Lillyhall landfill radioactive substances permit variation: Decision Document

Environmental permitting: radioactive substances activities

Date: 15th July 2021

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Executive summary

The Lillyhall Landfill Site is an existing landfill site operating under two Environmental Permits to dispose of non-radioactive waste (EPR/GP3037SJ) and high volume very low level radioactive waste (HV-VLLW) (CD7914). Disposals of non-radioactive waste commenced in 1972. The landfill is comprised of disposal cells that have been filled in stages. Stages 1 and 2 of the site are complete. Stage 3 has been operational since 1998 and comprises a partially filled clay-lined landfill, which accepts inert, non-hazardous, and household wastes. The site was granted a radioactive substances activity permit in 2011 to dispose of HV-VLLW, which has an activity disposal limit of less than 4 Becquerels per gram (Bq/g) or 40 Bq/g for tritium.

FCC Recycling (UK) Ltd has applied to vary their radioactive substances permit (CD7914) to accept waste with an average activity of up to 200 Bq/g, with a specific item limit (e.g. a drum in that consignment) of 1000 Bq/g to allow for some variability in the waste. The activity of this waste is at the lower end of the activity range for low level radioactive waste (LLW), which is radioactive waste with radioactivity not exceeding 4 gigabequerels per tonne (GBq/te) of alpha or 12 GBq/te beta/gamma. The term low activity low level waste (LA-LLW) is commonly used to refer to radioactive wastes at the lower end of the LLW activity range and typically has an activity of up to around 200 Bq/g and may be suitable for disposal at permitted landfill sites.

The justification for the increased activity concentration limit is supported by a revised Environmental Safety Case (ESC). The ESC consists of management, operational, technical and radiological procedures and assessments to show how people and the environment will be protected from the disposal of LA-LLW. The ESC considers various potential exposure scenarios from which people could be exposed to radiation from the disposal of LA-LLW. These are used in the radiological assessments to determine the radiological capacity of each of the radionuclides to be disposed. This is to ensure they are within the relevant regulatory dose criteria which are set at levels to ensure people and the environment are suitably protected.

We have assessed the ESC as part of our determination of the application and we have taken into account all relevant considerations and legal requirements to ensure the appropriate level of protection of people and the environment.

We have previously advertised the application and consulted on it (4 March 2019 to 15 April 2019.). We have assessed the application, considered the

responses we received and have made a decision to grant the application subject to the conditions in the varied permit that accompanies this document.

Permitting decisions

Radioactive Substances Regulation

We have decided to grant the application to vary the Lillyhall landfill site permit operated by FCC Recycling (UK) Limited. The decision is effective from 15th July 2021.

The permit number is EPR/MB3091DL/V002.

We consider in reaching this decision we have taken into account all relevant considerations and legal requirements and that the permit will ensure the appropriate level of protection of people and the environment.

These considerations are set out in:

- Government guidance on radioactive substances regulation (DEFRA, 2011)
- RSR RGN1 Radioactive Substances Regulation – Environmental Principles (Environment Agency, 2010)
- Near-surface Disposal Facilities on Land for Solid Radioactive Wastes: Guidance on Requirements for Authorisation (Environment Agency et al, 2009)
- Guidance Note for Developers and Operators of Radioactive Waste Disposal Facilities in England and Wales. Near-surface Disposal Facilities on Land for Solid Radioactive Wastes: Guidance on Requirements for Authorisation. Supplementary guidance related to the implementation of the Groundwater Directive (Environment Agency, 2012)

Purpose of this document

This decision document provides a record of our decision making process. It summarises the decision making process to show how we have taken all relevant factors in to account in reaching our decision.

Unless the decision document specifies otherwise we have accepted the applicant's proposals.

Variation for the disposal of radioactive waste

Introduction describing the application

The Lillyhall Landfill Site is an existing landfill site operating under two Environmental Permits to dispose of non-radioactive waste (EPR/GP3037SJ) and high volume very low level radioactive waste (HV-VLLW) (CD7914). Disposals of non-radioactive waste commenced in 1972. The landfill is comprised of disposal cells that have been filled in stages. Stages 1 and 2 of the site are complete. Stage 3 has been operational since 1998 and comprises a partially filled clay-lined landfill, which accepts inert, non-hazardous, and household wastes. The site was granted a radioactive substances activity permit in 2011 to dispose of HV-VLLW, which has an activity disposal limit of less than 4 Becquerels per gram (Bq/g) or 40 Bq/g for tritium. Cell 6B is currently active and accepts non-radioactive and HV-VLLW wastes. Cell 6C is a separate adjacent sub cell currently active for the acceptance of asbestos and HV-VLLW. To date, no HV-LLW has been disposed of at the site.

FCC Recycling (UK) Ltd has applied to vary their radioactive substances permit (CD7914) to accept waste with an average activity of up to 200 Bq/g, with a specific item limit (e.g. a drum in that consignment) of 1000 Bq/g to allow for some variability in the waste. The activity of this waste is at the lower end of the activity range for low level radioactive waste (LLW), which is radioactive waste with radioactivity not exceeding 4 gigabequerels per tonne (GBq/te) of alpha or 12 GBq/te beta/gamma. The term low activity low level waste (LA-LLW) is commonly used to refer to radioactive wastes at the lower end of the LLW activity range and typically has an activity of up to around 200 Bq/g and may be suitable for disposal at permitted landfill sites. There are currently three other landfill sites permitted to accept LA-LLW in England: East Northants Resource Management Facility (ENRMF) in Northamptonshire; Clifton Marsh in Lancashire and the Calder Landfill Extension Segregated Area (CLESA) on the Sellafield Site in Cumbria, although this landfill only accepts wastes from the Sellafield site.

The LA-LLW to be disposed of is likely to be varied, but will typically comprise concrete, rubble and metals from decommissioning activities on nuclear licenced sites, soils contaminated with low levels of radioactivity, operational wastes from nuclear licenced sites and non-nuclear sector radioactive waste. The nature of the types of waste acceptable will be defined in the waste acceptance criteria (WAC).

The justification for the increased activity concentration limit is supported by a revised Environmental Safety Case (ESC). The ESC consists of management, operational, technical and radