that the presence of vegetation will reduce erosion, however, roots will take up contaminants and their growth may adversely affect the structural integrity of the capping layer. In addition, we are unable to accept arguments relating to management controls after surrender of the permit. The cap will form a topographic high that could increase the potential for erosion by wind and rain or damage by drought. The erosion potential could be reduced by careful selection of vegetation. Radioactive waste may contain long-lived radionuclides that remain hazardous over the very long-term. Augean Plc should demonstrate the steps that it will take to ensure that the erosion potential is minimised and assess the time period likely to be taken before the cap could be eroded enough to expose the waste.

Paragraph 741 and 742 of the ESC discuss enhanced rainfall caused by climate change in the context of the HRA and the use of a durable GCL in the landfill capping system. The second paragraph was not meant to offer an argument that inspection and maintenance would continue in perpetuity and was qualified “as appropriate”. The appropriate timescale for inspection would be the period of authorisation and the permit could not be surrendered until it has been shown that the site does not require ongoing maintenance.

The site topography, slope and vegetation plans are designed to limit the formation of preferential channels for run-off and limit the damage that could occur to vegetation from drought or to the integrity of the capping layer from the action of roots. Indeed, we are not aware of any evidence that for a modern designed and constructed landfill, such as Port Clarence, significant root penetration of the cap occurs or that there is significant uptake of contaminants into the plants (see comments on the Forestry commission research below). The maintenance period will be used to reprofile or replant any problematic areas.

Landfills designed and constructed as containment sites with low permeability caps and domed profiles haven't been around for more than about 30 or 40 years therefore the experience available doesn't reflect the timescales in the ESC. It is routine for completed and capped landfill sites to be covered with restoration soils and vegetated in order to bind the cover layer and minimise soil runoff. Generally limited maintenance is needed for these sites once the vegetation has become established which is generally within 2 to 3 years of planting.

The uncontrolled flow of water over the capping and restoration system could result in the erosion of the restoration soils and potentially the underlying mineral layers. Monitoring of erosion is undertaken by regular walkover surveys in the early years following restoration which is the period when the profile of the site may change as the wastes settle and the flow of water may also change to produce channelling in previously unaffected areas. These surveys allow early improvement and remediation works to be carried out which minimise the risks of development of deeper erosion features. Significant settlement of the waste is unlikely to occur after approximately 5 years after completion of waste deposition.

The vegetation and restoration infrastructure developed on the restored landfill will be subject to a ten year aftercare period following the completion of the restoration works under the conditions of the planning permission. However, because some planting will have been carried out whilst areas of the landfill remained operational, some areas will have been in the care and management of the operator for a much longer period of time during which time considerable experience will have been gained in ensuring vegetation establishes well and ground cover is sustained. In addition, the landfill site (non-LLW) permit will be in place for at least 60 years after site closure during which any necessary maintenance and improvement works will be carried out.

The restored site slope gradients are not excessive (the restored surface will have a slope of less than 7.5 degrees) and there are no sudden changes in topography as shown on the attached approved restoration plans so there is no reason to anticipate the development of erosion channels which may result in erosion of the restoration soils and then the low permeability cap. Well established vegetation protects the soil and prevents runnel developing. All designs for landfill sites including the capping systems are subject to stability risk assessments as part of the permit applications and construction of the capping systems and subject to CQA and Verification, all of which is approved by the EA. Accordingly the stability and long term integrity of the designed and constructed systems have a high degree of reliability and confidence.

Concerning the reference to contaminant take up and root development we note that LLW will be at least 2.6 m below the restored surface. The main rooting depth is within 1 m of the surface and few roots can penetrate to this depth and take up moisture and nutrients. We note that uptake from depth is very limited (see response to Item 62 below). If the risks of root intrusion into a compacted low permeability cap is the issue of concern, there is government funded research data for work carried out by Forest Research which shows that the roots of plants including trees planted on landfill sites with at least 1 m (or 1.5 m for trees) of cover soils do not penetrate into the compacted capping layer in the first 16 years after planting – the roots simply spread laterally above the cap (Department for Communities and Local Government, 2008). This is normal root behaviour in any soil. The Forestry Commission research has challenged the perception that trees are deep rooting.

54. The coastal erosion assessment is based on an assumption that erosion will not take place before 2,500 years after present at the earliest. As we discuss in Section 6, we consider that, on the basis of evidence included in the ESC, it is not possible to make a case for erosion not occurring in the next few 100 years. We realise that addressing our feedback on prediction of coastal change would involve a lot of work, potentially disproportionate to the application. One way forward would be to treat it in a similar manner to human intrusion that is by assuming that no credit can be made for the effect of coastal or other defences after the period of institutional control. This would be conservative, but in the absence of additional information, could be defensible. The current assessment shows that coastal erosion of the landfill at 2,480 years after closure is limiting for 15 radionuclides, most of which are long lived (>103 year half-life) and many of which have relatively high proposed activity concentration limits. Although it will not make a significant difference to the capacity of the 15 radionuclides currently limited by this scenario, which are relatively long-lived, other radionuclides may come into play if the erosion timing is brought forward.

The updated erosion scenario that will be presented in the ESC is described in Appendix E and this now uses the end of the Period of Authorisation for the inventory of the site whenever natural disruption of the site occurs from coastal erosion. See also our response in Section 6 above.

Clearly, the approach proposed here by the Environment Agency for a natural disruptive process is not really similar to the treatment of human intrusion. The main arguments used by the Environment Agency when arguing for human intrusion assessments immediately after the period of institutional control is that there are then no active controls over management of the site and that records will not be a deterrent or be available to indicate that radioactive waste is buried at the site. The assumption that natural disruptive processes will occur 60 years after closure (i.e., assuming that coastal defences fail to prevent erosion at this time) may be analogous in some ways but the scenario is used to limit disposals using a dose guidance level of 20 μSv y^{-1}, applying a completely different criterion to human intrusion.

55. The assessment calculations for a coastal walker are described in Section E4.5. The dust loading factor (Minh) is not specified, nor are the landfill volumes and density and the dose coefficients referenced. These data should be clearly referenced to support the audit trail for the calculations and to demonstrate consistency in parameters used in the different models. We query the timing of these calculations (2,540 years after site closure) as being nonconservative above. A dog walker exposure time of 73 h/y is calculated in paragraph 908, while the bullet after paragraph 909 states an occupancy of 57 h/y. Augean Plc should clarify which occupancy rate was used and, if the lower one was used, justify its derivation.

The table below will be added to the section when the ESC is re-issued to clarify the parameter values used. The coastal walker exposure time specified in the text (73 h/y; paragraph 908) was used for the assessment and the equation bullet point will be updated to be consistent when the ESC is re-issued.

Parameters for the coastal walker exposure assessment

Parameter	Units	Value	Description
$V_{landfill}$	m^3	See Table 61	Volume of landfill (cells) in which activity is homogeneously distributed
M_{inh}	kg m^{-3}	1 10^{-7}	Dust load of contaminated waste inhaled by the coastal walker
ρ_{waste}	kg m^{-3}	1,530	Density of the waste
$D_{irr,slab}$, D_{inh} D_{ing}	Sv Bq^{-1}	See Tables 200 and 201	Dose coefficients

The timing of the onset of erosion is discussed in response to Item 25 above.

56. The landfill erosion scenarios all assume that the LLW is mixed with non-radioactive waste in the ratio 20:80 respectively. We consider that the assumption that exposures are dependent on the average activity concentration in the exposed cliff face for scenarios that are compared with the risk guidance level (or its dose equivalent) is appropriate. We discuss assessment of heterogeneity relating to exposure to large or discrete items and via human intrusion later in this section.

Accepted.

57. The criticality assessment prepared for ENRMF (paragraph 746) is based on a maximum activity concentration of 200 Bq/g. However, Augean Plc proposes significantly higher activity concentration limits for disposal to the Port Clarence landfills for fissile radionuclides (U-233, U-235 and Pu-241). Therefore, the ENRMF assessment is not an appropriate comparator. We do not expect significant amounts of fissile material to be disposed of to near-surface facilities, however, we accept that small quantities may be present within waste sent for disposal. In line with the GRA, we consider that “the environmental safety case should consider the issue of a criticality event, although we recognise that a simple analysis should be sufficient to demonstrate that such an event will not occur” (paragraph 7.3.31). Augean Plc should also determine whether additional controls on fissile radionuclides would be needed. Augean Plc suggests use of the IAEA Transport Regulations (SSR6 2018) provisions for fissile-excepted material are used as a trigger for requiring prior agreement with the Environment Agency that disposals are acceptable. Without further substantiation, we suggest that a threshold value of 0.25 g of fissile material, along with the other provisions of paragraph 222 of SSR6 (i.e. based on the definition of non-fissile material) would be a more appropriate trigger for requiring prior agreement with the Environment Agency.

Theoretically, if fissile materials in the waste move over very long time periods and re-concentrate, it may be possible to achieve criticality if there is enough fissile material present in one of the landfills. This would require a critical mass of fissile materials to be both present in a single cell and subsequently to become arranged in an ideal configuration that allows criticality conditions to arise. The proposition presented in the ESC was that criticality conditions during transport, handling and site operations are prevented effectively through adherence to radioactive materials transport package limits for fissile materials.

The criticality assessment prepared for the ENRMF (Augean, 2009) was based on a very cautious assessment of the behaviour of fissile material relative to the site radiological capacity. It was not based on an activity concentration of 200 Bq/g. It is important to note that criticality is not considered realistically feasible for LLW facilities under practical circumstances and has not been observed in such facilities. The conclusion of the study for the ENRMF was that a long term overall average % wt of U-235 in U-238 of less than 1% wt would ensure long term criticality safety of the landfill. The radiological capacity of other fissile elements did not reach a critical mass in that assessment.

The following table was suggested in the ESC for use at Port Clarence as appropriate for disposal of packages that may contain small amounts of fissile material.

Table 100: Provisions whereby material and packages are excepted from classification as fissile (IAEA, 2018)

SSR 6 Para	Requirement
417 (a)	Uranium enriched in uranium-235 to a maximum of 1% by mass, and with a total plutonium and uranium-233 content not exceeding 1% of the mass of uranium-235, provided that the fissile nuclides are distributed essentially homogeneously throughout the material. In addition, if uranium-235 is present in metallic, oxide or carbide forms, it shall not form a lattice arrangement
417 (c)	Uranium with a maximum uranium enrichment of 5% by mass of uranium-235 provided: (i) There is no more than 3.5 g of uranium-235 per package. (ii) The total plutonium and uranium-233 content does not exceed 1% of the mass of uranium-235 per package. (iii) Transport of the package is subject to the consignment limit provided in para. 570(c).
417 (d)	Fissile nuclides with a total mass not greater than 2.0 g per package, provided the package is transported subject to the consignment limit provided in para. 570(d).
570 (c)	45 g of fissile nuclides per consignment
570 (d)	15 g of fissile nuclides per consignment

The UK Transport regulations currently align with the 2012 publication of IAEA SSR 6, however the relevant values remain the same in Rev. 1 of SSR 6 (IAEA, 2018) as presented above.

The Environment Agency accept that small quantities of fissile materials may be present within waste sent for disposal. The Environment Agency have therefore proposed that the following limitations (from IAEA SSR 6) are used as a trigger above which prior agreement for disposal of a consignment is required.

> 222. *Fissile nuclides* shall mean uranium-233, uranium-235, plutonium-239 and plutonium-241. *Fissile material* shall mean a material containing any of the *fissile nuclides*. Excluded from the definition of *fissile material* are the following:
>
> (a) *Natural uranium* or *depleted uranium* that is unirradiated;
> (b) *Natural uranium* or *depleted uranium* that has been irradiated in thermal reactors only;
> (c) Material with *fissile nuclides* less than a total of 0.25 g;
> (d) Any combination of (a), (b) and/or (c).

We accept this definition but request that U-235 enrichment up to 1% by mass of uranium is also excluded from the definition of fissile material (from IAEA SSR 6). This is then consistent with the treatment of slightly enriched uranium under transport regulations.

58. The ESC outlines the reasons for considering that abstraction of contaminated water underlying or down hydraulic gradient from the site is unlikely (paragraph 734). We agree that use of the groundwater in the immediate vicinity of the landfill is unlikely due to the proximity to the tidal part of the Tees Estuary (in addition to the salinity and the future sea level rise/flooding issues, the existing groundwater is contaminated).

Accepted.

59. Figure 19 and supporting text in paragraph 788 is confusing since the term ‘q_out’ is not presented and the infiltration through the cap is not visible after about 300 years. The figure appears to show that infiltration through the cap will be approximately an order of magnitude greater than the actual flow of water through the base of the cells. If this situation is correct then we’d expect a rapid increase in leachate levels after the end of leachate management. Augean Plc should address and clarify this point.

The new GoldSim model includes a dynamic water balance model that has been created to consider sea level rise as an additional potential source of water influx into the waste cell. In the revised ESC the text and figure representing the water flow will be replaced with updated versions representing the most recent GoldSim model. The new model no longer uses the term ‘q_out’.

Flows into the waste cell include:

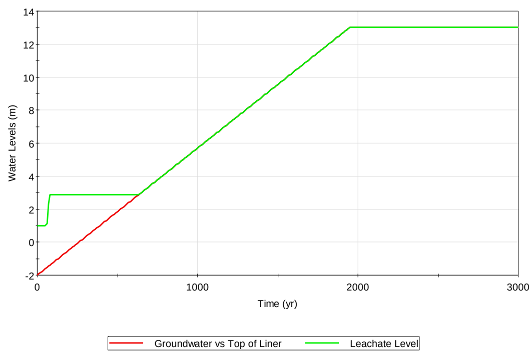
- Infiltration – due to rainfall;
- Inflow through Liner and Barrier – due to groundwater level rising above leachate level; and,
- Inflow through Cap – due to groundwater level rising above the height of the bund.

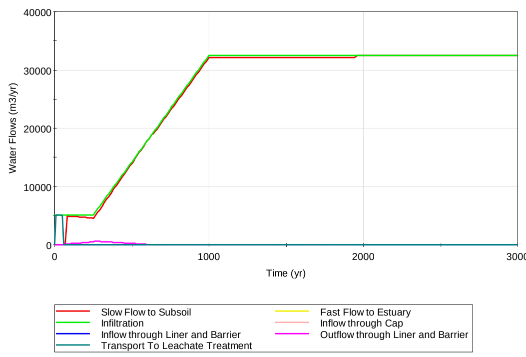
Flows out of the waste cell include:

- Outflow through Liner and Barrier – due to leachate head;
- Slow Flow to Subsoil – due to leachate rising above the bund; and,
- Fast Flow to Estuary – present only if the leachate breakout exceeds the capacity of the soil. In the examples below, fast flow to estuary does not occur.

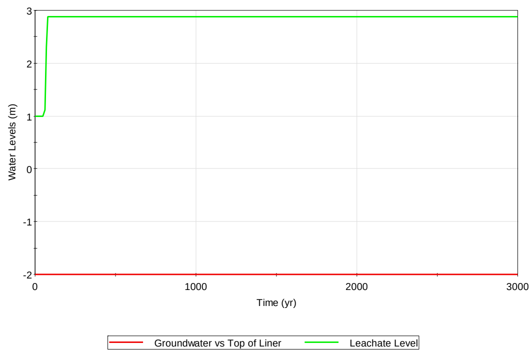
During the period of authorisation (assumed to last 60 years), the leachate is actively managed. If the leachate level is higher than 1 m, any excess leachate is pumped off and transported to a leachate treatment facility.

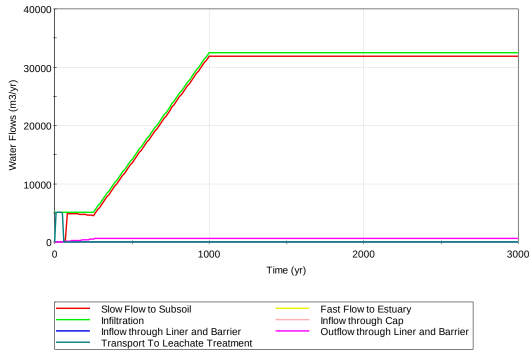
Example scenario 1: Linear Climate Change. The seawater level is assumed to rise 15 m over a period of 1950 years. After the period of authorisation, the leachate level rapidly rises to the bund level and leachate breakout occurs. After 250 years, the basal geosynthetic liner is completely deteriorated and the flow through the liner and barrier is completely governed by the clay barrier. The maximum outflow through liner and barrier of 584 m^3/y occurs at 270 years because the leachate head continues to decrease due to sea level rise. The groundwater reaches the top of the perimeter bund after 630 years and there is no more leachate pressure on, and hence no leachate flow through, the base of the repository.



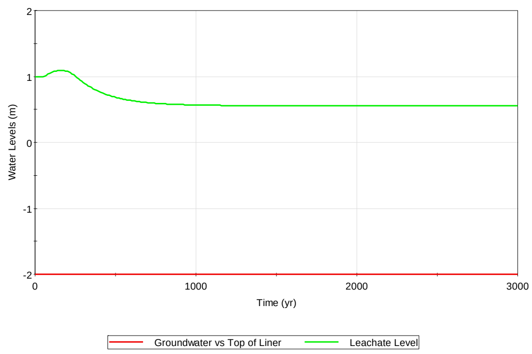


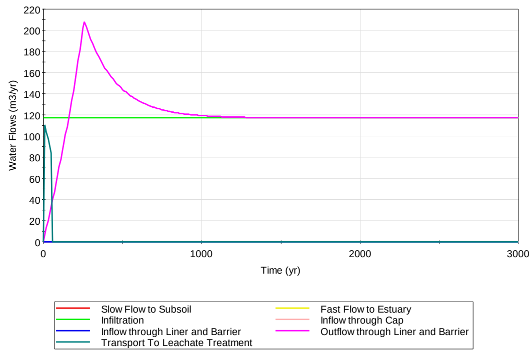
Example scenario 2: No Climate Change. Because the groundwater is expected to remain at the current level, an equilibrium sets in after 280 years, the basal geosynthetic liner having fully deteriorated after 250 years, with a flow through the basal clay barrier of 606 m3/y. Excess infiltration water is released to the subsoil as leachate breakout.





Example scenario 3: GCL Cap without Degradation and No Climate Change. With the much lower infiltration rate of 0.73 mm/y, the waste cell does not fill up to the level at which leachate breakout occurs. The flow through the basal barrier and liner increases until the geosynthetic basal liner is completely deteriorated and the flow is governed by the basal clay barrier. At this stage the maximum flow rate of 208 m3/y is reached then the leachate head adjusts itself to a level at which the infiltration rate and the flow rate through the basal clay barrier are both equal to 118 m^3/y and equilibrium sets in.





60. The ESC states that the irrigation rates used in calculations is based on soil moisture deficit calculations from Wittering near Peterborough, which is close to ENRMF (paragraph 868). However, a different rate is quoted in Table 119 (90.3 m/y) compared with the 2015 ENRMF ESC (0.15 m/y). Also, Table 119 quotes an infiltration rate for grassland of 202 mm/y from the 2011 ENRMF assessment, however, this was updated in the 2015 ENRMF ESC to 74.3 mm/y. Augean Plc should justify its choices for data used in the Port Clarence landfills assessment and, if taken from the ENRMF assessments, substantiate them for use at the Port Clarence landfills.

Table 119 in the Port Clarence ESC reports an irrigation rate of 0.3 m y^{-1} (the default value used in SNIFFER) with an infiltration rate for grassland of 202.4 mm y^{-1} (from 2019 HRA for Port Clarence). Table 56 in the ENRMF ESC reports an irrigation rate of 0.15 m y^{-1} with an infiltration rate for grassland of 74.3 mm y^{-1} (the latter from the 2014 HRA for the ENRMF).

We have reviewed the irrigation rate assumptions. The irrigation rate can be considered in terms of a regional soil moisture deficit or the difference between supply and demand for a particular crop. A site specific irrigation rate has now been derived for Port Clarence based on a soil moisture deficit (108 mm y^{-1}) calculated from monthly average rainfall recorded at Teeside weather station (reference DCNN 3263) from May to August (257 mm) and a daily water requirement for green vegetables (about 365 mm over the same period).

Bathtubbing

61. The bathtubbing scenario assesses impacts associated with the contamination of farmland. It appears to be assessed as a single event that can occur no earlier than 135 years after closure, assuming that leachate management has ceased. This date is not substantiated, nor does the ESC consider the potential for more than one bathtubbing event occurring in a year. Despite this, Augean Plc considers that the bathtubbing scenario may be considered analogous to flooding, and doses for 14 radionuclides exceed 20 µSv/y in the scenario as modelled, which may not be conservative.

A revised seepage/bathtubbing model has been developed based on the conceptual model description presented to the Environment Agency (MJCA, July 2020) and summarised in Appendix D.2.

62. We query the conceptualisation of bathtubbing in paragraph 888. The assessment assumes that 1% of activity in overtopped leachate reaches the groundwater. We do not consider this percentage is justified in the context of the Port Clarence landfills. A more appropriate calculation could be to model the transport of the leachate through the unsaturated zone in a similar manner to the groundwater pathway calculations. In the situation of sea level rise decreasing the distance between the landfill and the estuary, Augean Plc should consider the potential for overtopping leachate directly entering the estuary via surface water pathway rather than groundwater. Augean Plc should also substantiate the reason for assuming the hydraulic head in the subsoil in the event of bathtubbing is set to 10% of the initial leachate head in the waste cells (paragraphs 820 and 887).

The assessment considers the transfer of radionuclides following overtopping of the basal liner. Water that overtops the basal liner will be below restoration profile and will not therefore directly contaminate the soil surface layer because water will drain to lower soil layers. With a restoration layer of at least 1.3 m a mechanism is needed to transfer radionuclides from a saturated layer to a shallower depth where the majority of root activity occurs (noting that the roots of some plants will extend to a depth of 1.3 m). Studies at Imperial College provide observations of radionuclide transfer from a saturated layer upwards towards the soil surface (Wheater, et al., 2007). Based on a paper from these studies (Shaw, et al., 2004) we adopted a value of 1% for activity that is transferred from subsoil to surface soil. The remaining activity (99%) was assumed to drain to groundwater. Shaw et al. reported the movement of two very mobile radionuclides, Tc-99 and Cl-36 from a water table at 0.7 m depth to the upper soil layers. For Tc-99 the activity in upper soil layers was two orders of magnitude lower than that at the water table and Shaw et al. reported much lower transport of less mobile radionuclides. The study showed Cl-36 with upper soil activity at about 10% of that in the lowest layers but declining with distance above the water table. A value of 1% was therefore adopted as conservative for most radionuclides and probably realistic for Cl-36 with a water table at a depth of greater than 1 m.

A later, more detailed report (Wheater, et al., 2007) provides information for other radionuclides and we have used that information to assign percentage transfer to surface soil based on Kd. The revised ESC will detail this approach.

63. The ESC assumes that bathtubbing is very unlikely to occur in practice and it is not used to constrain radiological capacity for the same reason that groundwater pathway doses from irrigation and drinking are not (that is, due to the proximity of the site to the Tees Estuary). Whilst we consider this reasonable for agricultural exposures, we consider that other potential pathways may exist during a bathtubbing scenario given the geographical setting of the Port Clarence landfills, allowing migration of contamination along a fast pathway into the Tees Estuary. The length of this pathway may be gradually reduced due to sea level rise (and at some point in time it is likely that the landfill will form an island surrounded by the estuary/sea). This will lead to dispersal in the estuarine and marine environment, thereby affecting biota in these environments as well as those who eat contaminated seafood.

A seepage/bathtubbing scenario has now been included and a description of the revised model is presented in Appendix D.2.

64. Augean Plc should consider the doses associated with more than one bathtubbing event per year and reconsider the impacts associated with flooding of the bottom of the landfill postclosure, for which a single bathtubbing event per year will not be conservative. We can envisage a situation in which flooding or bathtubbing results in semi-continuous releases throughout much of the year. Augean Plc should also consider doses to additional exposures groups, such as a fishing family, and impacts to the wider environment. Doses to these latter groups should be used to limit the radiological capacity of the site if the relevant dose criteria are exceeded. In preparing the updated bathtubbing assessment, Augean Plc should take into account additional guidance provided by the Environment Agency in July 2020.

A seepage/bathtubbing scenario has now been included and a description of the revised model is presented in Appendix D. The revised model takes account of the correspondence of July 2020.

Gas pathway

65. In its ESC, LLWR Ltd noted that interactions between waste streams containing C-14 and waste streams that generate significant quantities of methane could promote releases of C14 bearing methane. This prompted LLWR Ltd to carry out a detailed assessment of C-14 gas generation, transport and behaviour in the biosphere. Generation of methane, which can act as a carrier for C-14 gas, is not likely to be significant in the hazardous landfill. However, it could be important in the non-hazardous landfill. The Port Clarence landfills ESC assesses the impact of C-14 labelled gas during the period of authorisation, using output from the GasSim model, and concluded that peak doses were below the dose guidance level. For the post-closure period, impacts associated with radioactive gas are calculated via the doses to site residents (intact cap) scenario, and were again shown to be below the dose guidance level.

Accepted.

66. Proposed activity concentration limits for C-14 are 10,000 Bq/g. In the LLWR ESC, impacts from gaseous C-14 in the period immediately post-closure have been subject to significant assessment. This work concluded that C-14 releases from activated steels and steel treatment products will take place during corrosion, leading to generation of hydrogen and release of C-14 bearing gas. Maximum activity concentration limits for C-14 for the LLWR are 12,000 Bq/g that is only just in excess of the limits proposed for the Port Clarence landfills. Augean Plc needs to demonstrate that corrosion of C-14 bearing waste, for example activated steel, will not lead to exceedances of the risk guidance level, or put in place additional waste acceptance criteria that restrict the waste form of C-14 bearing waste or other potentially organic gas generating waste.

The LLWR study, referenced above, of C-14 bearing gas (LLWR Ltd, 2013a) is cited in paragraph 635 of the ESC as the basis for the post-closure release rates of C-14. This is the same study summarised in the development overview document referred to by the Environment Agency (LLWR Ltd, 2013b) that was published a month later.

The activity concentration limits quoted by the Environment Agency above are based on the definition of Low-Level Waste (12,000 Bq/g) for LLWR and the Paris Convention (10,000 Bq/g) for Port Clarence. These numbers are included in the proposed waste acceptance criteria along with many other criteria to be fulfilled. Both LLWR and Port Clarence limit C-14 doses based on the total activity disposed, not the specific activity (i.e., activity per unit mass) of C-14 bearing wastes. Note that the proposed activity limits for loose-tipped waste are much more restrictive than those for packaged waste, to protect the workers handling the waste. The specific activity limit for C-14 at Port Clarence will be reduced to 2,000 Bq/g as per the response to Item 26. However, this reduction is **not** as a result of the risk posed by C-14 bearing gas.

Augean has determined radiological capacities for all relevant radionuclides, considering various scenarios. The limiting scenario for C-14 is the gas release and external exposure scenario, for which the parametrisation is based on the LLWR model. The LLWR C-14 model is based on a complex structure of waste in grout in container in vault, while the waste structure of Port Clarence is much simpler, i.e., packaged or loose tipped waste mixed with soil-like materials. The release rate for C-14 used in the Port Clarence assessment is 5% per year (or 5.0 10^{-2} y^{-1}), which is conservative compared to all referenced materials in the LLWR study. Release rates quoted in the LLWR study (LLWR Ltd, 2013a) are as follows:

- 1.0 10^{-5} y^{-1} for graphite to atmosphere;
- 4.1 10^{-4} y^{-1} for graphite to container;
- 2.70 10^{-4} y^{-1} for metal matrix and slag;
- 3.16 10^{-2} y^{-1} for organics, pucks, and other materials.

In addition, the C-14 is cautiously assumed to be released from Port Clarence to the atmosphere, whereas the LLWR model includes various intermediate retardation stages, defined per material.

The radiological capacity for the Port Clarence site is limited by the gas release and external exposure scenario. Augean will manage the site to ensure that this limit will not be breached.

Irrespective of the above and in the response to Item 26, we will reduce the specific activity limit for C-14 to 2,000 Bq/g per consignment.

Inadvertent human intrusion

67. The inadvertent human intrusion scenarios are assumed to take place from between 60 years after closure (that is, at the assumed time of permit surrender) and 200 years. The Near-surface GRA is clear on our position on the acceptability of controls after surrender of the permit. It states that “We do not envisage that the developer/operator will be able to substantiate that human intrusion into a near-surface disposal facility is unlikely to occur after the period of authorisation” (paragraph 6.3.37 “Human intrusion after the period of authorisation”). The ESC does not demonstrate the case for reliance on active controls after the time of surrender of the environmental permit, including those relied on to prevent future human intrusion into a disposal facility. We therefore expect the human intrusion calculations for all scenarios to be considered from the period of surrender of the environmental permit. This position is consistent with our feedback on the 2015 ENRMF ESC, which also assessed some intrusion events at times after the assumed time of permit surrender, but included doses at the time of permit surrender as a sensitivity study. Where the results of the sensitivity study indicated a capacity limiting scenario, we asked Augean Plc to reduce the radiological capacity accordingly (for example, for Sr-90 for the smallholder exposed group).

The intrusion scenarios are all now calculated at the end of the period of authorisation, 60 years after closure. The smallholder intrusion scenario at 60 years had already been included to reflect the 2015 request (see Table 28 of the Port Clarence ESC) and this remains more limiting than the scenarios that involved excavations on site at 150 and 200 years (that have all now been recalculated at 60 years). The 60 year assumption will be used in the revised ESC although our view remains that available records (planning records, Environment Agency, maps, location) will deter future development of the site for a considerably longer period.

68. Section E5 on human intrusion scenarios includes assessment of impacts associated with excavation for housing or road. These scenarios are only considered at 150 years. Augean should assess these scenarios at 60 years to determine whether they could be limiting for any radionuclides.

These scenarios have been assessed at 60 years and we can confirm that they do not limit any radionuclides either for a worker undertaking excavations or for a site resident. The 60 year assumption will be used in the revised ESC.

69. Paragraph 1014 demonstrates that a 5 Bq/g Ra-226 limit in the upper part of the landfill will not be conservative since an activity concentration limit of 2.7 Bq/g results in a dose of 3 mSv/y to an infant. Because of this, we suggest that there should be a 3 Bq/g limit for Ra-226 disposals in the upper part of the landfill (i.e. less than 5 m from the restored surface).

The inhalation rates and time spent not at home indoors have been changed and are now consistent with ICRP 66 (the basis for NRPB W36 and NRPB W41). The relevant concentrations for an adult, child and infant are now 5.4, 4.0 and 2.8 Bq g^{-1}. On this basis there will be a limit of 3 Bq/g for Ra-226 disposals in the upper part of the landfill (i.e., less than 5 m from the restored surface). The habit data now used for the resident living above contaminated spoil excavated from within the top 5 m of the landfill are shown below (see Tables B16A and B16B of ICRP 66).

Age group	Breathing rate at home indoors (m^3 h^{-1})	Fraction of time at home indoors	Fraction of time out of the home
Adult	0.90	0.92	0.08
Child	0.61	0.87	0.13
Infant	0.21	0.96	0.04

10.4 Large and discrete items

70. The ESC includes an assessment of doses associated with representative large items, which have a maximum average activity concentration of 200 Bq/g. These are described as "typical decommissioning wastes that may contain large heterogeneously contaminated items". They are the same as those assessed in the 2015 ENRMF ESC, which we accepted as appropriate. However, in the context of the significantly higher activity concentration limits applied for at the Port Clarence landfills, and the high likelihood of erosion of the landfill, we consider that they are not sufficient to assess heterogeneity over the upper end of potential activities that could be accepted for disposal. Thus the statement in paragraph 1092, to the effect that the calculations indicate that these risks are broadly consistent with the risk guidance level, has not been substantiated in the context of this application.

Section E6 of the ESC does not state that representative large items have a maximum average activity concentration of 200 Bq/g, in fact the ESC states "*the overall specific activity (activity concentration) may be less than a given value, e.g. 200 Bq g^{-1}, but the activity concentration within certain fractions of the waste may exceed this value, e.g. certain fractions may exceed 200 Bq g^{-1}*".

Proportionality was a key argument concerning the proposed activity concentrations for disposal that were outlined in the ESC. Radioactivity concentrations that represent the lower limit at which a material is considered radioactive are presented in Part 3 Table 2 of the EPR 2018. Out of scope activities for listed radionuclides range from 0.01 to 10,000 Bq/g - a range of several orders of magnitude and proportionate to the hazard presented by a radionuclide. Following discussions with the Environment Agency since the ESC was submitted, we have reduced the upper limit of the activity concentrations for low risk radionuclides to 2000 Bq g^{-1} in a consignment.

The revised ESC will consider the activity concentrations applied for in the context of the large items assessments.

71. We note that the dust load of contaminated waste in the core is over an order of magnitude lower than the equivalent calculations for ENRMF (Tables 153/154 of the Port Clarence landfills assessment compared with Tables 122/123 of the 2015 ENRMF ESC). The latter document states that the "adopted dust load is also higher than in previous scenarios presenting the maximum for a single event rather than an average. This is considered to be appropriate since the activity envisaged in this scenario does not involve deliberate handling of the waste." Why has this assumption changed?

The dust loads used in the ENRMF and Port Clarence assessment spreadsheets for the large contaminated items are the same but were reported incorrectly using the values assigned to only two of the worksheets that provided comparisons to earlier work for the ENRMF (Wilmot, 2014) on which the assessments are based. The values used in the ESC spreadsheets for a worker and for an occupant were 1.5 10^{-7} kg m^{-3} and 5 10^{-8} kg m^{-3}, respectively.

The quotation above extracted from the 2015 ENRMF ESC is relevant to the dust load used for the worker relative to that reported elsewhere for site occupants in the ESC ($1\ 10^{-7}$), and we believe this basic assumption remains valid. We also note that these scenarios are mostly dominated by the external exposure pathways and the dust load would need to increase by orders of magnitude to impact the total dose.

We have therefore reviewed the use of dust loading values used throughout the ESC and conclude that the values used in the revised ESC will be as follows:

- for site occupants and workers not directly handling waste, exposure is due to a dust load in air of $1\ 10^{-7}$ kg m^{-3} as used currently (see Tables 66, 80, 82, 119, 146 and 149);

- for workers handling waste use $6\ 10^{-7}$ kg m^{-3} as used currently (see Table 132); and,

- for workers and occupants involved in a single event non-handling assessment use $1\ 10^{-6}$ kg m^{-3}.

72. Given the lower dust load of contaminated waste used in the Port Clarence landfills assessment, we would expect doses to the site occupant to be lower than calculated in the ENRMF assessment, given that other parameters and equations appear the same. However, the doses calculated for the Port Clarence landfills are higher for the site occupant and site investigator for exposure to contaminated concrete demolition blocks, the main difference being due to higher inhalation doses. There are also differences in calculated doses for exposure to the other large items assessed, despite similar conceptualisation.

All dose coefficients have been reviewed for the Port Clarence ESC and the changes for these scenarios, in most cases small, are all due to the update of the inhalation dose coefficients previously used in the ENRMF ESC calculations.

There are three cases where this increases the total exposure significantly (up to about 70%), the concrete demolition slabs for the site occupant and worker and the worker exposed to contaminated crushed concrete. Given the proposed changes to the dust load under Item 71 there will also be differences between the revised Port Clarence assessments and the ENRMF assessments.

73. The discrete item assessment is not used to constrain radiological capacity but places limits on the activity of specific discrete items within consignments. As stated in paragraph 1132, all proposed discrete item limits are less than or equal to those used at the LLWR. Table 170 summarises the proposed limits for use at the Port Clarence landfills. The highest limits for the Group E radionuclides are 1000 GBq/t for discrete items between 1-100 kg in weight.

Accepted, noting that the assessment has been revised to account for the earlier date of erosion.

74. The maximum activity concentration limits for radionuclides in Groups D and E are greater than the LLW upper limits for alpha and beta/gamma activity. The maximum activity concentration limits for Group C radionuclides (which includes a number of alpha emitters) is also greater than the LLW upper limit for alpha activity. The ESC goes on to state that the discrete item limits for individual radionuclides will be used in a sum of fractions calculation to determine the overall acceptability of a discrete item. Although the ESC also states that the discrete item will be subject to meeting all other waste acceptance criteria (WAC) and consignment-specific activity limits, we are concerned that this could lead to ILW discrete items being disposed of in the landfill. We expect Augean Plc to acknowledge that use of the calculated discrete item upper limits could lead to disposal of items that are ILW, and to revise the limits down accordingly.

A waste consignment may include a sub-volume of waste or discrete items for which the specific activity of the sub-volume or discrete item is greater than the specific activity limits applied to the whole consignment. The specific activity sum of fractions calculated over the whole consignment (i.e., total activity for each radionuclide divided by total mass of the consignment) must be less than 1, as set out in Section 7.4.1.2 of the ESC. The specific activity limits will ensure that the consignment has a specific activity less than the upper limits for alpha and beta/gamma activity used to define what constitutes LLW, noting that these are now lower than submitted in the ESC, and the CFA (PC LLW01) includes the statement that the site is only authorised to accept LLW.

The discrete item assessment calculates limiting values that are not used as absolute limits. As stated in paragraph 311, a sum of fractions approach will be used to limit the activity concentration of discrete items. It will be made explicit in paragraph 310 that activity concentrations will not exceed those for LLW. On the basis that the total activity concentration of a discrete item is permitted to be greater than average waste, it is logical to apply a sum of fractions approach within the LLW limits for discrete items. However, the 4 GBq/T and 12 GBq/T upper limits for alpha and beta/gamma activity used to define LLW are radionuclide independent and are therefore not risk based. For example, two alpha emitters of a different element at 4 GBq/T will have different risks depending on the chemical and biological behaviour of the element. If low risk radionuclides are capped at the LLW limit this will constrain the residual sum of fractions that is available for the more limiting radionuclides. For example, capping a “Group E” radionuclide at 12 GBq, will overstate the risk associated with that radionuclide and thereby constrain an acceptable activity concentration of a radionuclide in “Group A”. We do not therefore agree that the upper Group limits for the sum of fractions calculation should be capped to the value of LLW. However, we do agree that the total activity concentration of a discrete item, i.e., the total activity of all radionuclides associated with the item divided by the total mass of the item, should not exceed the limits for LLW. We suggest that for individual radionuclides, the discrete item assessment limit could be above the LLW upper limits. However, this could not lead to consignment of a discrete item that has an overall specific activity above the LLW upper limits because the specific activity over the whole item must also be less than the LLW limits. Augean is happy to accept a condition to this effect.

75. The definition of discrete items has raised considerable debate in the nuclear industry since the concept was introduced into the LLWR WAC. Although LLWR Ltd has published a library of information to support decision-making, we are aware that ongoing determinations and liaison with potential consigners is taking considerable effort. If Augean Plc was to take this process forward we would wish to review internal procedures and satisfy ourselves that Augean Plc has sufficient technical support to implement these limits effectively. Disposal of such items to landfill would need to be demonstrated to represent best available techniques (BAT) by the consignor.

The maximum discrete item limits for disposal to the Port Clarence landfills should not exceed the LLW upper limits that is 4 GBq/t for alpha and 12 GBq/t for beta/gamma. The proposed discrete item limits for Group C, D and E radionuclides exceed this. We also note that the effective doses for some higher impact radionuclides in all the groups disposed of at the proposed discrete item limits exceed a dose of 20 µSv/y at some weights (Figures 31-35).

The suitability of all radioactive waste consignments for disposal will be assessed using internal procedures to ensure the waste is consistent with the assumptions used in the ESC. This approach has worked at the ENRMF where the pre-acceptance process has identified wastes for further appraisal. Augean has sought external technical support when there is any uncertainty over novel wastes and these assessments have been discussed with the Environment Agency.

The maximum discrete item limits in relation to the LLW upper limits are discussed in our response to Item 74.

76. We expect Augean Plc to: (1) update its discrete item limits and groupings in line with an updated time of erosion, taking into account our comments above; and (2) clarify its approach to assessment of acceptability of higher activity discrete items that meet the limits in Table 26 but which exceed the radionuclide-specific maximum activity concentrations in Table 32 (and potentially the LLW upper limit).

We will update our discrete items assessment to reflect erosion at unknown time and apply an inventory calculated at 60y after closure.

If a discrete item meets the discrete item sum of fractions limits but exceeds the consignment maximum activity concentrations that are given in Table 32 of the ESC, there are three potential outcomes:

- If the consignment as a whole meets the limits set out in Table 32 and the overall activity concentration of the discrete item meets the limits set out in Table 26 and is less than the upper bounds defining what constitutes LLW, the consignment would be accepted.
- If the consignment as a whole meets the limits set out in Table 32 and the overall activity concentration of the discrete item is more than the upper bounds defining what constitutes LLW or exceeds the limits set out in Table 26, the consignment would **not** be accepted due to the presence of the discrete item.
- If the consignment as a whole exceeds the limits set out in Table 32 the consignment would **not** be accepted.

10.5 Heterogeneity

77. The ESC discusses disposal of discrete items and particles but does not mention control of heterogeneous waste. The assessment calculations for the groundwater, gas, human intrusion and erosion pathways are based on an assumption that consignments are homogenous and that radioactive waste is mixed with the non-radioactive waste. Over large averaging areas, such as those used for the groundwater pathway calculations and intrusions involving large-scale disturbances, this assumption is appropriate. However, Augean Plc needs to further consider the impacts of heterogeneity.

ESC Section 6.4 considers the heterogeneity of waste and discusses the variation in doses that may arise due to different waste forms, such as particles, discrete items and large concrete objects and demolition rubble. In some human intrusion scenarios, there is limited mixing with non-radioactive waste (smallholder scenario) in others there is no mixing (borehole excavator). Further clarification was therefore requested by Augean Plc and was provided by the Environment Agency (letter from [redacted] dated 07/07/2020) as follows:

The baseline assumption in the Port Clarence ESC is that radioactive waste is homogenously mixed with other waste. This is appropriate for exposure pathways that involve dilution and dispersion of activity within the environment. However, there will be heterogeneity of activity within the radioactive waste itself, reflecting the heterogeneity of operational and decommissioning wastes, as well as localised areas within the landfill where radioactive waste is poorly mixed with non-radioactive waste. The ESC considers 3 scenarios for assessment of heterogeneity – exposure to discrete items and particles following erosion and exposure to heterogeneously contaminated large objects following erosion/intrusion (Table 24). What it does not consider is the impact of exposure to heterogeneity related to poor mixing of radioactive waste either at the consignment or landfill scale. We need to be satisfied that such heterogeneity will not lead to unacceptable risks during erosion or inadvertent human intrusion. Relevant scenarios have been considered in other landfill assessments; for example, the ENRMF assessment considered the impact of heterogeneity within a consignment, whilst Clifton Marsh considers the effect of poor mixing of radioactive waste with non-radioactive waste on human intrusion scenarios (selecting a smallholder scenario, with a residence constructed on top of the landfill, through to assessment) and on erosion (exposure during erosion of river banks).

The statement that “the baseline assumption in the Port Clarence ESC is that radioactive waste is homogenously mixed with other waste” is not accurate. The mixing assumptions for each of the scenarios supporting the ESC are presented below, showing that for the total of 45 listed: dilution with other waste is assumed to occur in 21 scenarios; there is no dilution and waste as disposed is assessed in 21 scenarios; and dilution is not considered in a further 3 scenarios involving gas generation. In the 13 scenarios that consider the fate of leachate, the concentration in leachate is calculated assuming that other waste comprises 80% by volume of the landfills - an indirect effect of the chemical interaction of radionuclides with the uncontaminated waste.

Relevance to ESC	Scenario description	Basis$
Radiological capacity calculations	Erosion - Dog walker (60y); Public	20%
	Erosion to coast - Fishing (60y); Public	20%
	Fire in non-hazardous cell - Operations; Public	no dilution
	Flooding; Public	20%
	Gas + External - Recreational user (0y) Ra-226 below 5m; Public	no dilution
	Gas used for energy generation - Operations; Public	n/a
	Intrusion - Smallholder (60y) Ra-226 below 5m; Public	20% + Cap
	Leachate spillage - Operations; Public	20%

Relevance to ESC	Scenario description	Basis[$]
Specific activity and other calculations	Dropped load (bag) - Operations; Worker	no dilution
	Dropped load (tipper)- Operations; Public	no dilution
	Dropped load (tipper)- Operations; Worker	no dilution
	ERICA - small-burrowing mammals	20%
	Exposure to discrete items	no dilution
	Exposure to large objects	no dilution
	Exposure to particles	no dilution
	Intrusion - Trial pit excavator (60y) Ra-226 below 5m; Worker	no dilution
	Loose tipping - Operations; Worker	no dilution
	Waste emplacement - Operations; Worker	no dilution
	Waste handling - Operations; Worker	no dilution
Assessed but not restricting	Dropped load (bag) - Operations; Public	no dilution
	ERICA results for Estuary	20%
	ERICA results for Freshwater	20%
	ERICA results for Terrestrial	20%
	Gas - Operations; Public	n/a
	Gas - Operations; Worker	n/a
	Gas + External - Resident (60y) Ra-226 below 5m; Public	no dilution
	Gas + External - Resident (150y) Ra-226 below 5m; Public	no dilution
	Gas + External - Smallholder (60y) Ra-226 below 5m; Public	no dilution
	Gas + External - Smallholder (200y) Ra-226 below 5m; Public	no dilution
	Groundwater to estuary - Fishing; Public	20%
	Intrusion - Borehole excavator (60y) – worker	no dilution
	Intrusion - Excavator (For Housing 150y) Ra-226 below 5m; Worker	no dilution
	Intrusion - Resident (60y) house over spoil; Public	20% + Cap
	Intrusion - Resident (150y) Ra-226 below 5m; Public	20% + Cap
	Intrusion - Smallholder (200y) Ra-226 below 5m; Public	20% + Cap
	Loose tipping - Operations; Public	no dilution
	Waste entering wound - Operations; Worker	no dilution
Assessed but very low risk - what-if only	Seepage/Bathtubbing - Leachate to freshwater; Public	20%
	Seepage/Bathtubbing - Residential; Public	20%
	Groundwater - Abstraction at boundary (100,000 y); Public	20%
	Groundwater - Barrier failure (100,000 y); Public	20%
	Leachate - Reed bed treatment (0y); Worker	20%
	Leachate - Sewage treatment/angling (0y); Public	20%
	Leachate - Sewage treatment/farming (0y); Public	20%
	Leachate - Sewage treatment (0y); Worker	20%

Note: $ The basis for the calculation is shown in this column. A value of 20% indicates that the scenario assumes that LLW disposal to the landfill is limited to 20% of the volume disposed to the landfills, where "+ Cap" indicates that the excavated waste is also diluted by the overlying capping materials and 1 m of uncontaminated waste that is placed over the LLW. No dilution indicates exposure to waste as disposed.

The baseline assumptions are:

- that exposure during the operational period following a dropped load or a fire considers waste as disposed;
- that a worker on-site is exposed to waste as disposed, whenever this occurs;
- that contaminated leachate/groundwater/floodwater/seepage considers the chemical interaction of liquids with the landfill mass and has therefore considered LLW to comprise 20% of the total landfill disposal;

- that disturbance of the site due to erosion or excavation that leads to exposure of a member of the public considers mixing of LLW with uncontaminated wastes and capping materials as appropriate; and,

- the inputs to Erica are taken from the contaminated leachate/groundwater model and has therefore considered LLW to comprise 20% of the total landfill disposal

Mixing within a consignment is considered further below (Item 78).

78. For other landfills, we have asked operators to assess impacts associated with exposure to undiluted radioactive waste during erosion. Relevant scenarios considered include assessment of informal scavenging and local organised material recovery as potential base case intrusion events into heterogeneous radioactive waste and assessment of an intrusion that includes a volume of undiluted radioactive waste at the maximum activity concentration limits. As an example, the 2011 LLWR ESC considers 4 potential such events: informal scavenging; local organised material recovery; commercial excavation; and technical or archaeological excavation. Following qualitative screening, it took the informal scavenging through to quantitative assessment. We expect Augean Plc to carry out a similar assessment for the Port Clarence landfills (also see Section 10.1).

Two examples are provided of assessment approaches to consider waste heterogeneity.

- Clifton Marsh: intrusion (selecting a smallholder scenario, with a residence constructed on top of the landfill, through to assessment) and erosion (exposure during erosion of riverbanks).
- LLWR: informal scavenging considered after screening out local organised material recovery, commercial excavation and technical or archaeological excavation.

Please see Item 40.5 for a description of our intended approach in the revised ESC.

11 Ecological assessment

79. The site lies close to Saltholme Pool and Dorman's Pool and to the North Tees mudflat, all of which are constituent parts of the Tees and Hartlepool Foreshore and Wetlands Site of Special Scientific Interest (SSSI), which forms part of the Teesmouth and Cleveland Coast Special Protection Area (SPA) and Ramsar site. Based on the plans submitted, Natural England considers that the proposed development will not have likely significant effects on these sites[11]. This is because the proposals will take place within the existing operational landfill site, with appropriate safeguards in place to ensure contaminants do not enter the designated sites, or affect the features associated with these sites and are unlikely to directly or indirectly impact on any designated site features.

Accepted.

80. The ESC includes an assessment of impacts to non-human biota. We consider the use of the ERICA assessment tool along with data from the FREDERICA database to be an appropriate means by which to assess impacts to non-human biota. However, Augean Plc should justify that none of the 28 radionuclides missing from the ERICA assessment tool (and therefore not carried through to the assessment) are significant.

We note that the ERICA Tier 1 assessments do not include all the radionuclides considered at Port Clarence. Tier 2 assessments include all the radionuclides considered at Port Clarence and were undertaken for terrestrial media (details in Table 185, and summary in paragraph 347), freshwater media (details in Table 184 and summary in paragraph 344) and for burrowing animals (details in Table 186 and summary in paragraph 352). The estuary assessment was performed using Tier 1 only and the justification for this is provided in paragraph 1220 explaining that a Tier 2 assessment was undertaken for Ca-41.

Not all radionuclides considered in the Port Clarence assessment are available in Tier 1 of the ERICA assessment tool. There are 28 radionuclides not included in the Tier 1 list of radionuclides within ERICA. Of these, Ac-227, Ag-108m, Am-242m, Am-243, Ba-133, Cm-245, Cm-246, Cm-248, Eu-155, Gd-153, Mo-93, Nb-93m, Pm-147, Pu-244, Sm-147, Sm-151, Sn-199m, Sn-123, Sn-126, Te-127m, U-236 and Zr-93 represent a small fraction in the UK Radioactive Waste Inventory (see Table 45 for the LLW composition); U-232 and U-233 are minor contributors to the U-vector; Th-229 is a minor contributor to the Th-vector; and, Pu-242 is a minor contributor to the Pu-alpha-vector. The remaining radionuclide, Ca-41, was therefore the only one considered further, in a Tier 2 assessment.

Further justification is based on the relative risk coefficients in Tier 1 and Tier 2. The following radionuclides that are not covered in Tier 1, have a risk coefficient higher than one tenth of the maximum risk coefficient of Tier 1 radionuclides in at least one of the assessments: U-233, U-236, Am-242m, Cm-245, Cm-246 and Cm-248. While U-233 and U-236 can exist in trace amounts in natural uranium, these are radionuclides that would appear in irradiated nuclear fuel. It is unlikely that irradiated fuel would intentionally be disposed of in a landfill but some limited contamination could be present in LLW. Principal actinide radionuclides in these wastes are U-234, U-235, U-238, Pu-239, Pu-240, Pu-241 and Am-241.

81. We have reviewed the ERICA assessment to non-human biota. We accept the case that impacts to biota in the estuarine environment will be minimal. For the freshwater environment, we query above a factor of 100 reduction in activity concentrations to account for transport to the upper soil layers (paragraph 888). As the U-234 dose rate is slightly in excess of 40 µGy/h, and dose rates for some other radionuclides, including Cl-36, are approaching 10 µGy/h, we expect Augean Plc to reconsider these calculations in the light of any change in the reduction factor. Similarly, the terrestrial biota assessment takes into account this reduction factor in concentrations from the GoldSim topsoil compartment. Dose rates to terrestrial biota for U-236 and U-238 are in excess of 40 µGy/h. We also consider that the results from these scenarios should be used to limit radiological capacity of relevant radionuclides including U-234 and U-236 (for which a capacity of 2,000 Bq/g is proposed).

The ERICA model for Freshwater is based on the peak activity concentration in water in topsoil (including the 0.01 subsoil to topsoil factor), with the peak activity concentration in sediment derived from this. The factor was considered cautious for transfer following a sub-soil release. We have since included a pathway in the GoldSim groundwater model to simulate transfer to the freshwater environment.

The new GoldSim model calculates release rates into the pond that would serve as a better basis for the Freshwater calculations, in combination with the IAEA SRS 19 lake model, which is implemented in the ERICA tool. The results of this approach will be included in the revised ESC.

82. Doses to burrowing animals from a number of radionuclides exceed 40µGy/h. In line with feedback we gave on the 2015 ENRMF ESC, we would like the capacities of these relevant radionuclides to be reduced to ensure that dose rates will be below 40µGy/h to ensure that burrowing animals are sufficiently protected. We consider that a landraise may be more attractive to burrowing animals than a landfill.

The amended timescale used for the inventory when the potential erosion of the landfill occurs has reduced the radiological capacity of the site and the dose to burrowing animals is now limiting the radiological capacity of the site for Ag-108m (reduction by a factor of 9.5 required), Sn-126 (reduction by a factor of 1.1 required), Eu-152 (reduction by a factor of 1.7 required) and Eu-154 (reduction by a factor of 2.7 required). These values may yet change. This burrowing animal assessment will be used to limit the radiological capacity even though burrowing animals are unlikely to get into the waste due to the presence of membranes and the drainage layer. Any doses are also likely to only affect individuals and not the whole population that guidance seeks to protect.

Notwithstanding the response above, we are not aware of any difference to the above ground level landforms between a landraise and a landfill that would result in preferential attraction to burrowing animals.

12 Radiological capacity management

12.1 Waste acceptance criteria

83. WAC should be suitably defined and prescriptive to ensure that waste consignors understand the requirements and are suitably informed as to how to comply. They should clearly specify the acceptable approach to activity averaging and define acceptable levels of heterogeneity in the activity distribution across a consignment. They should include quantitative criteria that are consistent with the assessments in the ESC, for example averaging masses, volumes or areas.

The NS-GRA (paragraph 7.2.18) notes that the environmental safety case should help to underpin the developer/operator's waste acceptance criteria and emplacement requirements. These and other requirements will be included in the CFA for Port Clarence and a draft is provided with this response (see Item 9 above). The document will comprise a generic set of conditions for the acceptance of low level radioactive waste for disposal at the Port Clarence landfills. The document will be based on the operational requirements of Augean and the Environmental Permit conditions issued by the Environment Agency. It is anticipated that the conditions, subject to the regulatory constraints, will be tailored to meet the requirements of each consignor. On this basis the conditions would be used as a guide for discussion of contractual arrangements between Augean and each consignor.

84. The WAC need to clearly state Augean Plc's expectations for the homogeneity of radioactive waste consignments.

Accepted.

85. We accept the particles waste acceptance procedure outlined in paragraph 1184, which is the same as that employed at ENRMF. Augean Plc should clarify whether it also intends to use the activity limits in Table 174 to screen particles or whether these limits are included for reference. We consider that the waste acceptance procedure, which was developed for human intrusion scenarios, is consistent with our previous advice [12]. Consignors will need to demonstrate that disposal of LLW that may include radioactive particles to the Port Clarence landfills represents BAT.

Paragraph 1184 states that a spreadsheet tool (prepared for the ENRMF and reviewed by the Environment Agency) will be used to assess the dose from the type of particle in the waste and Table 174 is therefore for reference. Paragraph 1182 is clear that it is not possible to determine generic waste acceptance criteria for waste containing particles as the characteristics of the particles (e.g., nuclides, size, solubility) will be specific to the consignment. Therefore, for waste acceptance purposes, waste containing particles will be considered on a case-by-case basis. The tool developed for the ENRMF would be updated for the Port Clarence radionuclides [Particle assessment tool v2.0 Final.xlsx].

86. We have reviewed the calculations for exposure to particles following erosion of the site and consider that the waste acceptance procedure is protective of human health in this situation.

Accepted.

87. The ESC describes the derivation of limiting radionuclide activity concentrations for each radionuclide in Section E6.5. These are derived using an intrusion scenario, the dropped bag scenario and worker doses after emplacement and during handling of a consignment. In the light of the requirement to update data in Tables 177 to 180, we have not reviewed the data currently presented.

Further discussions have taken place concerning the derivation of the activity concentrations that are presented in Tables 177 to 180. These activity concentrations will now be based on the scenarios for site erosion at an unknown time using an inventory based on 60 years after closure, the dropped bag scenario and worker doses after emplacement and during handling of a consignment and the limits specified in the NEA Paris Convention.

12.2 Approach to capacity management

88. The proposed approach to capacity management is complex. It involves comparing the radionuclide activity content of each potential waste stream against all the relevant scenarios for the relevant part of the landfill and disposal type (loose tipped or containerised) to calculate the sum of fractions for each scenario and then selecting the sum of fractions value associated with the limiting scenario to take forward for the site capacity management. In addition, each potential waste stream needs to meet maximum activity concentration limits that are set for each radionuclide. We are concerned that the proposed criteria will be complex for Augean Plc to manage and thus prone to error. They will also be difficult for consignors to characterise for, and to review in the context of their waste streams, thereby increasing the potential for misconsignment.

A spreadsheet is used by Augean for site capacity management at the ENRMF. This spreadsheet shows the cumulative activity of disposals and the activity concentration in each consignment. This spreadsheet has been adapted to provide a monitoring tool for disposals at Port Clarence, it includes an assessment of the activity concentration in each consignment and calculates the sum of fractions for each scenario based on the cumulative inventory (Bq). A consignment would not be accepted for delivery if that consignment caused the Sum of Fractions for any of the scenarios to exceed one. Whilst there is an increase in the number of scenario comparisons it is not complex and is the same as the approach used at LLWR. The characterisation required by a consignor is exactly the same, all consignment information is reviewed by Augean before waste can be sent to site which prevents mis-consignment to Port Clarence.

A copy of the spreadsheet Is provided with this response [Monitoring Tool Blank v5+examples (draft).xlsx].

89. In contrast, the ENRMF permit includes a single table for the limiting capacity for each radionuclide, defined as the lowest capacity across all scenarios assessed. In this way, a single sum of fractions calculation is required for each waste stream. There is also a single activity concentration limit for total activity. This is a more conservative approach, but one that is significantly easier to manage and is more transparent.

Please also refer to Item 88 above.

The introduction of the NEA Paris Convention on Third Party Liability now means that the sum of fractions has to be used to monitor activity concentrations in consignments containing total activity concentrations greater than 100 Bq/g. It is therefore not possible to assess disposal based on a single activity concentration if the activity limit used exceeds 100 Bq/g.

90. We suggest that a simpler method of managing site capacity would be more appropriate for the Port Clarence landfills and closer to the way in which it manages capacity at the ENRMF.

Augean accepts that it needs to demonstrate how it will manage waste acceptance ensuring that waste accepted does not exceed capacity or activity limits. It is recognised that the system must be auditable and a suitable spreadsheet has been developed for this purpose (see Item 88).

We consider that the waste management procedures that will be put in place will be robust and appropriate to ensure that the radiological capacity of the site is not exceeded. At the ENRMF, and proposed for the Port Clarence site, a sum of fractions provides a check that radiological capacity is not exceeded. There is no difference in the management processes that require LLW consignments to be entered into a monitoring spreadsheet by Augean staff, in which the sum of fractions is calculated and then reviewed.

91. NORM waste will be accounted for as a separate waste stream and compared with the NORM radiological capacity (paragraph 35, p27). We have agreed that it is appropriate to manage NORM and LLW waste streams separately; the NORM under the terms of the exemption and the LLW in line with the requirements of the GRA and the assumptions of the ESC[13]. We will require Augean Plc to maintain records of both NORM and LLW disposals and to maintain a record of combined impacts from both waste streams for relevant exposure scenarios covering both the period of authorisation of the landfill and after the period of authorisation. We have the following queries on the NORM assessment in the ESC:

Appropriate records will be maintained.

91.1 Augean Plc should confirm whether this NORM radiological capacity refers to the NORM weight capacities of 2.8×10^5 t and 1.5×10^6 t for the hazardous and non-hazardous landfills respectively, rather than a radiological capacity.

The ESC approach has developed further following clarification from the Environment Agency (see Appendix F). We intend to adopt an adjusted radiological capacity for LLW that will then be applied separately to the NORM disposals. The adjusted radiological capacity scales the radiological capacity calculated for relevant LLW radionuclides using the ratio of the NORM dose constraint to the LLW dose constraint. The NORM exemption specifies a legal limit of 1 mSv/y but is not explicit about a dose constraint. We have therefore applied a NORM dose constraint of 300 µSv/y in all situations. For NORM waste only this increases the radiological capacity where the LLW dose constraint is 20 µSv, reduces the radiological capacity calculated from intrusion scenarios (3 mSv/y), and has no impact for the period of authorisation where the same dose constraint is used for both waste types (LLW and NORM).

The revised ESC will detail the relevant NORM tonnages associated with the two landfills and the capacity limiting scenarios that determine the radiological capacity of the site.

91.2 Has Augean Plc updated its NORM capacities for each landfill taking into account the updated design?

The radiological capacity calculations and suggested adjustments discussed above take account of the updated landfill design. The tonnage capacities from the PHE study will be updated reviewing both the PHE calculations and the revised ESC calculations.

91.3 Para 35 goes on to say that a further check will ensure that the combined dose from the NORM and LLW disposal does not exceed the ‘appropriate dose criterion’. Augean Plc should clarify whether its calculations for NORM take account of the different dose criteria that are associated with NORM and LLW disposals.

Further clarification was provided by the Environment Agency concerning the dose criterion to be applied to the NORM disposals and this is presented in Appendix F. The ESC applies a dose constraint of 300 µSv/y during the period of authorisation to both NORM and LLW disposals. The NORM exemption specifies a legal limit of 1 mSv/y but is not explicit about a dose constraint or the period when this should apply. We have now applied a NORM dose constraint of 300 µSv/y to the period after authorisation in all situations.

91.4 Augean Plc proposes to limit future NORM disposals and notes that current receipts are around 100,000 t/y (paragraphs 413-313, p138). Does Augean Plc intend to treat this tonnage as an annual capacity?

The ESC did not specify an annual capacity for NORM disposals and Augean would not wish to be commercially constrained by an annual tonnage limit. Augean do not intend to treat this as an annual capacity but provided the value as an indication of future receipts. Items 91.1 and 91.3 provide the basis for the controls on NORM disposals.

92. Augean Plc proposes to bury waste containing > 5 Bq/g Ra-226 at least 5 m below the restored surface of the site (paragraph 40, p28). We assume this will relate to LLW disposals. Can Augean Plc confirm that this limit will also apply to NORM disposals if relevant, and confirm whether it has received any NORM disposals to date that could challenge this limit, or could receive such disposals in the future?

For simplicity, the limit will apply to any material that is known to contain >3 Bq/g Ra-226, whether NORM or LLW (see Item 69 above). We will not be applying the different dose constraints that are relevant to NORM waste to derive an alternative activity concentration in the upper 5 m of the landfill.

There are no NORM disposals to date that could challenge this limit.

93. As noted in Section 4, we will wish to review the proposed process for capacity management prior to any permit issue to make sure that they are fit-for-purpose and clear and transparent and that Augean Plc has suitably qualified and experienced technical support in order to assess the disposability of candidate waste streams and to manage radioactive waste disposals.

As stated in Item 88, we consider the waste management procedures that will be put in place will be robust and appropriate to ensure that the radiological capacity of the site is not exceeded. The procedures will be fit-for-purpose, have clarity and be transparent.

Augean Plc has a suitably qualified and experienced technical team that assess the disposability of candidate waste streams and to manage radioactive waste disposals.

13 Monitoring

94. The proposed monitoring regime is described in Section 7.5.2. The analytical suite contains fewer determinands than the one used for background monitoring (Appendix B). While measurements of total activity are an appropriate screening tool, they might not identify radionuclides present at low activities if the monitoring equipment is not appropriately calibrated. Augean Plc should demonstrate that the equipment it uses for its routine monitoring is sensitive enough to identify changes in activity of key radionuclides of interest, including NORM radionuclides and significant radionuclides in disposed LLW.

Draft Monitoring and Action Plan are provided with this submission for the Agency to consider. Four draft documents are provided separately for Port Clarence describing the monitoring and action plans for groundwater, leachate, landfill gas and particulates and asbestos (Port Clarence Groundwater MAP LLW 2022_draft.pdf, Port Clarence Landfill Gas MAP LLW 2022_draft.pdf, Port Clarence Leachate MAP LLW 2022_draft.pdf, Port Clarence Particulates Asbestos MAP LLW 2022_draft.pdf).

The radionuclides that will be disposed at Port Clarence has not yet been determined and it is not possible to state what the monitoring regime will need to detect. This results in a reliance on total alpha, beta and gamma to indicate any variance from the background samples that would then be the subject of further analysis. The analytical detection limits of initial samples were: total alpha <0.00085 Bq g^{-1}; total beta <0.0053 Bq g^{-1}; and, total gamma <0.31 Bq g^{-1}. These detection limits are lower than the out-of-scope entry point for radionuclide concentrations under regulatory controls.

All equipment used for environmental monitoring purposes is calibrated in line with the manufacturer's recommendations. The equipment used for dose rate monitoring is approved by the UKHSA for monitoring purposes and the UKHSA undertake re-assurance monitoring at other Augean sites to confirm the data collected. This approach will be undertaken at Port Clarence as part of the RPA provision for the site.

95. The role of environmental monitoring is both to demonstrate that the landfill system is performing as intended, and thus that the ESC assumptions remain valid, and to provide reassurance that the impacts associated with off-site migration of contaminants are low. To address the latter requirement, Augean Plc should consider the need for an enhanced monitoring suite that includes significant radionuclides of interest, to provide reassurance to the public. As an example, we carry out reassurance monitoring at ENRMF on an annual basis. In addition to total H-3 and total alpha, beta and gamma measurements, we use spectrometry to assess activities of radionuclides of interest, including alpha emitters (Pb210, Th alphas, U alphas, Pu-238, Pu-239+240 and Am-241), beta emitters (H-3, Sr-90 and Pu-241) and gamma emitters (K-40, Co-60, Cs-134 and Cs-137). Augean Plc should consider a similar monitoring scheme for providing public reassurance at the Port Clarence landfills (to include C-14).

Augean plc confirms that it is prepared to undertake re-assurance monitoring. As requested, the groundwater monitoring regime at Port Clarence will include spectrometry on an annual basis including the radionuclides of interest:

Alpha emitters (Pb-210, Th alphas, U alphas, Pu-238, Pu-239+240 and Am-241);

Beta emitters (H-3, Sr-90 and Pu-241);

Gamma emitters (K-40, Co-60, Cs-134 and Cs-137); and,

C-14.

The monitoring will be reviewed on an annual basis as part of the annual reporting with a review of the nuclides of interest, and additional monitoring locations or analysis included as necessary.

96. We consider that the description of Augean Plc's proposed monitoring regime (paragraph 445) lacks detail. We have the following queries:

96.1 Augean Plc should specify how many groundwater boreholes will be sampled and their locations. Groundwater should be sampled from both up and down hydraulic gradient boreholes to understand background inputs as well as any impact from the landfill, including several boreholes between the landfill and the River Tees along the nearest (south-eastern) site boundary.

Groundwater monitoring will be undertaken at the following locations (shown on plan auus22103 that accompanies this submission and discussed in Section 4.0 of the Groundwater MAP):

Upgradient boreholes: PC09, PC10a/b, PC15, PC14; and,

Downgradient boreholes: PC08, PC22, PC18, PC19, PC01a/b, PC03a/b, PC04a/b, PC12a/b, PC11a/b.

96.2 Paragraph 455 states that routine groundwater monitoring will include analysis for H-3 and Pb-210, however, the latter is not included in the analytical suites listed under paragraph 455.

Pb-210 will be included in the monitoring suite.

96.3 Augean Plc suggests that it will analyse an annual sample of bulked leachate. In comparison, bulk leachate samples are analysed from each cell at ENRMF. We expect the Port Clarence landfills to have a similar leachate monitoring regime, and to assess whether there are any significant differences in leachate composition between the hazardous and non-hazardous parts of the landfills.

Bulked leachate samples will be taken from each cell receiving LLW (hazardous and non-hazardous) on a quarterly basis, see the accompanying Leachate MAP.

96.4 Augean Plc proposes quarterly analysis of leachate treated off-site. We query whether this is sufficient to determine whether the leachate remains either out of scope of Radioactive Substances Regulation, or meets the receiving site’s permitted limits. Augean Plc should clarify the procedures that it has in place to make sure that no leachate goes off site that does not meet the receiving site’s limits.

Monthly sampling will be undertaken where leachate is being transported off site, where leachate is not being removed from site then the frequency will be reduced to Quarterly.

96.5 Augean Plc states that it will undertake biannual analysis of radioactive gas in the landfill gas generator input. It should confirm that this will include analysis of tritium, C-14 and radon. We suggest that an initial quarterly frequency would be more appropriate.

Analyses will include tritium, C-14 and radon, monitoring will be undertaken on a quarterly basis for the first 12 months and then a review of the frequency will be undertaken during the annual monitoring review. (Note - evidence from the LFG monitoring at the ENRMF has shown that radon concentrations in the landfill are lower than background levels due to the geological barrier provided by the landfill engineering.)

96.6 Augean Plc should clarify the locations of surface water samples. These should include the ponds and the Tees Estuary adjacent to the site.

The following surface water locations are monitored under the current landfill EPR permits and it is proposed that radiological monitoring will be undertaken at these locations.

PCSWPC09	This is an existing sampling point of standing surface water approximately 50m east of PC09 at approximate National Grid Reference 451280, 522610;.
PCSWWBLAG	This is a body of surface water directly adjacent to the drum compound at approximate National Grid Reference 451380, 522450.
PCSWGATE	This is a body of surface water south of cell 1A, next to the gate adjacent to the weighbridge, located at grid reference 451420, 522380.
PCRTEES	The River Tees lies adjacent to the southeastern boundary. When appropriate and during periods of high water a sample will be collected at grid reference 452200, 521800.

96.7 Augean Plc should specify the locations of the site perimeter dose rate monitoring and the dust monitoring points.

The site permitter dose rate monitoring was undertaken at the following locations (shown on plan auus22103:

- Site office;
- Site office car park;
- Adjacent to groundwater borehole PC22;
- Adjacent to groundwater borehole PC16a;
- Adjacent to groundwater borehole PC10a;
- Adjacent to dust location PCDD07; and,
- Adjacent to dust location PCDD05.

The dust monitoring was undertaken at PCDD04 and PCDD05 (shown on plan auus22103), this is up and downwind of the landfill operations on the prevailing SW wind direction. The Particulates and Asbestos MAP sets out monitoring locations and ability of monitoring equipment in Section 4.

96.8 Augean Plc should document its method for ensuring that the locations of the random surface soil samples are representative.

The following method, detailed in the Monitoring Action Plan is used to collect surface soil samples. A soil sample will be taken from each of the locations specified in Table 1.1 using a Soil Sampler Pro, Cross Sectional Soil Sampler.

- Samples will be taken to a maximum depth of 10cm.
- The soil sampler will be marked at a depth of 10cm, and the monitoring technician will then hammer the tube into the ground or use the footrest for extra force as required.

- The sampling tube will be twisted at least twice to break the base of the soil core and extract the sample.
- Once extracted the discharge rod will be used to push the sample out into a clean sample pot.
- The sample pot will be labelled with the date and location of sampling and returned to the laboratory as soon as practicably possible.

96.9 Augean Plc should specify detection limits.

UKHAS laboratory detection limits are detailed in table 5.4 below.

Radiochemical analysis	HPA-CRCE Scotland Generic LoD (Bq/l and Bq/g)	UK Drinking Water Quality Standards (Anglian Water Guidance)
Gross alpha	Water – 0.1 Bq/l Soil – 0.05 Bq/g	0.1 Bq/l
Gross beta	Water – 1.0 Bq/l Soil – 0.05 Bq/g	1 Bq/l
Gamma spectrometry	Water – 0.001 Bq/l Soil – 0.001 Bq/g	n/a
H-3 (Tritium) by distillation	Water – 5 Bq/l Gas – not tested at this lab	100 Bq/l
H-3 (Tritium) by combustion (solid samples)	Leachate/Soil- 0.005 Bq/g	n/a

96.10 Paragraph 454 notes that additional radionuclides would be analysed as the inventory of the radionuclides increases and passes certain trigger levels. Trigger levels will also be set for standard analytes (total alpha, total beta, gamma and H-3) in groundwater that would require analysis of additional radionuclides. Augean Plc should confirm what these trigger levels will be, the basis for decisions on exceedance (single measurement or number of measurements) and what additional radionuclides will be included in the extended suite.

The revised ESC will include the trigger levels requested above, the radionuclides that will be analysed and the basis for decisions on exceedance.

97. We are pleased to see that Augean Plc has carried out background monitoring of environmental radioactivity concentrations in surface water, groundwater, leachate, soil and dust samples. These data indicate low local environmental concentrations of radionuclides analysed for. The analytical suite includes total alpha and beta activity, H-3 and a number of gamma emitters, which we assume have been identified using gamma spectrometry. We have the following comments:

97.1 As noted above, measurements of total activity might not identify radionuclides present at low activities if the monitoring equipment is not appropriately calibrated.

Accepted. All analyses undertaken are by suitably accredited laboratories. The laboratory accreditations are included in the Monitoring and Action Plans.

All equipment used for monitoring purposes is calibrated in line with the manufacturer's recommendations. Records of calibration are retained and this information is regularly audited.

97.2 The suite does not include common alpha emitters such as Th-230, U-234 and U-238, which may be important contaminants in NORM and would be identified via alpha spectrometry.

The suite of radionuclides considered in the analyses includes markers for NORM in addition to an analysis of total alpha, total beta, total gamma and other selected radionuclides. Analysis of Ra-224, Ra-226, U-234 and U-235 are indicative of their respective decay chains. The common alpha emitters Th-230, U-234 and U-238 will be added to the monitoring suite and alpha spectrometry will be undertaken on an annual basis to ensure that common alpha emitters are regularly monitored.

The baseline monitoring undertaken on site to date is to provide an indication of the levels of background radioactivity at the site. The purpose is not to identify every radionuclide that is currently present in the materials used to reclaim land from the estuary. The sampling programme would be amended in due course to reflect disposals at the site when triggered by an increase in any of the baseline measurements.

97.3 It can be difficult to differentiate between Ra-226 (another common component of NORM) and U-235 using gamma spectrometry.

Augean Ltd use accredited laboratories for radiochemical analysis. For the monitoring information presented in the ESC all ground/surface waters, dust, soils and leachate samples were analysed by the PHE's CRCE Scotland laboratory (formally the Health Protection Agency (HPA)) accredited to ISO/IEC 17025: 2005 for radionuclide analysis through the United Kingdom Accreditation Service (UKAS).

98. Augean Plc should demonstrate that the screening analyses it has carried out would be sufficiently sensitive to identify background concentrations of all NORM radionuclides of interest (for example, with reference to detection limits of indicator species and using a valid fingerprint) or carry out additional analysis.

The monitoring schedule proposed for Port Clarence landfill site is consistent with the approach taken at the ENRMF site. This monitoring is supported by independent monitoring and verification from the Environment Agency and UKHSA. Once the monitoring programme has been agreed a full round of background monitoring will be undertaken in line with this programme prior to the receipt of LLW.

99. We would be happy to work with Augean Plc to develop an appropriate monitoring programme

This offer is welcomed, and we trust that the draft MAPs will provide the basis for discussion on this matter.

14 Optimisation

100. GRA Requirement R8 on optimisation states that, “The choice of waste acceptance criteria, how the selected site is used and the design, construction, operation, closure and post-closure management of the disposal facility should ensure that radiological risks to members of the public, both during the period of authorisation and afterwards, are ALARA, taking into account economic and societal factors.” Augean Plc’s approach to optimisation is discussed in pp106-109 of the Port Clarence landfills ESC.

Accepted.

101. Augean Plc’s case that the landfill is optimised with regard to LLW disposal is based on the landfill design and engineering being consistent with best practice for the disposal of hazardous and non-hazardous waste and strategies for enhancement of waste management (namely emplacement of waste with significant radium content at depth and strategies to reduce doses during operations). We accepted arguments that the ENRMF design was optimised based on consistency with best practice for the disposal of hazardous and non-hazardous waste when we permitted that site. However, this decision was based on a permit for disposal of low activity LLW with a maximum activity concentration limit per consignment of 200 Bq/g. The maximum average activity concentration limits applied for the Port Clarence landfills are significantly higher for many radionuclides. As discussed in section 9, the ESC does not discuss additional engineering requirements for these higher activity disposals. It also does not discuss any additional requirements related to location (that is, unlike ENRMF, the Port Clarence landfills are in a position with a high potential to be affected by flooding and/or erosion); for example, whether the design could be optimised to minimise leachate leakage to the surface environment via bathtubbing or flooding. While emplacement strategies for the disposal of certain waste streams at depth can be used to reduce impacts associated with inadvertent human intrusion, they will not be effective in reducing impacts associated with erosion of the site, which we consider to be a likely future at some time after surrender of the permit.

The revised maximum average concentration limits have been re-calculated and now include consideration of coastal erosion (at an unknown time in the future using an inventory based at the end of the period of authorisation). The concentrations that will be included in the revised ESC will be substantially lower and for many radionuclide fingerprints will be lower than an average value of 200 Bq g^{-1}. The specific activity of radionuclide generated from our updated assessments have also been capped at a maximum average of 2000 Bq g^{-1}, in order to give the Environment Agency comfort that the upper limit of the definition of LLW is not approached.

We detail below the ways in which the design and operation of the disposal facility is optimal for the disposal of LLW up to an average maximum of 2000 Bq g^{-1}. We have not carried out comparative assessments of the various options because these are limited both in terms of the approach to landfill design/construction that follows prescribed standards and because the final inventory is unknown.

Design

The landfill is designed and operated based on the principle of containment in accordance with modern standards and the use of Best Available Techniques in accordance with the Environmental Permitting Regulations (Schedule 7). The choices for further design optimisation are constrained by past decisions and by legislation relating to the disposal of hazardous and non-hazardous waste. It is not possible to generate a record that shows how the NS-GRA requirement of optimisation influenced site design. The adopted design features include:

- a leachate drainage system – a system is in place. The thickness, porosity and aggregate selection takes into account the need to minimise the potential for clogging and longevity of the material as well as including an element of redundancy. Accordingly, there are no further decisions to optimise, leachate generation is reduced by phased capping and utilised on site, monitoring ensures there is no transfer of in-scope activities off-site;
- an engineered geological barrier, made of clay – construction is subject to quality assurance testing and the hydraulic conductivity and thickness of the layer is already optimal for restricting contaminant flow, further optimisation is not appropriate;
- a 2 mm HDPE liner and protective geotextile – the basal and side liner prevent leachate movement into the engineered clay barrier, it is cautiously assumed that this layer deteriorates over time, the standard of the membrane is already optimal for containment, further optimisation is not appropriate;
- a low permeability engineered cap1 covered by a surface water drainage layer and restoration materials – quantitative consideration has been given to the impact of different engineered caps on leachate generation and the impact that can result from the permeability of this barrier, there have been further discussions on optimisation for this barrier focussing largely on accumulation of leachate and barrier degradation. The combined provision of a low permeability capping layer and an overlying high permeability surface water drainage layer provides optimisation in terms of the minimisation of the rate of infiltration hence minimisation of the potential for the generation of leachate;
- optimisation of the vegetation cover will be undertaken prior to seeking agreement of the final restoration scheme to ensure that suitable coastal vegetation types will be encouraged and the potential for surface erosion is minimised;
- arrangements for the management of leachate – leachate is now primarily managed on site and returned to the landfill – this is an optimal approach for the management of leachate;
- arrangements for dealing with landfill gases - a system is in place and there are no decisions to optimise; and,
- a systematic approach to monitoring environmental impacts – the monitoring plan agreed with the Environment Agency and specified in the permit would be modified should any unexpected levels radioactivity be discovered, UKHSA review all monitoring results and advise whether further investigation is required.

These design attributes accord with good practice for landfills and provide an appropriate strategy to limit the environmental impacts arising from contaminants present in waste. The design satisfies the requirements set out in the EU Landfill Directive and adopted in the Environmental Permitting Regulations. In the context of the assumed timescales and approach to landfill risk assessment, these measures will also be effective in limiting the environmental impacts arising from radioactive contaminants. In this sense, the design of the facility may already be considered to have been optimised.

[1] The detailed design of the low permeability capping layer at the site will be agreed with the Environment Agency and will comprise, a 0.3 m regulating layer, a protection geotextile, a low permeability geosynthetic clay liner and 1 m of restoration soils

A recent modification to the barrier between the two landfills considered whether LLW could be included in the engineered material used for the barrier. It was decided to exclude LLW from this part of the site thereby reducing the potential dose to operators from loose tipping and working of materials in-situ. This decision also keeps potential doses to the public as low as reasonably achievable by preventing exposure of the public off-site to resuspended dusts contaminated with LLW. The commercial impact is not quantifiable but it reduces the available radiological capacity of the site and has a cost impact.

The maximum average activity concentration limits applied for at Port Clarence are based on the relative risk associated with each radionuclide. This was not the case at the ENRMF where the activity concentration was constrained by planning consent that adopted a nominal value of 200 Bq g^{-1}. The NS-GRA makes no mention of 'low activity LLW' being distinct from LLW or a requirement for additional engineering measures if waste is not considered to be 'low activity LLW'. The risk associated with disposal has been used to assign proposed specific activity concentration limits for the Port Clarence landfill to each radionuclide, for example 200 Bq g^{-1} of Ra-226 having a broadly equivalent risk to 2,000 Bq g^{-1} of U-235 in the ESC. The risks upon which these limits were based were derived based on the engineering specification set out in the ESC. We intend to further reduce these limits as set out in Item 26 above. It is our view, therefore, that there is no requirement for additional engineering measures or optimisation beyond those already set out in the ESC.

The profiling of the restored surface will encourage surface runoff, preventing the development of puddles and reducing infiltration. Areas of the site will also be developed as woodland and these areas will have a deeper soil layer over the cap. This will further reduce the chance of intrusion disturbing waste or the already relatively low prospect of housing development at the site. The profiling also ensures that any seepage from the joint between the cap and basal liners will occur at depth (>1 m below the surface) reducing the potential impact of this event. The seal between the cap and basal liner is resilient and constructed by keying the engineered capping layer into the previously constructed side liner. The works at these boundaries, as with all engineering works for the containment system, are subject to the preparation of design and a Construction Quality Assurance Plan (CQA Plan) which must be approved by the Environment Agency. The construction is subject to third party Quality Assurance in accordance with the CQA Plan and the preparation of a Verification Report. The Verification report must be submitted to the Environment Agency for approval before the works are accepted as complete. All engineering works are subject to ongoing monitoring for the duration that the Environmental Permit is in place. This design, construction, Quality Assurance and approval process limits water flow across these barriers reducing the potential for seepage as well as the impact of any seepage and the potential for flood water to mix with waste.

Waste Location Requirements

As the landfill is constructed, the areas of the landfill that are currently in the Flood Zone 2 area of the site will be built up to the same level as the rest of the site, which is in Flood Zone 1. As such, it is not appropriate to limit LLW disposals to a certain area of the landfill, because the whole landfill will be at a similar risk of flooding.

Local flooding or sea level rise may see saturation of soil/made ground rise to a level that is above the base of the landfill at some locations. The design includes an engineered clay barrier beneath each cell and a HDPE liner to minimise water entering waste cells. There are also coarse materials and drainage pipes on the base of the liner to assist with leachate collection. When the HDPE liner degrades (and although still protected by the clay layer) there is the potential for saturation of the base of the landfill from floodwater for short periods and subsequent drainage to surrounding land. The design requires 2 m of waste, from which LLW will be excluded, to be emplaced on top of the base liner before LLW can be disposed. This 2 m of waste would also have to be saturated before the LLW begins to be saturated. The emplacement approach is intended to reduce the risk resulting from leachate build-up that can result of flooding or bathtubbing.

Waste emplacement 2 m above the drainage layer delays the time at which flood water could reach the base of LLW within the landfills. The relative height of the flood plain to the north and northwest (2.5 to 3 m AOD with some roads at 4 m AOD) will require flooding to a height of 8m AOD before LLW is impacted.

Operational considerations

A number of specific considerations have led to enhancements to the operational or emplacement approach to ensure that performance for radioactive waste receipt and disposal is optimised. Site operating procedures have been provided to the Environment Agency (see Item 9). Operational aspects in place for reasons of optimisation include:

- the use of waste packages for the vast majority of waste which reduce the probability of doses during operations, will also reduce leaching post-closure (in the case of drums), increase the prospect of the waste being recognised as hazardous during future human intrusion and reduces contact with non-human biota;
- the implementation of a limit on putrescible materials accepted at Port Clarence hazardous landfill ensures that microbial activity is minimised and gaseous release from microbial action or the potential for fire is minimised, specific limits are assessed for the waste disposed in the non-hazardous landfill to account for potentially greater organic matter content;
- Augean places a constraint on the dose rate 1 m from the surface of waste packages to ensure packages do not present a hazard on site;
- there will be no double handling of waste on site, it will be offloaded directly to the landfill and placed where it will be buried, operational procedures detail placement at the foot of a prepared face so that subsequent burial is facilitated using material higher up the prepared face;
- Augean places a constraint on the level of dust on the surface of waste packages to ensure this does not represent a hazard. Wastes placed in the landfill are also covered daily to prevent dust suspension and hence the risk of impacts via the inhalation pathway during the operational period;
- dust suppression is also undertaken in the case of loose tipped waste that could produce suspended particles, practical suppression measures would include avoidance of tipping during windy conditions and use of water spray suppression as required;
- a check is also undertaken on dose measurements at 1 m above the surface of the covered LLW, to ensure exposure of less than 2 $\mu Sv\ hr^{-1}$. The depth of cover will be increased if necessary to ensure that this limit is not exceeded. All operational staff involved in the LLW operations wear a TLD, despite expected doses not being high enough to require this. These precautions will provide additional confidence that no specific protective measures are needed for workers at the site who are closest to the LLW and will provide additional confidence that anyone off site is also suitably protected;
- operational constraints have been put in place to restrict the placement of waste in a landfill cell, placing non-radioactive waste to a specified depth at the base (2 m), distance from sides (2 m) and top (1 m) of a cell. This creates a barrier between the LLW and the side liner of a waste cell which will need to be located when the cell is capped - to make certain that workers do not come into contact with LLW packages when the landfill is permanently capped;

- cell caps will be constructed once disposal cells are full, eliminating potential dust resuspension if LLW became exposed and reducing water ingress, and hence reducing potential leachate generation; and,
- an additional limitation is proposed for wastes with significant radium contamination. Such wastes will be disposed at least 5 m below the restored surface of the site. This places radium below a reasonable intrusion depth and reduces the potential dose due to radon gas release from the landfill.

Coastal Erosion

LLW Repository Ltd apply specific activity limits to consignments on the basis of an 'informal beach scavenger' human intrusion scenario. A second human intrusion scenario, local organised material recovery, was also considered in the 2011 ESC, but doses were lower. These exposure scenarios are possible because the LLWR site is expected to be eroded by the sea, with the potential for wastes to be accessed from the beach. We consider a potential human intrusion scenario in which a person using the estuary (e.g., recreational walker) passes waste exposed by erosion and interacts with it in our revision to the ESC.

102. Also missing from the ESC is a discussion on optimisation of the waste form. Landfill disposals of bagged and drummed waste, and ISO containers where compatible with landfill stability requirements, have been demonstrated to represent application of BAT for the disposal of low activity LLW. However, the current practice for disposal of higher activity LLW is containment in grouted ISO containers and disposal to the heavily engineered LLWR. Augean Plc has not demonstrated that disposal of some of these higher activity LLW streams in either bags, drums or ungrouted ISO containers to a landfill represents BAT.

The current practice of grouting ISO containers at the LLWR is performed to improve structural integrity within a vault by limiting void space. This is important because ISO containers are the only waste form accepted and therefore the voidage is key to the stability of the site. Recent studies have identified there is also an associated benefit from grout chemistry reducing radionuclide release to the near field. The Port Clarence landfill will receive wastes in other types of packages, and loose non-rad wastes (which form the majority of the waste). The design has been subject to stability risk assessments as part of the landfill permit applications and construction of the capping systems (MJCA, 2019); construction is subject to Construction Quality Assurance (CQA) and Verification, and all processes are subject to approval by the Environment Agency. Accordingly, the stability and long-term integrity of the designed and constructed systems at Port Clarence have a high degree of reliability and confidence. Hence, grouting is not needed to maintain the stability of the facility by reducing the void space. In fact, it is BAT not to add grout to the waste for disposal unless there is a good reason to do so. Similarly, putting bags and drums into ISO containers and then grouting them would not be BAT as there is no benefit gained by the additional grout. We do not believe a discussion of waste form optimisation is proportional to the disposal of waste to a landfill. It is proportional to waste disposal in the Geological Disposal Facility and it is arguable whether such a discussion is even proportional for disposal at the LLWR.

Any disposal of LLW to the Port Clarence Landfills has to comply with the Conditions For Acceptance of waste (CFA; see Item 9) and the waste acceptance criteria and these are subject to agreement with the Environment Agency before waste disposal commences. If the consigning operator has established that disposal to landfill is the Best Available Technique (BAT) for the waste stream and it meets the CFA for Port Clarence, then the waste is considered acceptable for disposal. Although the requirement to demonstrate BAT for potential waste streams is not something the landfill operator is required to demonstrate and is not a requirement of the NS-GRA, the CFA requires the consigning operator to provide a

BAT assessment for disposals and this is reviewed by Augean before waste is accepted for disposal. The principles of optimisation in the management and disposal of radioactive waste are discussed in guidance from the Environment Agency (Environment Agency, 2010) and apply to the disposals received at Port Clarence. There is an expectation that, when disposing of radioactive waste, operators need to ensure that the radiological impacts on people are kept as low as reasonably achievable during the period of authorisation and afterwards. There is an expectation that this is achieved through use of BAT in the relation to the management of the generation and disposal of radioactive waste.

The Environment Agency require use of BAT to help minimise impacts of LLW disposal to the public and on the environment. The design of the landfill sites at Port Clarence are consistent with best practice and regulatory requirements for the disposal of hazardous wastes and non-hazardous wastes and are therefore considered to be optimised landfill designs and are based on BAT. The procedures for receipt and burial of waste minimise the immediate radiological effects on the environment and members of the public (burial within 24 hours with non-radioactive cover materials). Environmental sampling and monitoring use a best practice approach for landfill sites and will be subject to independent verification monitoring by the Environment Agency. The radiological assessments supporting the ESC use cautious assumptions to limit disposals ensuring that actual doses will be substantially lower than the limits specified in the NS-GRA. Use of BAT by the consigning operator further helps to ensure that any radiation risks to the public and the environment will be as low as reasonably achievable.

103. The ESC states that the “use of waste packages, which reduce the probability of doses during operations, will also reduce leaching post-closure and increase the prospect of the waste being recognised as hazardous during future intrusion” (paragraph 484). This claim is only applicable to drums and ISO containers, not bagged or loose tipped waste.

The ESC discusses operational strategies that optimise the reduction of exposure and waste packages are mentioned in paragraphs 345 and 484 reproduced below.

345. The waste packages reduce the probability of doses during operations, reduce leaching post-closure and increase the prospect of the waste being recognised as hazardous during future intrusion. The activity concentration associated with loose tipped waste is limited to a lower value so that disposals cannot result in unacceptable doses. Dust suppression is used where required.

484 A number of specific considerations have led to enhancements to the operational or emplacement approach to ensure that performance for radioactive waste is optimised. These include:

- *The use of waste packages, which reduce the probability of doses during operations, will also reduce leaching post-closure and increase the prospect of the waste being recognised as hazardous during future intrusion. Lower limits to the activity concentrations of any loose tipped waste and site procedures to cover these operations which will minimise dispersion of the waste material during tipping.*

We agree that not all waste packages will reduce leaching post-closure and for clarity will separate the statement. We note that the safety case does not rely on this claim to reduce contamination of leachate. All contaminants in waste are assumed to be chemically available for transport to and in leachate. The text will be amended to read:

> *“The use of waste packages reduces the probability of doses during operations and increase the prospect of the waste being recognised as hazardous during future intrusion. Some waste containers will also reduce or delay leaching post-closure.”*

We note that the bags used to transport LLW are constructed to high standards and are engineered to be durable and water resistant (e.g., PacTec Type IP-3 LiftPac).

104. We expect Augean Plc to make a case that the Port Clarence Landfills represent an optimised approach for the disposal of all LLW streams covered by the permit application, and that the landfill engineering and management procedures are optimised to ensure that impacts are ALARA. We also expect Augean Plc to demonstrate that the waste form and packaging represents BAT.

There is no requirement in current guidance to provide evidence that the disposal to landfill is the optimised approach for all LLW streams covered by the permit. It is the operator that generates the waste that is required to show that disposal to Port Clarence is BAT and waste generation is minimised. It is a requirement for Augean to show that the landfill operation is BAT (landfill design, management procedures, receipt of waste, burial, discharges, landfill closure etc) and that impacts of disposal are ALARA as discussed above.

It is our contention, and that of the operators at other landfill sites receiving LLW, that compliance with the requirements of the Landfill Directive ensures that the facility is applying BAT. Whilst there are differences between the default BAT applied to a landfill receiving hazardous or non-hazardous waste, and these largely concern the thickness of the clay basal liner, the default design criteria are replaced by the findings of a site specific hydrogeological risk assessment (HRA) where this demonstrates that the requirements of the EU Groundwater Directive are met. The approach to and the objectives of the site specific HRA are the same for both non-hazardous waste and hazardous waste landfill sites. It is this site specific HRA approach that is used to design the engineered containment system for the site. The design is therefore optimised for the site specific setting and circumstances rather than simply being based on the default criteria.

15 Comments on data and equations

105. We have identified a number of errors in the data and equations supporting the ESC assessments. We would like Augean Plc to provide a copy of the quality assurance process that it and its contractors were working to during preparation of the ESC and supporting assessments. These errors have made our review more challenging and time consuming. In addition, they have lowered our confidence in the overall assessment. Augean Plc should carry out a thorough quality assurance check to avoid similar issues with re-submitted information.

The relevant checking procedure for the assessment models and reports is part of Eden NE project management instructions. There relevant sections are extracted below.

4.6 Technical Reports

4.6.1 Each technical report shall have a responsible author who shall be appointed by the Project Manager. The responsible author must check and review the report to assure themselves that it is of sufficient quality. This review must cover the formatting of the report, referencing, quality of English and technical content. They should record the check and review by signing the document history at the front of the report.

4.6.2 Each technical report must be reviewed by a reviewer. This review must cover the formatting of the report, referencing, quality of English and technical content. The reviewer should set out a series of comments (either a list or a marked up version of the report) and pass these back to the responsible author.

4.6.3 Where possible the document reviewer should be independent of the project team. Where this is not possible members of the project team should review the report contributions and calculations of other team members. To ensure some independence, no one should review their own work.

4.6.4 The reviewer shall identify any amendments or required clarifications and pass this on to the responsible author.

4.6.5 The responsible author should consider the comments. A record of how each comment has been tackled should be retained (e.g., a list of comments with ticks or annotations to explain why a comment has not been actioned).

4.6.6 Any disagreements resulting from the process of checking and review should be discussed and resolved with the responsible Project Manager.

4.6.7 A revised report should be submitted to the reviewer. If the reviewer is content with the revised report, the Document Record Sheet at the front of the document should be signed.

4.6.8 Each report shall be approved for submission to the client by a Director who shall ensure:

- *that it meets the customers specification;*
- *that the general quality of the report is appropriate;*
- *that an appropriate review has been carried out and that responses have been appropriate;*
- *that key messages and conclusions are reasonable; and,*
- *that a further review is not required.*

4.6.9 The Director shall record their approval by signing the QA sheet at the front of the report. A Director can nominate someone to undertake this final review on their behalf and this appointment should be recorded in the Project Checklist.

4.6.10 It is noted that clients will have a strong interest in the processes of checking and review. Additional requirements to those set out in the procedure may be agreed with clients for particular pieces of work.

4.6.11 Technical Notes may be produced as a basis for discussion or to set out information. The level of review may be less than for a Technical Report. Technical notes must include an appropriate statement describing the level of review. Such technical notes are outside the scope of this procedure.

4.7 Review of Calculations

4.7.1 All calculations shall be checked by a checker, to be appointed by the Project Manager. The Project Manager shall specify the requirements of the check, which should take account of the importance and subsequent use of the data.

4.7.2 Calculations shall be the responsibility of a calculation author.

- *The calculation author shall document all formulae used, assumptions made, input data, conversion factors; units and other required information so that the calculation can be checked independently.*

- *Each spreadsheet should carry a unique identification number, to include a version number.*

4.7.3 The calculation author shall check their own work and sign and date the front sheet to indicate this.

4.7.4 The checker should identify any points of potential disagreement arising from their review of the calculations. The checker shall discuss these points with the calculation author. When such issues are resolved to the satisfaction of the calculation checker (e.g., by resolving a misunderstanding or by repeating calculations), the checker shall record their approval (e.g., by an appropriate signature on a calculation sheet).

4.7.5 Both the calculation authors and checkers should satisfy themselves that the results of calculations are reasonable and should consider the extent to which calculations can be checked by example hand or scoping calculations.

The procedure is part of our ISO 9001(2015) accredited quality management system. A thorough quality assurance check was undertaken on all spreadsheets and transcription checks were undertaken to verify relevant data were transferred to the report correctly. This will be repeated when the ESC is reissued.

There are very few actual errors identified in the following paragraphs. There are a number of minor typographical mistakes that will be corrected in the revised ESC. We also note there are a large number of comments about interpretation or focusing on a different view of the approach that should have been taken, that are raised as questions but presented as an error.

106. Units should be cm^{-2} rather than cm^2 in paragraph 432.

Accepted, the units will be corrected when the ESC is re-issued.

107. The dose rates in Table 44 are quoted in mSv/h. We presume this is incorrect otherwise they are worryingly high.

Accepted, the units will be corrected to µSv/h when the ESC is re-issued.

108. There is an error in the statement in paragraph 510.

This error is a Word referencing error “**Error! Reference source not found.**” and this occurs when the Word programme cannot locate a cross-reference. The cross-reference was to Table 46 located immediately before paragraph 510. This cross-reference will be corrected when the ESC is re-issued.

Our approach to document checking before issue includes a search for these errors which can occur when editing large documents, however our search did not find this occurrence.

109. We have made some spot checks against data tables from the 2015 ENRMF ESC and have noticed some differences, for example in the clay Kd for Fe-55 (Table 199), the Cm grain uptake factor (Table 203), and the Am transfer factor for meat and the Cm transfer factors for meat, milk and fish (Table 204). The data source for the grain uptake factor and the food stuff transfer factors in the Port Clarence landfills and ENRMF ESCs are apparently the same; Augean Plc should explain the differences.

Response provided at Item 142 below that includes the same question.

110. The sources of some data used in the assessment are not clear and should be justified, for example worker and public inhalation rates and time in the plume (Table 67).

The inhalation rate for a worker is referenced in Table 80 and this reference will be added to Table 67 when the ESC is re-issued. The source of the public inhalation rates is discussed below in Item 111. It is not clear what other data is referred to by this comment, but it is our intention that all data sources are clearly referenced. This is not an error but an omission.

111. There are inconsistencies in adult inhalation rates used in different parts of the assessment, for example between data in Tables 67 (public habit data for exposure to dust and gas: applicable during the Period of Authorisation) / 138 (habit data for site resident family) and Tables 123/127 (habit data for fishing families), even when taking into account the different units used. We would expect inhalation rates for members of the public to be consistent between calculations or the differences explained, for example sedentary habits will be associated with lower inhalation rates, however, inhalation rates for exposure to dust and gas during the period of authorisation will presumably be associated with walkers.

This is partly due to the different approaches used in the underlying models adopted for different assessments, for example PC Cream uses one rate and SNIFFER an alternative rate. There is an alternative argument that would say the answers from those models would have greater weight if the models used their respective defaults parameters.

The inhalation rate for adult members of the public is 1 m^3/h in all models (the default SNIFFER value; see Tables 67, 83, 93, 101, 116, 125, 138, 146 and 149) except where PC Cream was used (fishing family exposures following release to estuary; Tables 123 and 127) with a default adult value of 0.92 $m^3\ h^{-1}$ which derives from NRPB W41 (Smith & Jones, 2003) and is appropriate for a family living close to a beach. Parameters used for adults were therefore consistent with the default values in the respective models used. The introduction of calculations for child and infant required new data for the SNIFFER models that were appropriate to these other age groups.

In line with the suggestion to use inhalation rates that are more appropriate to walking on or close to the site we have reviewed the rates used in all calculations. ICRP Publication 66 was the basis for the inhalation rates recommended for use in NRPB W41 (Smith & Jones, 2003) and NRPP W36 (Oatway & Mobbs, 2003), and ICRP 66 has been used to derive the values that will be used in the updated Port Clarence calculations that were previously based on SNIFFER default values.

Taking the ICRP 66 reference respiratory values at different levels of activity breathing rates for heavy work (adult males) and for outdoor and indoor activities involving infants, male children and adult males. PC Cream values for the fishing family are not changed.

The breathing rate for a worker and an adult labouring on a smallholding is based on 1 h of heavy work (3 m^3/h) and 7 h light work (1.5 m^3/h) producing a blended rate of 1.69 m^3/h.

The breathing rate for an adult outdoors is based on 0.25 h of heavy work (3 m^3/h), 0.75 h light work (1.5 m^3/h) and 1 h sitting (0.54 m^3/h) producing a blended rate of 1.21 m^3/h.

The breathing rate for a child outdoors is based on 2 h light work (1.12 m^3/h) and 1 h sitting (0.38 m^3/h) producing a blended rate of 0.87 m^3/h.

The breathing rate for an infant outdoors is based on 0.67 h light work (0.35 m^3/h) and 0.33 h sitting (0.22 m^3/h) producing a blended rate of 0.31 m^3/h.

The breathing rate for an adult indoors is based on 8.5 h sleeping (0.45 m^3/h), 4.67 h light work (1.5 m^3/h) and 2.33 h sitting (0.54 m^3/h) producing a blended rate of 0.78 m^3/h.

The breathing rate for a child indoors is based on 10 h sleeping (0.31 m^3/h), 5.33 h light work (1.12 m^3/h) and 2.67 h sitting (0.38 m^3/h) producing a blended rate of 0.56 m^3/h.

The breathing rate for an infant indoors is based on 14 h sleeping (0.15 m^3/h), 3.33 h light work (0.35 m^3/h) and 1.67 h sitting (0.22 m^3/h) producing a blended rate of 0.19 m^3/h.

112. In paragraph 596, X in the equation should be distance not dose rate.

The corrected equation is:

596. The dose rate at 50 m can be estimated from:

$$D_1 = D_2 \cdot \frac{{X_2}^2}{{X_1}^2}$$

where:

- D_1 and D_2 are dose rate at positions 1 and 2 (µSv h^{-1}); and,
- X_1 and X_2 are the distances for measured dose rate at positions 1 and 2 (m).

113. Absorption through the skin is an important pathway for immersion in a tritiated water cloud (Table 76). Has Augean Plc taken this skin absorption component into account? A reference for the external dose coefficient for immersion in a cloud should be provided (paragraph 648).

The radiological assessment of methane gas collected from the non-hazardous landfill and then used for electricity generation has applied the PC Cream default parameters.

We note that the PC Cream help file indicates that a factor or 1.5 is applied to ICRP inhalation dose coefficients for tritiated vapour in order to account for a skin absorption component.

The external dose coefficients for submersion in air referenced in paragraph 648 relate to the SNIFFER model of a landfill fire. The dose coefficients will be included in Table 201 and are taken from US EPA Federal Guidance documents (US EPA, 1993). An update (US EPA, 2018) was finalised in 2020 after the ESC was submitted and this update will be used in the revised ESC.

114. There are two entries of ‘Delay between spreading sludge and animal grazing” in Table 82. Augean Plc should clarify when each is used.

The text entry to Table 83 will be corrected as shown below, the second refers to crop harvesting.

Table 82 Parameters characterising the application of treated sludge to agricultural land: applicable during the Period of Authorisation

Parameter	Value	Comment
Rate of application of treated sludge (kg m^{-2} y^{-1})	5	Amended from the DPUR default value of 8 kg m^{-2} y^{-1} to comply with UK practice.
Delay between spreading sludge and animal grazing (d)	21	Standard assumption in (Environment Agency, 2006; Environment Agency, 2006).
Delay between spreading sludge and crop harvest (d)	300	
Density of soil (kg m^{-3})	1,250	
Transfer of strontium to next soil layer (y^{-1})	0.464	
Transfer of other radionuclides to next soil layer (y^{-1})	0.243	
Dust in air (kg m^{-3})	1 10^{-7}	

115. Augean Plc should clarify some of the data in Table 83 (farming family habits data):

Accepted and dealt with in sub-paragraphs below.

115.1 The supporting text in paragraph 665 implies that the farming family consists only of adults, which we do not think is correct.

The assessed group are adults, children and Infants, the text will be updated to be consistent with Table 83 when the ESC is re-issued.

115.2 Mean adult consumption rates of root vegetables and milk do not correlate with the quoted source (Smith and Jones, 2003[14]). The sources of data for soil ingestion, inhalation rates and outdoor occupancy are also unclear (but does not appear to be Smith and Jones, 2003). Augean Plc does not justify using mean consumption rates instead of 95th percentile values for consumption rates for some foods (for all but the 2 most limiting pathways for the farming family), which is not in line with values used in IRAM. Similarly, it does not clarify whether it uses mean or 95th percentile values for angling family consumption rates nor justify its choice.

The mean adult consumption rate for root vegetables in the quoted source is 60 kg y^{-1} and this will be corrected (Table 83 shows 65 kg y^{-1}). The adult mean milk consumption rate was a combination of milk and other milk products but this approach was not used consistently across the age groups. Milk consumption (mean adult value) will be adjusted to comprise only milk (95 kg y^{-1}) using the (Smith & Jones, 2003) data set rather than an adjusted value.

The soil ingestion rate is considered at Item 155.5 below.

The inhalation rates are considered at Item 111 above and Item 155.6 below.

The basis of the outdoor occupancy rates (SNIFFER, 2006) and (Oatway & Mobbs, 2003) will be referenced appropriately.

It is stated at paragraph 669 that the DPUR provided by IRAM are scaled to the parameters adopted for the Port Clarence assessment and this provides appropriate application of alternative parameters as suggested in the IRAM documentation (Environment Agency, 2006). We have extended the scaling approach to apply the IRAM methodology in a way that is consistent recommendations of the National Dose Assessment Working Group (NDAWG) concerning critical groups (NDAWG, 2013). Where an IRAM parameter value is given in Table 83 and an alternative is listed then these values (mean or 97.5th percentile) are used to scale the DPUR.

Our approach to the selection of consumptions rates where multiple foodstuffs are considered is described at several points in the ESC and follows NDAWG recommendations concerning critical groups (NDAWG, 2013). For example, this is referenced at paragraphs 464, 671, 852-854, 992 and 1028 in the ESC. Further reference to this approach, for example reiterating the approach for the angling family consumption rates (paragraph 676), will be included as appropriate in a revised ESC.

115.3 Augean Plc should also clarify how the non-food data for infants and children are used (inhalation rates, soil ingestion rates etc.). Are non-adults assumed to spend time in the conditioned field or does this represent wind-blown material getting into areas occupied by the family?

The EA description (Environment Agency, 2006) of the scenario indicates inhalation to airborne dusts is whilst outdoors (see Appendix G.6) and external exposure occurs both outdoors and when shielded indoors. No further detail is provided about their location. The DPUR are calculated using the FARMLAND module in PC CREAM.

115.4 The data provided could be read as a farmer would spend over 4300 hours in the field (DPUR outdoor occupancy of 0.5) or 2200 hours (mean outdoor occupancy of 0.25); clarification to which was considered is needed.

It is stated at paragraph 669 that the DPUR provided by IRAM are scaled to the parameters adopted for the Port Clarence assessment and this provides consistent application of habit parameters as requested by the EA. Where an IRAM parameter value is given in Table 83 and an alternative is listed then these values (mean or 97.5th percentile) are used to scale the DPUR. Text will be inserted in the re-issued ESC to further clarify this approach is used for all parameters listed in Table 83. To further clarify, the IRAM total occupancy relates 8,760 h y^{-1} and the fraction outdoors (0.5) was assumed in IRAM for the farming adult. We adjust the IRAM DPUR for the time spent outdoors using the mean outdoor occupancy in Table 83 in the same way other values are adjusted.

115.5 For the adult the mean inadvertent ingestion rate (30 g/y), at 5 mg/h implies a time for ingesting soil of 6000 hours – this is much higher than the recommended annual rate given in Smith and Jones, 2003 (of about 8 g/y for a critical rate and 4 g/y for an average rate). Is this intended? How does this annual ingestion rate relate to the outdoor occupancy time given in the table 83 (see point above)?

This was not intended and the very large ingestion rate for adults has been replaced with the recommended annual rates given in (Smith & Jones, 2003). The updated row in Table 83 is shown below.

Table 83 Farming family habits data

Habit data	Adult			Child			Infant		
	DPUR basis	Mean	97.5th	DPUR basis	Mean	97.5th	DPUR basis	Mean	97.5th
Soil ingestion (inadvertent) (kg y^{-1})	7.0 10^{-5}	3.7 10^{-3}	8.3 10^{-3}	6.0 10^{-5}	1.1 10^{-2}	1.8 10^{-2}	7.0 10^{-5}	3.7 10^{-2}	4.4 10^{-2}

These changes will reduce the estimated doses from inadvertent soil ingestion. This pathway was not used to determine the radiological capacity of the site and would not therefore have had an impact on the safety assessment presented in the ESC.

115.6 The mean inhalation rates represent daily average values from Smith and Jones, 2003 and therefore include time spent sleeping. Are these appropriate given that what is being assessed is the dose to a farmer working in a field?

We agree that the inhalation rate of a farmer working in the field is likely to be greater than the average daily value. The IRAM model for inhalation can be scaled both for the breathing rate and the time breathing contaminated dust outdoors. These have been updated to correspond to ICRP 66 values.

Table 83 Farming family habits data

Habit data	Adult			Child			Infant		
	DPUR basis	Mean	97.5th	DPUR basis	Mean	97.5th	DPUR basis	Mean	97.5th
Inhalation rate (m^3 h^{-1})	0.92	1.6875		0.64	0.87		0.22	0.31	
Outdoor occupancy	0.5	0.5		0.2	0.125		0.1	0.042	

The overall impact of these changes is to increase the adult DPUR and decrease the DPUR for other age groups.

116. What is the scaling factor for the specific pathway discussed in paragraph 673? Where are these listed and what do they represent, given that the dose rate for each pathway has been explicitly calculated.

The scaling factors are used to adjust the dose rate presented for the standardised IRAM calculations of dose per unit release factor (DPUR reproduced in Tables 84 to 86). The use of scaling factors is described in paragraphs 669 (F_P), 671 (F_P) and 672 (F_{SAR}) and Table 88 (F_E). They are used to scale the DPUR calculated in IRAM based on site specific pathway considerations. In paragraph 673 the scaling factors for the farming family pathways are factors derived from the consumption rates for each food type, for time outdoors, for inhalation rate and for soil ingestion rate. Table 83 shows the DPUR basis and the values adopted for Port Clarence, in each case the scaling factors were determined by dividing the Mean or 97.5th value adopted in the ESC by the value used in IRAM to produce the DPURs. It was considered unwieldly to present every combination of F_P calculated because this also considered the two most important foodstuffs, using 97.5th percentile consumption rates, for each radionuclide.

117. The text in paragraph 675 states that the exposed group are only adults whilst Table 97 shows infants and children.

The text will be amended to state that it is an angler and family that is exposed when the ESC is re-issued. It is also clear from the paragraph 676, inputs and results presented that the assessment is not restricted to adults.

118. The equation after paragraph 695 needs to be clarified so it is clear what is the inventory assumed, what is the release fraction or are they the same parameter and how this relates to the respirable fraction.

There is no equation after paragraph 695 and assuming it is the equation after paragraph 694. The definitions of I and RF_1 will be amended as shown below and the following clarification will be added to paragraph 695.

- I is the inventory of radionuclide *Rn* releasable (Bq), bag containing 1 tonne at 200 Bq/g ($2\ 10^8$ Bq);
- RF_1 is the release fraction, 0.1% of spilt material;

695. The parameters used in this calculation are given in Table 93. The Inventory is 1 tonne of material at 200 Bq/g ($2\ 10^8$ Bq) of which 10% is spilt ($2\ 10^7$ Bq) and the respirable fraction is that proportion of the material released from the spillage that could be inhaled (i.e., it is 10micron diameter or less). The waste acceptance criteria at Port Clarence do not permit disposal of powders and hence the dusts that are released will be fine materials associated with larger masses, e.g., associated with rubble. The inhalation dose coefficients are given in Table 200.

119. Augean Plc should clarify what the decontamination factor represents in paragraph 694.

The decontamination factor (DF) allows some flexibility in the calculation to allow for clean-up. It is assumed in this scenario that there is no clean-up and a value of 1 is applied (Table 93) – leaving the calculation un-factored.

120. Augean Plc should clarify what the value for dsoil is under paragraph 721.

The following table will be inserted following paragraph 721 to detail the parameters used in the equation.

Properties for soil irrigation.

Parameter	Units	Value
Irrigation in 1 year	m	0.108
Density of soil	kg m^{-3}	1300
Depth of soil layer irrigated	m	1

121. Doses should have units in paragraphs 724, 857, 867 and 871.

Section E.3.2 introduces the presentation of dose assessments and defines units used in the ESC. In the remainder of the document only 2 of about 40 equations provide the units for the doses calculated (see paragraphs 970 and 1170). Whilst all righthand elements of the equations are given units, and the dose units are therefore implicit, we will add units for each of the equations when the revised ESC is issued.

122. Augean Plc should explain why the occupancy rates for infants and children have been adjusted from the generic time of 750 h/y in paragraph 757. Why are these values not included in Table 101?

All recreational exposure periods have now been made consistent with the Park User scenario (Oatway & Mobbs, 2003) and use the generic time of 750 h/y. The values are included in Table 101 and the last sentence of paragraph 757 will be deleted when the ESC is re-issued.

The impact of this change will be to reduce doses to a child and an infant under this scenario 60 years after site closure. However, it was the assessment immediately after site restoration that was proposed for the set of sum of fractions to constrain disposals (See Table 34) and that scenario used the generic time of 750 h/y.

123. The inhalation rates given in Tables 101 and 125 are the 24-hour average rates from Smith and Jones, 2003. If exposure is from the recreational use of the land then a higher rate, not including time spent sleeping for example, would be more appropriate.

The rates in Tables 101 and 125 are 1.0 $m^3 h^{-1}$, 0.64 $m^3 h^{-1}$ and 0.22 $m^3 h^{-1}$, for an adult, child and infant, respectively. A revised rate has been adopted for recreational users based on the recommendations of ICRP Publication No 66 (ICRP, 1994) that were also used by the NRPB (Smith & Jones, 2003).

The ICRP derive a breathing rate for outdoors travel and sports (Table B. 16B.) based on a male spending time sitting (0.5), light exercise (0.375) and heavy exercise (0.125) to derive a rate of 1.21 $m^3 h^{-1}$ using the relevant breathing rates for those activities (Table 8 of ICRP 66). Based on the ICRP assumptions for a child and infant, the rates are 0.87 $m^3 h^{-1}$ and 0.31 $m^3 h^{-1}$, respectively.

This has been applied to the recreational use scenario (Section E4.2) and the dog walker after coastal erosion (Section E4.5). This reduces the radiological capacity of C-14 and H-3 under the recreational use scenario.

124. Paragraphs 850 and 851 state that the exposed group is comprised of adults only. However, the text and Table 116 also discusses and shows data for exposure to infants and children. If infants and children are included why is only adult drinking water rate listed in paragraph 858? In Table 117 only dose coefficients for adults are given.

The reference to adults only will be corrected to read adult, child and infant age groups in paragraphs 850, 851 and 858. The water consumption rates used for child and infant are 350 and 260 $l\ y^{-1}$, respectively. Table 117 will be updated to show the dose coefficients for the other age groups.

Table 117 Dose coefficients used in Goldsim to match the modelling of the decay chains

Radionuclide	Ingestion ($Sv\ Bq^{-1}$)	Inhalation ($Sv\ Bq^{-1}$)	External Irradiation from slab ($Sv\ y^{-1}\ Bq^{-1}\ kg$)
Adult			
Pb-210	$6.91\ 10^{-7}$	$5.69\ 10^{-6}$	$2.21\ 10^{-11}$
Ra-226	$2.80\ 10^{-7}$	$9.53\ 10^{-6}$	$4.74\ 10^{-9}$
Ra-228	$6.90\ 10^{-7}$	$1.60\ 10^{-5}$	$8.71\ 10^{-10}$
Th-232	$2.30\ 10^{-7}$	$1.10\ 10^{-4}$	$8.65\ 10^{-14}$
U-232	$3.30\ 10^{-7}$	$3.70\ 10^{-5}$	$2.39\ 10^{-9}$
Am-242m	$1.90\ 10^{-7}$	$9.20\ 10^{-5}$	$1.74\ 10^{-13}$
Cm-243	$1.50\ 10^{-7}$	$6.90\ 10^{-5}$	$9.09\ 10^{-11}$
Child			
Pb-210	$1.90\ 10^{-6}$	$7.33\ 10^{-6}$	$2.44\ 10^{-11}$
Ra-226	$8.01\ 10^{-7}$	$1.20\ 10^{-5}$	$5.21\ 10^{-9}$
Ra-228	$3.90\ 10^{-6}$	$2.01\ 10^{-5}$	$9.59\ 10^{-10}$
Th-232	$2.90\ 10^{-7}$	$1.30\ 10^{-4}$	$1.06\ 10^{-13}$
U-232	$5.70\ 10^{-7}$	$4.30\ 10^{-5}$	$2.61\ 10^{-9}$
Am-242m	$2.00\ 10^{-7}$	$9.40\ 10^{-5}$	$2.30\ 10^{-13}$
Cm-243	$1.60\ 10^{-7}$	$7.30\ 10^{-5}$	$1.02\ 10^{-10}$
Infant			
Pb-210	$3.61\ 10^{-6}$	$1.83\ 10^{-5}$	$2.72\ 10^{-11}$
Ra-226	$9.62\ 10^{-7}$	$2.91\ 10^{-5}$	$5.77\ 10^{-9}$
Ra-228	$5.70\ 10^{-6}$	$4.82\ 10^{-5}$	$1.07\ 10^{-9}$
Th-232	$4.50\ 10^{-7}$	$2.20\ 10^{-4}$	$1.26\ 10^{-13}$
U-232	$8.20\ 10^{-7}$	$9.70\ 10^{-5}$	$2.85\ 10^{-9}$
Am-242m	$3.00\ 10^{-7}$	$1.50\ 10^{-4}$	$2.75\ 10^{-13}$
Cm-243	$3.30\ 10^{-7}$	$1.50\ 10^{-4}$	$1.15\ 10^{-10}$

125. Why do the farming family irrigating soil with groundwater (Table 116) have different consumption rates to the farming family habits data (Table 83)? One table quotes mean data and the other quotes average data (which are not always the same) and one breaks meat consumption down into a number of classes while the other doesn't. For clarity, data should be consistent for similar exposure groups throughout the assessment.

For all habits data used in the ESC it is assumed that the average is equivalent to the arithmetic mean (mean) of consumers. We do not define an alternative meaning to average as used by (Smith & Jones, 2003) where it relates specifically to a "*per caput*" value. The text will be amended when the ESC is re-issued to refer only to mean values to avoid any confusion.

There are two class of foodstuffs showing differences between Tables 116 and 83 that relate to the consumption rates applied to meat consumption, and milk consumption in Table 83. In the case of meat consumption, the difference relates to the underlying models used in these scenarios and the more detailed breakdown of meat classes that are used in the IRAM model (Environment Agency, 2006). We will zero the IRAM model outputs for some meat classes and only apply the cow meat consumption rate presented in Table 116. In the case of milk consumption, the mean rate combined consumption of raw milk with other milk products and these have now been removed. All farming families will now use the same consumption rates that are based on NRPB W41 (Smith & Jones, 2003).

126. The exposure time in the equation after paragraph 909 (57 h/y) does not match that in Table 125 (73 h/y).

This raises the same query as Item 55 above. The coastal walker exposure time specified in the text (73 h/y; paragraph 908) was used for the assessment and the equation bullet point will be updated to be consistent when the ESC is re-issued.

127. Augean Plc should clarify the sources of information used in the Port Clarence landfills local marine compartment (Table 128).

This query drew our attention to a PHE publication of September 2019 (Smith, 2019) that discusses the parameters used for the local marine compartment in the DORIS module and makes recommendations for sites around the UK.

Hartlepool Power Station is located on the mouth of the Tees estuary. PHE report that the majority of the discharges of radioactive liquid effluent from the power station are made to Hartlepool Bay, located outside of the Tees Estuary. PHE recommended that the DORIS default parameters for a generic sheltered coastal location are used when considering releases from Hartlepool Power Station. The PC-Cream models used for the erosion of the Port Clarence site have been updated to reflect this recommendation for Hartlepool, because at the time erosion occurs the coastline will approximate a sheltered coastal location rather than the current estuary.

128. Paragraph 934 states that the potential dose to a road construction worker will be limited by that to a borehole worker. Greater justification for this assumption should be given as potential volume of spoil and the potential of a road passing through the ground at depth could result in exposure to contaminated waste rather than just spoil.

Whilst a road may excavate a larger amount of waste and exposure to contaminated waste rather than spoil could occur the road construction worker is likely to spend much less time in contact with waste and spend a lot of that time in a vehicle.

The potential dose to a road construction worker can be considered using scenario SCE7B produced by the IAEA for an assessment of potential radiological impacts from near surface disposal facilities (IAEA, 2003).

Scenario SCE7B assumes that a road is constructed after institutional control is withdrawn (60 years after closure at Port Clarence). Exposure duration is based on an average construction speed of 10 km in six months (working 8 hour days for a 20 day month). The exposure pathways include inadvertent inhalation, inhalation of dust and external exposure but exclude doses direct to the skin of workers. A road construction worker will be using machinery and it is reasonable to exclude the direct contact pathway compared to the borehole excavator who will be in close contact with waste.

The length and location of a new road through the site that should be used to calculate exposure duration is very uncertain. It is extremely unlikely that the road will be aligned with the maximum distance across bordering waste cells or that it would traverse the highest part of the restored site. It is therefore assumed that the road will clip one corner of the site for a distance of 300 m with excavation to a depth of 9 m (IAEA, 2003). The recommended single carriageway width for new roads is 7.3 m (Highways England, 2020) and assuming a 3 m verge, and a slope of 1 in 7.7 (MJCA, 2019a) the dilution factor for excavated waste would be 0.72 (close to the IAEA suggested value of 0.7). The concentration of activity in exposed materials is based on the proposed activity concentration limits for the site and assuming that LLW comprises 20% of waste deposited. The IAEA scenario also includes a short period (4 h) of exposure to higher concentration material (no dilution, activity concentration in waste as disposed but allowing for radioactive decay).

The peak dose to a borehole excavator is 18 µSv from Pa-231 disposal at an activity concentration in LLW of 200 Bq g^{-1}. The corresponding dose to the road construction worker is 9 µSv. If the workers are exposed to undiluted waste, then the maximum dose is 90 µSv to a borehole excavator.

There are several practical reasons why a road would probably not be constructed through the site (surrounding areas may flood, there is an existing road adjacent to the northern edge of the site, it would be cheaper to go around the site than through it). It is our view that the road construction scenario remains highly unlikely.

129. ICRP 89 recommends are that, for radiation protection purposes, the dose rate to the skin should be estimated to a depth of 70 µm and over an area of 1 cm^2. The beta dose rate in the borehole excavation scenario is assumed to be a depth of 40 µm (paragraph 946), this approach is not consistent with ICRP recommendations.

The first part of Environment Agency Item 141 makes reference to a similar concern: “The reference for the point source dose rates to the skin in paragraph 1180 should be given. References for point source exposure of the skin for beta dose factors at 70 µm do exist (Delacroix, et al., 2002). In order to remain consistent with recommendations from ICRP 89 then a depth of 70 µm should be used.”

The external dose to skin is calculated for an excavator (borehole drill operative, trial pit worker, worker on housing development) exposed to contaminated materials (Section E5.2, E5.3 And E5.4, respectively), for a geotechnical worker exposed to large objects (Section E6.1) and for the assessment of particles (Section E6.3).

Whilst acknowledging the ICRP reference anatomical recommendations in ICRP 89 and averaging area and depth discussed in ICRP 103 to derive dose limits for skin (paragraph B 207) that both suggest using a skin depth of 70 µm. Our approach in the ESC is the same as that used in SNIFFER and applies dose conversion factors for skin depths of 40 µm (beta exposure of face), 70 µm (gamma exposure) and 400 µm (beta exposure of hands).

The availability of dose conversion datasets for all the radionuclides considered in the ESC is limited. The reference cited above (Delacroix, et al., 2002) provides data sheets for 35 of the radionuclides considered at Port Clarence, whereas the data presented in RP65 provides better coverage (European Commission, 1993). The methodology adopted in SNIFFER considers beta doses to the face and hands where skin depth is assumed to be 40 µm and 400 µm, respectively, and draws on the RP65 dataset. For comparable radionuclides, the 40 µm dose coefficients for beta emitters are more cautious that those produced for a skin depth of 70 µm. The beta dose at 70 µm depth is less than the beta dose at 40 µm depth because the beta radiation has travelled through a greater thickness of skin and hence the attenuation is greater. This is illustrated in Table 81 of reference (Oatway, et al., 2011), which gives calculated dose rates at skin depths of 40 µm, 70 µm and 350 µm depths for a number of beta-rich particles. Oatway et al. also state that ‘skin dose rates from beta rich-particles are not strongly dependent on skin depth; the dose rates calculated for a skin depth of 40 µm are about 16% higher than the 70 µm dose rates…’. Use of data for a skin depth of 40 µm as a surrogate for the dose rate at a skin depth of 70 µm is therefore cautious for beta-rich particles and it is assumed it is also cautious for dust.

For the beta dose to a worker's hands that was calculated using a 400 µm skin depth to account for thicker layer of skin on hands, we have considered use of the more cautious 40 µm dose rate. The dose rate to a borehole excavator at 60 years for all pathways combined (mSv y^{-1} MBq^{-1} disposed) increases for 14 radionuclides, for seven of these the increase is small (<10%) and the largest increases are for C-14 (58%), Tc-99 (55%) and Pm-147 (98%). These changes would not impact the radiological capacity of the site and we do not propose changing the adopted approach.

130. The doses in Table 133 are in mSv/y per MBq not µSv/y per MBq.

The text in parenthesise at paragraph 950 has incorrectly indicated a dose rate in µSv/y per MBq whereas the results presented in Table 133 are mSv/y per MBq. The text in paragraph 950 will be corrected when the ESC is re-issued.

131. Paragraph 956 states that the highest dose to a trial pit excavator shown in Table 135 is 2.5 mSv from exposure to Th-232 whilst the dose given in Table 135 from Th-232 is 1.3 mSv; these do not appear to be consistent. The dose from Ra-226 and Pa-231 presented in Table 135 are also higher than that from Th-232.

The text has not been updated when the latest version of the Table 135 was copied to the ESC. Paragraph 956 should have read:

> The calculated doses to a trial pit excavator who is exposed to a single 10 t consignment containing waste at 200 Bq g^{-1} are shown in the last column of Table 135. The largest dose from a consignment containing a maximum specific activity of 200 Bq g^{-1} is 2.07 mSv y^{-1} for Pa-231, followed closely by Ra-226, Sn-126, Th-232 and Nb-94. Hence, a restriction on the activity concentration in a consignment of 200 Bq g^{-1} will protect the trial pit excavator for these radionuclides.

Table 135 values agree with the final ESC master spreadsheet. The point being made is that the concentration limit applied to consignments will restrict intrusion doses for the most sensitive radionuclides and this point remains valid. This has no impact on the ESC assessments.

132. Augean Plc should explain why different adult indoor occupancies are quoted in Table 138 (site resident family) and Table 141 (site resident no cap damage). We assume that the data in bottom 2 rows of Table 138 are for children and infants not adults.

The same fraction for time spent outdoors will be adopted for the site residents in both scenarios. This causes doses from exposure outdoors to decrease by about 7% for adults in the site resident scenario.

The labelling in Table 138 will be corrected to identify children and infants correctly when the ESC is re-issued.

133. Section E.5.6.2 (assessment calculations for the residential occupant) does not include a method for assessing the inadvertent ingestion of soil.

The following description will be added to the ESC when it is reissued.

Ingestion of contaminated soil

Dose from ingestion of contaminated soil is given by (Augean, 2009):

$$Dose_{ing,soil} = Q_{soil} \cdot C_{Rn,soil}(t) \cdot D_{Rn,ing}$$

where:

- Q_{soil} is the soil consumption rate (kg y^{-1});
- $C_{Rn,soil}(t)$ is the activity concentration of radionuclide *Rn* at time *t* (Bq kg^{-1}); and,
- $D_{Rn,inh}$ is the dose coefficient for ingestion of radionuclide *Rn* (Sv Bq^{-1}).

Parameter values are summarised in Table 146 and dose coefficients for ingestion are given in Table 200.

134. Some habits data tables quote average/mean values and 97.5th percentile values. The ESC should clearly state which data are used in the calculations (for example, Table 146 and paragraph 1000 for the long-term occupant scenario mentions which data would be more appropriate for a certain scenario but does not specify what was used in each calculation).

Our response to this question addresses two separate issues:

1. the selection of the two most important pathways contributing to dose that would use 97.5th percentile habits data with other habits using the mean rate; and,
2. a smallholder is likely to consume more home grown produce than a resident growing food in their garden because the resident will purchase most food from retailers.

The ESC states that National Dose Assessment Working Group (NDAWG) recommendations concerning critical groups (NDAWG, 2013) are used to determine the habits for the top two pathways. This approach is referenced and referred to in the ESC at paragraphs 464, 852-854 and 992. The scenarios using this approach are:

- farming family on land impacted by a leachate spillage;
- farming family irrigating soil with groundwater;
- farming family where soil is impacted by bathtubbing;
- residential family on housing above landfill; and,
- farming family where soil is impacted by sewage sludge.

In the case of the residential family on housing above the landfill, referred to in paragraph 1000, consumption rates are lowered to half of the mean or the 97.5th percentile relative to a smallholder because a resident would purchase food from retailers. We assumed only two types of vegetables grown on contaminated soil by a resident and it was assumed half of their consumption was purchased, so both are consumed at an adjusted 97.5th percentile value as shown in Table 146. The table will be amended when the ESC is re-issued to show parameters that are only half the 97.5th values from NRPB W41.

Table 146 Parameters used in the long-term residential occupant scenario*

Parameter	Substance	Units	Value
Consumption rate (adult)	Green vegetables**	kg y^{-1}	40
	Root vegetables**	kg y^{-1}	65
	Soil	kg y^{-1}	0.03
Consumption rate (child)	Green vegetables**	kg y^{-1}	17.5
	Root vegetables**	kg y^{-1}	47.5
	Soil	kg y^{-1}	0.018
Consumption rate (infant)	Green vegetables**	kg y^{-1}	7.5
	Root vegetables**	kg y^{-1}	22.5
	Soil	kg y^{-1}	0.044
Occupancy Indoors - adult		y y^{-1}	0.80
Occupancy outdoors** - adult		y y^{-1}	0.20
Occupancy Indoors – child		y y^{-1}	0.84
Occupancy outdoors** - child		y y^{-1}	0.16
Occupancy Indoors – infant		y y^{-1}	0.91
Occupancy outdoors** - infant		y y^{-1}	0.09
Shielding factor indoors**			0.1
Dust load		kg m^{-3}	1 10^{-7}
Breathing rate adult		m^3 h^{-1}	1
Breathing rate child		m^3 h^{-1}	0.64
Breathing rate infant		m^3 h^{-1}	0.22
Dilution factor	Soil in garden		0.0108
Dilution factor	Soil under house		0.108

*Values from (Augean, 2009), unless otherwise stated
**Taken from NRPB/HPA W41 (Smith & Jones, 2003), half of the 97.5th percentiles

In the other scenarios, the two pathways with the greatest dose at 97.5th consumption rates are used with others recalculated at the mean consumption rate. Tables were not produced showing the exact combinations of pathways using the 97.5th percentile habits data because the two pathways varied by radionuclide, age-group and scenario and would require a large number of additional tables to show an intermediate step in the calculation that adds little to the description of the methodology.

135. Augean Plc should clarify what the parameter 'Occupancy dust' is in Table 149 and what it is used for.

This is a derived value used in the calculation, it is the number of hours the fraction of a year outdoors specified in Table 149 represents. The value will be removed from the Table when the revised ESC is issued.

136. Paragraph 1022 should specify units for the gas release rates.

The text will be updated in a revised ESC to clarify the parameter used as follows:

"The average timescale for gas release of H-3 and C-14 was 50 and 900 years, respectively."

137. Parameter B, breathing rate, should be removed from the ingestion part of the equations at paragraphs 1054 and 1060.

The last part of these two equations should not include parameter B, the corrected equations are:

$$Dose_{occupier} = (D_{irr}^{Rn} \cdot \mathrm{T} \cdot A_{Rn}(t)) + (D_{inh}^{Rn} \cdot \mathrm{T} \cdot \mathrm{B} \cdot \mathrm{M}_{inh} \cdot C_w(t)) + (D_{ing}^{Rn} \cdot \mathrm{T} \cdot \mathrm{M}_{ing} \cdot C_w(t))$$

and,

$$Dose_{excavator} = \frac{(G_{irr}^{Rn} \cdot \mathrm{T} \cdot A_{Rn}(t))}{d^2} + (D_{inh}^{Rn} \cdot \mathrm{T} \cdot \mathrm{B} \cdot \mathrm{M}_{inh} \cdot C_w(t)) + (D_{ing}^{Rn} \cdot \mathrm{T} \cdot \mathrm{M}_{ing} \cdot C_w(t))$$

The calculations are implemented in an Excel spreadsheet as shown above.

138. The text in previous paragraphs relates to exposure from an uncovered slab whilst the text in paragraph 1056 mentions dust loading from a core which is confusing.

Text at paragraph 1053 states that dust arises from drilling through the slab. We will remove the incorrect reference to 1 10^{-7} kg m^{-3}. This has no impact on the ESC assessments.

139. More explanation is needed about the assumption that handling a core equates to a distance between core and skin of 5 cm (paragraphs 1068 and 1074). It would seem more appropriate to use the dose rate assuming the core is in contact with the skin of the hands.

The basis of the assessment is presented in paragraphs 1059 to 1062. It is assumed that the worker spends 2 hours examining a core and over this time they are on average 1 m from the core. When presenting the results, the sensitivity of the assessment to the worker being on average 0.05 m from the core for the same 2 hour period is considered in order to provide confidence that there would not be an unacceptable impact. The closer distance used is arbitrary and we do not consider it appropriate that a worker would spend 2 hours holding a core.

140. The inadvertent ingestion rate for contaminated material summarised in Table 162 differs from that given in the text in paragraph 1114. The rate presented in paragraph 1114 is for dust and small objects. Has pica and the potential, deliberate ingestion of a single, larger object (perhaps a few cm in dimension with associated activity in volume or on the surface) been considered, especially by a young child?

Pica or the potential, deliberate ingestion of a single, larger object were not considered. The Environment Agency have previously accepted that deliberate ingestion of stone-sized objects (by children or pica sufferers) should not be considered when deriving WAC for discrete items or particulates.

Soil ingestion rates used for different scenarios have been reviewed and are now all consistent with the values presented in NRPB W41 (Smith & Jones, 2003).

141. The reference for the point source dose rates to the skin in paragraph 1180 should be given. References for point source exposure of the skin for beta dose factors at 70 µm do exist [15]. In order to remain consistent with recommendations from ICRP 89 then a depth of 70 µm should be used. Section E9 contains tables of universal model parameters. The provenance of much of the data in these tables is not specified, making it difficult to check their appropriateness. Augean Plc should clarify their data sources where this is not already done so. We have made some spot checks against data tables from the 2015 ENRMF ESC and have noticed some differences, for example in the clay Kd for Fe-55 (Table 199), the Cm grain uptake factor (Table 203), and the Am transfer factor for meat and the Cm transfer factors for meat, milk and fish (Table 204). The data source for the grain uptake factor and the food stuff transfer factors in the Port Clarence landfills and ENRMF ESCs are apparently the same; Augean Plc should explain the differences.

The points made in the first three sentences above are addressed under Item 129 above.

The parameters used for the Port Clarence ESC were all transcribed from the original source references. This was not the case for the ENRMF ESC (Eden NE, 2015a) that largely used the dataset reported in the 2009 Augean permit application in order to maintain consistency between those radiological assessments. The parameters used for Port Clarence are therefore based on the same quoted reference sources which is why the earlier references used in the 2015 ENRMF ESC were kept, but there are differences between the source references and 2009 ENRMF dataset that we are unable to explain because assessment support was undertaken by different consultants to Augean.

We have cross referenced the dataset in the original version of the SNIFFER model published in 2006 (SNIFFER, 2006), the data set adopted in the 2009 ENRMF permit application (Augean, 2009) and then used in the 2015 ESC (Eden NE, 2015a) with the Port Clarence dataset. The reference sources used for the Port Clarence assessment will be clarified in the revised ESC.

Regarding the specific differences identified:

- clay Kd for Fe-55 – this was different to the ENRMF value and following a further check we found differences between several of the clay Kd values used in the Goldsim groundwater transport model and the final set of parameters adopted for the ENRMF ESC. A review of available Kd datasets ((SNIFFER, 2006), (IAEA, 2009), (IAEA, 2010)) provides a range of values adopted in various models. Based on the similarity of approach, prior scrutiny by the Environment Agency and the supporting information available, a dataset has now been adopted that gives preference to selection of Kd values in the order SNIFFER, TecDoc 1616 and then IAEA TRS 472. The exceptions being the Kd for Cl (TecDoc 1616) and Gd (based on Eu).
- Cm uptake for grain – the ESC value for grain is from (SNIFFER, 2006), the basis for the ENRMF value (Augean, 2009) is not clear;
- Am uptake factor for meat – the ESC value for meat is from (SNIFFER, 2006), the basis for the ENRMF value (Augean, 2009) is not clear; and,
- Cm uptake factor for meat, milk and fish – the ESC livestock values are all from (SNIFFER, 2006), the basis for the ENRMF values (Augean, 2009) is not clear.

142. Section E9 contains tables of universal model parameters. The provenance of much of the data in these tables is not specified, making it difficult to check their appropriateness. Augean Plc should clarify their data sources where this is not already done so. We have made some spot checks against data tables from the 2015 ENRMF ESC and have noticed some differences, for example in the clay Kd for Fe-55 (Table 199), the Cm grain uptake factor (Table 203), and the Am transfer factor for meat and the Cm transfer factors for meat, milk and fish (Table 204). The data source for the grain uptake factor and the food stuff transfer factors in the Port Clarence landfills and ENRMF ESCs are apparently the same; Augean Plc should explain the differences.

There are differences between the datasets. For the ENRMF, we used the parameter dataset from the previous ESC (SNIFFER) in order to avoid any disparity between datasets and the radiological assessments. For Port Clarence the datasets were largely taken directly from the original data references. We will identify any differences between the earlier parameters and the new dataset if that is helpful but will not be in a position to explain why the 2009 parameters are different.

References will be added for all parameter datasets where these are missing.

The checking process used for the original references will be reviewed to ensure that the Port Clarence datasets are consistent with the underlying literature. The Port Clarence parameter datasets will also be applied to an updated ESC being prepared for the ENRMF western extension.

16 Concluding comments

The Environment Agency review appears to place great emphasis on differences between the ENRMF and the Port Clarence assessments. The ESC at Port Clarence was not written with the intention of comparing outputs for similar scenarios at both sites. Although we recognise that performing such a comparison is tempting, we would request that this does not become a feature of subsequent ESC submissions whereby justification of minor changes extends to all or any other submissions by Augean.

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Appendix A Summary of public engagement

In line with Augean's policy to proactively communicate about any intended planning applications, engagement with Stockton on Tees Borough Council was initiated far in advance of the commencement of the project to apply for an Environmental Permit and planning permissions for the treatment and disposal of low level radioactive waste at Port Clarence Landfill and Waste Recovery Park. The first meeting, to discuss the project in broad terms was held in March 2018, at the feasibility study stage. This was intended to give advance notice in acknowledgement that it may be controversial so that council officers would have time to discuss the implications of such planning applications internally and with cabinet members of the council.

Once the Environmental Safety Case (ESC) was in the latter stages of preparation, another meeting was held in March 2019 to discuss the scope of Environmental Impact Assessments to be prepared for the Environmental Statements that would accompany the planning applications. The meeting included discussion regarding public consultation on the planning applications.

Council officers from Stockton Council asked that a summary of the proposed development should be prepared which would be used as a first step towards inviting Councillors and council officers to attend a briefing opportunity in advance of the scheme being made public through the wide circulation of invitations to the local community to attend pre application consultation events.

It was agreed with the Environment Agency (EA) that this briefing note and any subsequent meetings with the Councillors should be timed for shortly after the submission of the ESC, in case any of the Councillors chose to put details of the proposed development into the public domain before the EA was prepared to deal with any enquiries that would arise from that situation. Accordingly, the summary with an invitation to further brief the Councillors was sent out once the ESC had been duly made in August 2019.

The meeting to brief the Councillors on the proposals and discuss with them the most meaningful and effective ways of consulting with the local community was held at the end of September 2019. The EA's consultation on the ESC was not circulated to Councillors until the meeting had been held although it had already gone live on Citizen Space.

Unfortunately, one of the participants at the meeting, much as had been anticipated previously, decided to pass on the information to the Mayor of Teesside Combined Authority who unfortunately circulated misleading statements through news and social media channels regarding the proposed development before the intended programme of further communications to the elected representatives and the local community could take place. This undoubtedly generated misconceptions and misinformation and the consequent number of responses to the EA's consultation. The adverse comments placed in the public domain gave Augean a platform to ably rebut the misinformation through the interested news media and to amend the consultation programme to address the concerns of the community so that there has been little public response to the subsequent Local Authority consultation on the planning applications.

To give members of the public an opportunity to engage in the public consultation regarding the proposals, 18,000 public information leaflets were distributed to homes and businesses in Port Clarence, Cowpen Bewdley and Billingham as well as special interest groups. As a result of the substantially increased interest in the proposals Augean decided to extend the consultation area to include all of the Town and Parish councils within the Stockton on Tees Borough Council area as well as sending information to key stakeholders within

Middlesbrough Council, Redcar and Cleveland Borough Council and Hartlepool Borough Council and the Teesside Combined Authority.

The public consultation events were promoted further by posters displayed in the area, advertisements, engagement with the news media and through social media.

A preview event was held for near business neighbours and elected representatives at the Clarences Community Centre on 13 November 2019.

Public exhibitions for the local community to attend and discuss the proposals with Augean and their professional team were held in the Clarences Community Centre on 13 November 2019 and at Low Grange Community Centre, Billingham on 14 November 2019. The Environment Agency were available to answer questions as part of their separate consultation on the Environment permit application for the landfill sites. The exhibitions were well attended. The site visits as part of the consultation events were well received by all who took the opportunity to go on the tour.

Augean recognises the importance of promoting transparency and understanding about the site, the site operations and the company itself. An Open Day was arranged for 21 March 2020 but unfortunately this had to be postponed due to Covid -19 restrictions. It is intended to re-schedule the event as soon as is practicable. Other initiatives have been identified to help to reassure the local community in the long term which include:

- **Liaison Group**
  The creation of a Liaison Group would provide a forum where any concerns can be discussed on a regular basis. Augean would welcome attendance by the Environment Agency should it wish to participate.

- **Company newsletters**
  The Augean newsletter is produced normally on a biannual basis to provide elected representatives, special interest groups and near neighbours with updates about the company. Circulation of the newsletter could be extended to the local community in Port Clarence.

- **Electronic newsletters**
  An electronic newsletter is already a well-established method of communication at other Augean sites. It enables efficient feedback on issues raised, enables circulation of information regarding events and opportunities at the site.

- **Website and email**
  The company website: www.augeanplc.com not only gives company wide information about all operational sites and services but also has become an important hub to enable the public to access documentation relating to planning applications. There is a dedicated consultation email consultation@augeanplc.com which allows visitors to the website to submit questions, raise concerns or sign up to the Register of Stakeholders.

- **Telephone helpline**
  A dedicated helpline number exists to allow members of the public to request further information on the proposals or to raise concerns verbally.

- **Open Day and drop in sessions**
  Recognising the value to the local community of opportunities to visit the site, it is intended to hold a site Open Day as soon as restrictions relating to Covid -19 are lifted.

If there is a level of interest the Open Day could become an annual event. Transport to the site can be provided to make the site accessible to the local community.

- **Open Door Policy**
  The company has an Open Door policy and is pleased to welcome visitors at all its sites by appointment.

- **Publication of site monitoring data**

In response to requests at the exhibition, Augean has undertaken to publicly share a summary of the key monitoring results from the site to provide reassurance that human health and the environment are not being harmed by the presence of LLW and other wastes at the site. This will be updated on a regular basis.

Appendix B Major ESC uncertainties

Theme	Description of Uncertainty	Treatment in ESC	Remaining Bias
1 Landfill engineering	**Barrier performance**. The landfill design includes several barriers. There is uncertainty regarding operating life and rate of deterioration of some of these barriers.	It is cautiously assumed that the cap will degrade, although this comprises a geosynthetic clay layer. The radiological assessment assumes that the HDPE component of the cap gradually degrades between 250 years and 1000 years after construction. (see ESC Appendix E, Section E.1.3.1) The groundwater risk assessment takes into account gradual deterioration of the HDPE waste cell liner (see ESC Appendix E, Section E.4.3). This assumes a doubling time every 100 years for the HDPE component of the liner defects that allow a flux of water from the waste cells to the unsaturated zone beneath the waste cells and subsequently to the groundwater.	The basal clay layer (an engineered geological barrier) will not degrade.
	Settlement. Settlement is expected, which will result in a change in the shape of the landfill. Settlement may not be uniform and could affect the final gradient of the landfill	The landfill is designed based on the assumption settlement will occur and it is assumed that cap materials are able to cope with the expected settlement without it causing damage. A stability risk assessment has been undertaken (MJCA, 2019).	The aftercare period will address any differential settling evident at the restored surface.
2 Waste properties	**Heterogeneous activity distribution in landfill**. Many disposed wastes are heterogeneous in terms of the distribution of activity within packaged material. The activity will also vary across the landfill as different wastes are disposed over time.	For waste that remains in a waste cell, the safety case is based on the assumption that the wastes are broadly homogeneous. Where intrusion occurs the safety case needs to consider radionuclides that may be distributed heterogeneously in some waste materials. Consideration has therefore been given to the potential impact of variable activity within a waste package (see ESC Section E6) and for different types of waste that may be sent to the site for disposal.	Conservative assumptions are applied in calculating risks and doses. In most cases, doses are well below the risk guidance level. For some radionuclides, disposal is constrained by the scenario, and the risk from disposals is consistent with the risk guidance level.
	Waste form. It is not possible prior to near the time of receipt of the wastes to describe the specific form, amounts or types of wastes	Estimates of radiological impact based on 'illustrative inventories' for waste streams that might be typical of those contributing to the total impact from disposals at the facility have been produced. These estimates are presented in the ESC (Appendix E).	Consignment specific disposability assessments will be undertaken (as done at the ENRMF) where it is unclear that a waste type conforms to ESC assumptions.

Theme	Description of Uncertainty	Treatment in ESC	Remaining Bias
	Sorption in waste materials. As the waste form is uncertain, the sorption properties of the waste are also uncertain.	ESC calculations do not take into account sorption within waste materials, i.e. all radionuclides are readily soluble. This is a cautious approach as in reality radionuclides will be bound to sorption sites within waste for some radionuclides.	None.
	Gas generation rates. The impact of recreational users of the site after closure as a result of exposure from gases released from the waste is assessed using assumed gas generation rates.	A 20 year timescale for gas generation has been applied to the period after closure using the value recommended by IAEA (IAEA, 2003). A shorter period is used for assessments during the operational period (10 years). Sensitivity of dose to a recreational user to the gas generation rate is considered in the ESC (Subsection E.8.1.6).	The assumptions concerning gas release in this period are cautious and this results in overstating gas doses to recreational users of the site.
3 Pathways and Receptors	**Leachate spillage and use of contaminated water for irrigation.** A scenario is considered in which leachate spillage results in contamination of a water body. Contamination of a water body is difficult to remediate. It is assumed that farmland next to the contaminated water body also becomes contaminated due to irrigation and that the farming family use the water body for fishing and consume fish they catch.	The leachate spillage pathway is highly uncertain, both in terms of the possibility of occurring and duration. Sensitivity to the pathway is considered by calculating capacity if the pathway is excluded (see ESC Subsection E.8.1.5). For most radionuclides, the radiological capacity would increase by at least five orders of magnitude if exposure as a result of irrigation did not occur. The exceptions are Ba- 133, Eu-155 and Ac-227, for which the increase is smaller.	It is uncertain whether this scenario would occur and, if it does, where and how much remediation might be attempted.
	Volume of water body into which leachate is spilled.	It was assumed that the volume of the water body into which leachate is spilled was 2,000,000 m^3. The sensitivity of dose to this volume was investigated by varying it by a factor of 1.5, see ESC Subsection E.8.1.5.	It is uncertain whether this scenario would occur and, if it does, where and how much remediation might be attempted.
	Presence of a well.	The abstraction of potable water is not known to occur from the aquifer beneath the Port Clarence site. The groundwater is not potable due to saline intrusion and would also not be suitable for irrigation or livestock. This scenario is therefore considered as a ‘what if’ scenario in the ESC and is not used to limit the radiological capacity because water cannot be used for irrigation or animal consumption.	None.

Theme	Description of Uncertainty	Treatment in ESC	Remaining Bias
	Impact of tide on groundwater. It is likely that groundwater flow in the alluvium is affected by tidal influences of the River Tees.	It is assumed that the tide has no effect on groundwater in the ESC models.	The tide could affect the hydraulic gradient and therefore the transport of radionuclides. A detailed study would be required to understand the influence of the tides on groundwater, which would be disproportionate.
	Sorption parameter (Kd) for Tc	Mobile value adopted – low Kd.	
	Sorption parameter (Kd) for Cl	Mobile value adopted – low Kd.	
	Proportion of radionuclides in root zone of plants following bathtubbing. Bathtubbing may result in leachate seeping over the top of the basal liner at the sides where the cap and basal liners join. A proportion of any release is expected to accumulate in the rooting zone of plants and the remainder will drain to groundwater.	A value of 1% was adopted in the ESC for all radionuclides based on (Shaw, et al., 2004). Shaw *et al.* reported the movement of two very mobile radionuclides, Tc-99 and Cl-36 from a water table at 0.7 m depth to the upper soil layers. For Tc-99 the activity in upper soil layers was two orders of magnitude lower than that at the water table. For Cl-36, the upper soil activity was about 10% of that in the lowest layers but declining with distance above the water table. A value of 1% was therefore adopted as conservative for most radionuclides and probably realistic for Cl-36 with a water table at a depth of greater than 1 m.	For the revised ESC further consideration has been given to basis of this value for all radionuclides using the work undertaken at Imperial College by Shaw and colleagues (Wheater, et al., 2007). The selection of appropriate values for missing radionuclides will also be described in the revised ESC.
	Missing radionuclides from IRAM. The leachate treatment scenario uses the Environment Agency's IRAM to assess impacts to a treatment worker. IRAM does not include all of the radionuclides considered in the Port Clarence ESC.	This pathway has not been used to limit radiological capacity because leachate disposal is controlled by Augean and a discharge permit would be required to transfer radioactively contaminated leachate. Operational experience at the ENRMF shows that the assessment model assumptions concerning leachate concentrations are very cautious and would not be used to limit exposure. However, the calculations are considered in developing the trigger levels for leachate monitoring described in ESC Section 7.5.4.	Consideration will be given to the missing radionuclides in the revised ESC to scope their potential impact.

Theme	Description of Uncertainty	Treatment in ESC	Remaining Bias
	Behaviour of burrowing mammals. There is uncertainty as to whether burrowing mammals could break through the cap of the landfill and, if they could, how much time would be spent in burrows that are located in waste rather than clean material.	An assessment of dose rates to mammals burrowing into the waste 60 y after closure is carried out. It is assumed that the burrowing mammal spends 100% of its time in the soil, however in practice it will spend some of its time outside the burrow. The NS-GRA (UK Environment Agencies, 2009) states that *'For non-human species the general intent is to protect ecosystems against radiation exposure that would have adverse consequences for a population as a whole, as distinct from protecting individual members of the population.'* A whole population would not burrow into waste. However, the scenario is cautiously used to limit capacity for radionuclides where an individual burrowing mammal may be exposed to a dose rate higher than 40 µGy/h (see ESC Subsection E.8.1.7).	The granular layer in the cap will deter burrowing animals at least for a few hundred years, until it is naturally broken down and mixes with soil. LLW in containers would also deter direct contact with the waste.

Theme	Description of Uncertainty	Treatment in ESC	Remaining Bias
4 Site evolution	**Evolution of the estuary.** The estuary is expected to accumulate sediment and there is no information to support erosion of the estuary banks. It is possible that local or national policies for maintaining shipping access and management of local flood defences could change and impact the future evolution of the estuary.	If dredging activities stopped there would be accumulation of sediments and development of salt marshes and mudflats in the estuary. There is evidence of sediment deposits to the south of the landfill. The sediment deposits and sea level rise could lead to tidal erosion at the Port Clarence site from the seaward side. The Environment Agency have provided photographic evidence of slumping to estuary banks to the south of the site. Although Augean consider erosion is unlikely to occur in the next 110 years, erosion of the landfill has been assessed using cautious assumptions. Two assessments are carried out assuming that the facility will be eroded, and these are used to limit radiological capacity: • coastal walker/beach user • exposure from releases of leachate from the eroding site into the marine environment The coastal walker/beach user is assumed to be present once erosion begins, even though access to the site may be restricted once erosion begins due to low lying land surrounding the site becoming tidally inundated. Sensitivity to exposure time is assessed in ESC Subsection E.8.1.3. A sensitivity analysis was carried out to demonstrate the change in capacity if erosion does not occur (see ESC Subsection E.8.1.4). For all radionuclides limited by coastal erosion, the radiological capacity increases by at least one order of magnitude if coastal erosion does not occur.	It is cautious to assume the facility will be eroded at an unknown date in the future and to perform an assessment using the inventory calculated at 60 years after closure.
	Timing and form of erosion. The rate of erosion is influenced by several factors, including human actions, estuary behaviours, sea level, wave characteristics and storminess.	It is cautiously assumed that once erosion begins the inventory used is based on the time at which the site is released from regulatory control and that at this point in time, the landfill is also on the coast rather than being sheltered in an estuary. The erosion rate adopted is a factor of 2.5 greater than current coastal observations.	None, ESC approach is now very cautious.

Theme	Description of Uncertainty	Treatment in ESC	Remaining Bias
	Shape of the coastline if erosion did occur. An assessment is carried out considering exposure from releases of leachate from the eroding site into the marine environment. Erosion is considered unlikely to occur, and if it did happen, it is not known what shape the estuary or coastline might be at the time of erosion.	The local marine compartment used in the assessment of exposure from release of leachate to the coast following erosion uses the default local marine compartment values for a new local compartment. Detailed modelling would be required to determine the future shape of the coastline.	It would be disproportion to model evolution of the coast to determine what shape the coastline might be and whether the landfill would be on an estuary or the coast at the time of erosion, if it erodes at all. Such models also do not deal with appropriate timescales and the coastal modelling scenario approach does not appear suited to a radiological assessment.

Appendix C Floodwater scenario

The ESC considered a projected sea level rise and the potential for a storm surge of 3 m on top of a 95th percentile high tide (UKCP18 RCP8.5 Marine). In December 2013 the local maximum for the storm surge was 1.24 m over a spring tide of 3.85 m AOD whereas we have applied an estimated inshore storm surge maximum value of 3 m (Spencer, et al., 2015) based on the 1953 benchmark storm surge event. On this basis the earliest date when a flood could overtop the bund and flood water enter and mix with leachate is sometime after 2210 CE. We note that at this date flooding will be an unlikely event (reliant on a spring tide coinciding with a storm surge) and is expected to occur at very low frequency (60 years and previously 30 years between the most recent comparable events), however as sea level rises further the storm surge height required to overtop the bund will reduce until a smaller surge above a less extreme high tide will clear the top of the bund more frequently. The frequency of extreme weather events is also expected to change.

In order for a significant volume of flood water to overtop the bund and enter the landfill, the cap or the seal between cap and basal liner will also need to have degraded. It will not occur during the operational phase of the landfills due to the relative elevation of the rim of the bund where the basal liner stops and the lower lying areas around the site. This is not expected to have occurred by the time the first flooding could occur after 2210 CE, at this time the mean sea level will have risen to about 1.95 m AOD with a high tide of about 3.57 m AOD and at this time spring tides (4.43 m AOD) will exceed the height of current sea defences. It will not occur during the operational phase of the landfills because of the relative elevation of the rim of the bund where the basal liner stops and the lower lying areas around the site. We conclude that by the time there is the potential for flood water to enter the landfill, there will be regular tidal inundation of the surrounding land. This land will be unsuitable for agricultural use or regular access for recreational purposes and the main pathway to receptors is considered to occur through the transfer of draining leachate to the marine environment. Migration through the clay layer and basal liner is too slow to lead to equilibration of levels over a short flood duration. Our adopted approach is therefore very cautious.

We have considered the volume of leachate that might be generated after a flooding event, that then seeps into the ground next to the landfill once the flood recedes. We make the very cautious assumption that LLW bearing waste is saturated to a depth of 1 m across the whole site and then drains to the same area considered in the bathtubbing/seepage scenario.

The conceptual model for flooding is summarised below.

- Flooding extends to 1 m above the perimeter bund.
- Surrounding land and waste are saturated.
- After flooding subsides, leachate flows into the estuary (over a period of 1 week).
- An alternative less likely scenario is considered, where land drains/dries to original saturation levels first and leachate contaminants are absorbed.
    - Less likely because land would be saturated;
    - Less likely because when land is flooded regularly, there is less useable output from agriculture;
- There is one flooding event per year.

The exposure pathways that will be considered are:

- Transfer to estuary – fishing family and NHB (as in ESC);

- Transfer to freshwater pond – fishing family (as in leachate spillage scenario) and NHB; and,
- Transfer to sub-soil – farming family (as in leachate spillage scenario).

Appendix D Seepage scenario

The first section below discusses a response from the Environment Agency (11 November 2020) concerning the conceptual models for flooding and bathtubbing (July 2020) .

D.1 Infiltration through the cap

The Environment Agency have compared the cap design infiltration parameters used in the July 2020 CSM models (provided by MJCA) with those used in the hydrogeological risk assessment in support of the current Environmental Permit for the landfill (EPR HRA) at the site and the low level radioactive waste (LLW) Environmental Safety Case (ESC). As highlighted by the Environment Agency, the cap design infiltration used in the EPR HRA is higher than the July 2020 CSM models. The higher values used in the EPR HRA take account of the fact that cap design changes for completed phases have been agreed with the EA as part of Construction Quality Assurance (CQA) and include flexible membrane liners. The July 2020 CSM models assume a cap design comprising a geosynthetic clay liner (GCL) will be used in areas where LLW is placed. This is a higher specification cap than that assumed in the EPR HRA resulting in the differences in infiltration rate, cap thickness and hydraulic conductivity of the cap presented in the July 2020 CSM models compared with the EPR HRA.

Augean propose to use a GCL cap in areas where LLW is deposited hence infiltration parameters for a GCL cap are most appropriate for the July 2020 CSM models. The estimated infiltration rate through the GCL cap per unit area calculated using the site specific infiltration model is 0.73mm/year as presented in the July 2020 CSM models compared with the 31.52 mm/year used in the EPR HRA. The EA refer to a LandSim default value for infiltration through a cap of 50mm/year. This default value was presented in the first LandSim manual (Release 1) dated 1996 and was removed in subsequent releases of LandSim with the manual revised to state *"LandSim does not provide a default value for Infiltration. This should be determined on a site-specific basis taking into consideration the capping type and status."* Irrespective of the above, the bullet points set out in relation to the July 2020 CSM model scenarios compared with the EPR HRA are correct assuming that the reference is to the EPR HRA:

"This means the Scenario B1 and B2 models:

- *assess the risk from significantly less generation of leachate than the HRA does*
- *assess the risk for conceptual model conditions where less leachate needs to be extracted to keep pace with leachate generation than in the conceptual model used in the HRA*
- *cannot provide conclusions that can be compared equally with the HRA"*

The approach for the Scenario B1 and B2 models presented in the July 2020 CSM is justified as Augean propose to use a GCL cap in areas of LLW disposal at the site. More details are provided below consistent with the items raised in the Environment Agency letter of 11 November 2020.

Hydraulic conductivity

The Environment Agency comment that the hydraulic conductivity of the cap and liner used in the July 2020 CSM models are unrealistic. This is not the case as the hydraulic conductivity value for the clay component of the landfill liner of 5.91×10^{-11}m/s used in the July 2020 CSM models is consistent with the most likely values used in the EPR HRA and is verified in the HRA EPR report from the CQA testing carried out as part of the landfill construction works. The hydraulic conductivity of the GCL cap of 3×10^{-11}m/s is a standard GCL specification as provided by GCL manufacturers. These values are representative of the liner and cap as constructed.

Deterioration of the GCL

It is correct that deterioration of the GCL is not considered in the July 2020 CSM and this is consistent with Environment Agency guidance in respect of using GCL caps in LandSim models. The EA guidance states that you do not need to allow for degradation of a GCL cap. It is stated in the LandSim 2.5 manual that *"Deterioration in the performance of mineral (clay and geosynthetic clay liner (GCL)) caps is not included in LandSim 2.5. It is recognised that settlement of the wastes may affect the integrity of compacted clay and GCL caps, however the majority of this settlement will take place, and therefore should be identified, during the period of institutional control when remedial measures can be implemented. For these mineral caps, the impact of settlement on their performance must be specifically addressed at the design and construction stages."* Further information on the long term performance of mineral and GCL caps is presented in the Environment Agency publication entitled "The Development of LandSim 2.5" dated 2003.

As discussed, if we run a sensitivity analysis looking at gradual deterioration of the cap for the July 2020 CSM models we know that once the hydraulic conductivity of the cap increases significantly above that of the basal liner bathtubbing will occur. This is considered in the radiological assessment.

Site surface area

As stated in Schedule MJCA B2 of the July 2020 CSM:

"The spreadsheet model is based on the phase referred to as the non-hazardous landfill phase in the LandSim model which comprises Phase 3A-1, Phase 3B and future non-hazardous waste phases of the non-hazardous waste landfill. The non-hazardous landfill phase was chosen because, consistent with the results of the LandSim modelling presented in Schedule MJCA B1, the predicted leachate levels generally are higher in the non-hazardous phase compared with the hazardous phase. It is reasonable to assume that the results for modelling of the hazardous landfill phase would produce less conservative results than those presented at Schedule MJCA B2."

The LandSim models include all phases hence they have a larger surface area. The hazardous waste and non-hazardous waste areas of the site are hydraulically separate hence separate water balance calculations are carried out for each area. The non-hazardous landfill phase was chosen for use in the models presented in Schedule MJCA B2 of the July 2020 CSM as the predicted leachate levels in the LandSim models generally are higher in the non-hazardous phase compared with the hazardous phase. If the modelling was repeated for the hazardous landfill phase, it is reasonable to assume that the modelling results would produce fewer conservative results than those presented at Schedule MJCA B2.

Implications

For the reasons presented above it is considered that the Scenario B1 and B2 water balances are appropriate for the design of the site.

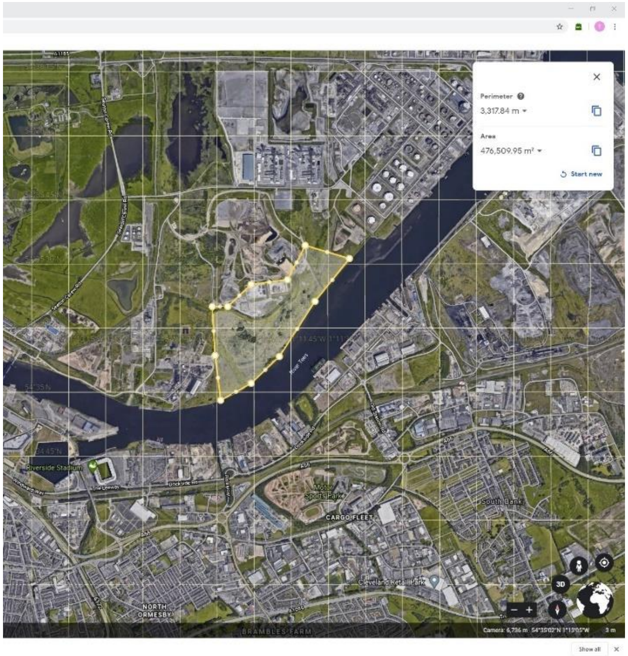
Implications for bathtubbing and flooding

As stated above if, against EA guidance on the performance of GCL caps, it is proposed that deterioration of the GCL cap is taken into consideration, we know that once the hydraulic conductivity of the cap increases significantly above that of the basal liner bathtubbing will occur.

D.2 Updated conceptual model for bathtubbing/seepage

We have therefore considered a what-if scenario that considers deterioration of the GCL over time.

Our approach to the assessment of bathtubbing/seepage has been amended to consider a flooded area to the south based on the assumption that the flow goes in the same direction as the groundwater flow and is not influenced by the southern raised bund.



Flooded zone after bathtubbing event

The GoldSim model for bathtubbing has been revised to include:

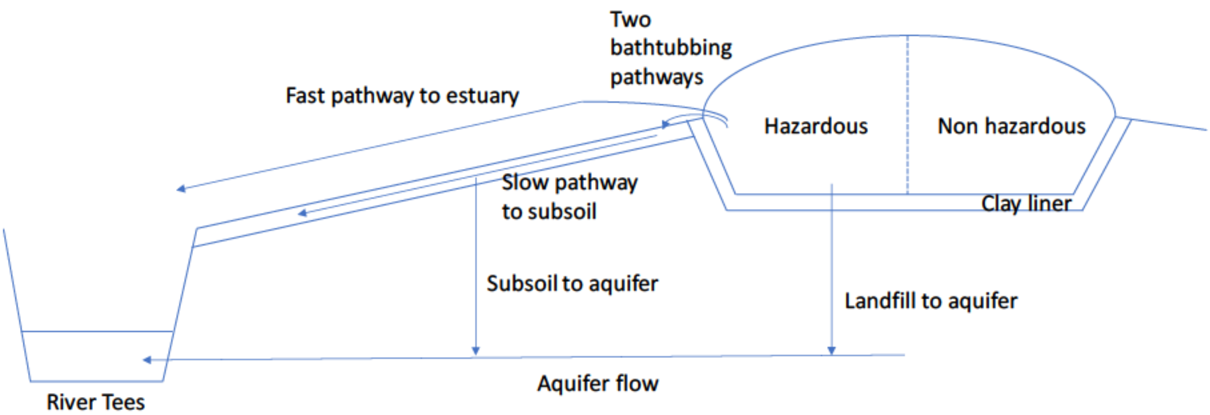
- A dynamic water balance model using different inflow and outflow processes, with an increase of leachate head due to infiltration after PoA due to climate change and change to depth of un-saturated layer beneath the landfill due to sea-level rise;
- An area based on pathway to estuary with release occurring over a broad front;
- A slow pathway to subsoil based on the subsoil capacity (difference between saturated and unsaturated soil) and the calculated leachate breakout volume;

- A fast pathway to estuary for the part of the leachate breakout volume that cannot be absorbed by the subsoil;
- A sub-soil to top soil transfer based on relative radionuclide mobility; and,
- The slope to the estuary will be based on the topographical survey.

The considered exposure pathways occurring over time (not limited to an annual event) are:

- Transfer to estuary – fishing family and NHB (as in ESC);
- Transfer to freshwater pond – fishing family (as in leachate spillage scenario) and NHB; and,
- Transfer to sub-soil – farming family (as in leachate spillage scenario).

Conceptual model illustration is provided below.



Conceptual illustration of bathtubbing model

Appendix E Coastal erosion

Revised coastal modelling assumptions for the coastal walker and releases into the estuary are presented below. The revised ESC will also include an Informal Scavenger scenario that is similar to the excavation scenarios for trial pits included in the ESC. Exposure would be calculated for:

- Inhalation - based on the concentration of radionuclides in air;
- Ingestion - based on waste concentration; and,
- Irradiation - based on semi-infinite slab adjusted for a bank when outside and sphere when object taken home.

The same exposure pathways apply to the Material Recovery scenario, apart from taking an object home. An Informal Scavenger scenario and a Material Recovery scenario will be included in the revised ESC and used in the assessment of activity concentrations.

E.1 Exposure of coastal walker following site erosion

1. The erosion of the landfill has been assessed using cautious assumptions and applies an inventory calculated to the end of the period of authorisation.

2. The landfill site is located on land that has been reclaimed from salt marsh and mudflats over many decades through the deposition of wastes, sediments from estuary dredging, clinker and slag deposits from industries including gas works, lime works, chlorine works, soda works, blast furnaces and salt evaporating pans (Augean, 2014). Some of these materials are not readily eroded in the low energy environment of the Tees estuary. The reclamation materials have created a land mass that is at least 2.5 m above the average tidal range and in places on site over 8 m.

3. The existing shoreline management plan was prepared in 2007 but this does not consider the most recent climate projections or the estuary itself. The landfill site is located inland, near to the head of the estuary, close to the point where the original single main channel connected to the river upstream. The current course of the estuary was trained using dense industrial waste and these are evident both at low tide in the estuary itself and along the current banks. Estuarine bank erosion rates are not readily found in available literature, but it is expected that erosion rates close to the landfills will be less than those occurring on the open coastline.

4. The tidal barrier limits the tidal reach up the estuary, but prior to construction tidal effects reached 21 km upstream from Teesmouth. It is possible that local or national policies for maintaining shipping access and management of local flood defence schemes will change over time and impact the future evolution of the estuary. If dredging activities stopped, or the North or South Gare fall into disrepair, or the tidal barrier be removed the behaviour of sediments in the estuary would change. These changes accompanied by sea level rise could lead to tidal erosion at the Port Clarence site.

5. The landfill restoration profile rises above the surrounding plain and in the existing plan there are two waste cells (in the north west of the site) that overlap with flood risk zone 2 used for planning purposes. An indication that the area around the site is likely to become inundated as sea level rises.

6. Radiation exposure of members of the public spending time at or near the site once erosion of the landfills has started could occur. Two exposure scenarios are considered; exposure through direct irradiation to a casual user who walks close to the

exposed waste (e.g., on the estuary bank or a beach); and, exposure from releases into a sheltered coastal location (see next section).

7. The dose criterion used is a dose of 0.02 mSv y^{-1} for the public (this is equivalent to the risk guidance level of 10^{-6} y^{-1} for exposure of the public post closure, for situations that are expected to occur).

Potentially exposed group

8. The intended end use of the site includes public access to scrub and grassland with paths. An assessment is therefore made of the doses to a member of the public who spends time walking over the restored site and it is assumed that this continues once erosion starts to impact the site even though the characteristics of the surrounding area when erosion occurs may restrict access to the site. Time spent close to and walking over the eroding materials is calculated assuming a daily walk of 1 hour, passing the exposed face once, assuming a face length of 1 km and walking at 5 km h^{-1} (about 73 h y^{-1}). The walker inadvertently ingests soil, inhales dust and receives an external exposure from exposed waste, and it is cautiously assumed that all three age groups walk together. The habit data are summarized in Table.

Table Habit data for exposure of coastal walker to eroded waste: applicable after the Period of Authorisation

Parameter	Value	Comment
Inhalation rate – adult (m^3 h^{-1})	1.21	Inhalation rates based on ICRP 66 (ICRP, 1994), see Table 67 for derivation
Inhalation rate – child (m^3 h^{-1})	0.87	
Inhalation rate – infant (m^3 h^{-1})	0.31	
Time on site – public (h y^{-1})	73	Time taken to pass exposed waste.

Assessment calculations for coastal walker

9. The coastal walker receives a dose from external irradiation, inhalation and inadvertent ingestion at the time of erosion (*t*, time unknown but using an inventory taken at 60 y after closure). The same calculation as used in the ESC is applied except that a geometry factor of 0.2 is applied to the external exposure dose coefficients to account for the exposure geometry along an eroding bank.

E.2 Exposure following site erosion and release of leachate into sea

10. As discussed in Section E.1, erosion of the landfill considers an inventory calculated at the end of the period of authorisation. This scenario considers exposure from releases of leachate from the eroding site into the marine environment at an unknown time in the future. It is assumed that erosion will occur from the seaward side of the landfill and that contamination will be leached from the landfill materials as they are eroded. It is also assumed that the leached contamination will predominantly enter the sea rather than a confined estuary. This is because, at the time erosion occurs, the coastline will approximate a sheltered coastal location rather than the current estuary. Doses relating to eroded landfill material on the beach are addressed in Section E.1 and are not addressed here.

11. The dose criterion used is a dose of 0.02 mSv y^{-1} for the public (this is equivalent to the risk guidance level of 10^{-6} y^{-1} for exposure of the public post closure, for situations that are expected to occur).

Potentially exposed group

12. An assessment will be made of the doses to a family (member of the public) who spends time on a beach or shore of the sea close to the site at some time in the future. It is assumed that the family fishes and collects seafood from the area, which they consume, receiving an ingestion dose. The family also receives external exposure from beaches and fishing equipment and inhalation dose from sea spray.

13. Habits data for the family are presented in Table.

Table Habit data for a fishing family exposed as a result of coastal erosion

Habit data	Adult	Child	Infant
Fish consumption (kg y^{-1})	100	20	5
Crustacean consumption (kg y^{-1})	20	5	0
Molluscs consumption (kg y^{-1})	20	5	0
Occupancy on shore (h y^{-1})	2000	2000	2000
Inhalation rate (m^3 y^{-1})	8100	5600	1900

Assessment for coastal erosion dose

14. Dose to the family from coastal erosion will be calculated using PC CREAM 08. A local marine compartment will be set up for Port Clarence using the parameters recommended by PHE (Smith, 2019) for a sheltered coastal location for Hartlepool, including dimensions, volumetric exchange rate, sediment parameters and dispersion rate. This was deemed appropriate as it is not possible to tell what shape the coastline or estuary may be following erosion. The parameters are given in Table.

Table Port Clarence Local Marine Compartment Parameters

Parameter	Value
Volume (m^3)	1 10^9
Depth (m)	10
Coastline length (m)	10000
Volumetric exchange rate (m^3/y)	2 10^{10}
Suspended sediment load (t m^{-3})	1 10^{-5}
Sedimentation rate (t m^2 y^{-1})	2 10^{-4}
Sediment density (t m^{-3})	2.6
Diffusion rate (m^2 y^{-1})	3.15 10^{-2}

15. The DORIS module in PC CREAM will be used to calculate activity concentrations in sea water, seabed sediment and seafood assuming a 1 Bq y^{-1} release to the local compartment. This can then be used as input to the ASSESSOR module of PC CREAM, in which the dose to the fishing family can be calculated using habits data as shown in Table, also for a 1 Bq y^{-1} release.

16. It is assumed that the inventory is calculated at a time 60 years after closure, and that the site is eroded at a rate of 1 m y^{-1} at some time in the future.

17. The activity of radionuclides and ingrown daughters 60 y after closure, assuming 1 MBq initial inventory, will be calculated using the Bateman equations. Any radionuclide or daughter for which the activity remaining was less than 10^{-10} Bq was excluded from further assessment.

Appendix F Port Clarence NORM capacity i1

creating a better place
for people and wildlife

Environment Agency

[redacted]
Augean Plc
East Northants Resource Management Facility
Stamford Road
Kings Cliffe
PE8 6XX

Our ref: PC-O-20-002
Your ref: n/a
Date: 1 April 2020

Dear [redacted]

[redacted] material at the Port Clarence Landfills

[redacted] radioactive material (NORM) under an exemption from the Environmental Permitting Regulations 2016. We are currently assessing a permit application for the disposal of low level waste (LLW) at the landfills. [redacted] radiological doses and risks associated with the disposal of these 2 waste streams, as outlined in the Port Clarence Environmental Safety Case (ESC) and as discussed at our meeting on 26 February 2020. We have also taken legal advice.

Augean Plc proposes that the NORM and LLW waste streams should be managed [redacted] compared with the NORM radiological capacity. It will then carry out a check to ensure that [redacted] NORM and LLW disposals do not exceed 300 µSv/year. This dose level is equal to both the dose criteria to any member of the public selected in order to demonstrate exemption as a Type 2 NORM waste (2018 [redacted] the Radioactive Substances Regulation in England, Wales and Northern Ireland) and the dose constraint from the facility to a [redacted] are made (UK Environment Agencies Guidance on the Requirements for Authorisation of near-surface disposal facilities for solid radioactive waste (the GRA), 2009). It does not propose to apply a similar check for post-closure doses, given the divergence between the NORM exemption dose limit and the dose equivalent of the risk guidance level (approximately equivalent [redacted] scenario occurring of 1).

We agree that it is appropriate to manage the waste streams separately; the NORM under the terms of the exemption and the LLW in line with the requirements of the GRA and the assumptions of the ESC. We are satisfied that Augean Plc's plan to manage the combined impacts to members of the public in line with a dose limit of 300 μSv/year during the period of authorisation is appropriately protective. After the period of authorisation, we consider that constraining combined doses to the dose equivalent of the risk guidance level in the situation where there is a probability of the scenario occurring of 1 (i.e. the lower of the relevant dose constraints) would be unnecessarily restrictive for the management of NORM disposals and outside the requirements of the NORM exemption. We therefore consider that it will be appropriate for Augean Plc to manage NORM and LLW post-closure impacts separately, in accordance with their respective dose and risk constraints. We will require Augean Plc to maintain records of both NORM and LLW disposals and to maintain a record of combined impacts from both waste streams for relevant exposure scenarios covering both the period of authorisation of the landfill and after the period of authorisation.

Do not hesitate to contact us if you have any queries.

Yours sincerely,

[redacted]

[redacted]
Environment Agency
Tel: [redacted] Mobile: [redacted] email address: [redacted]@environment-agency.gov.uk

Cc
Environment Agency: [redacted], [redacted], [redacted], [redacted] [redacted]
Augean: [redacted]
Eden Nuclear and Environment: [redacted], [redacted]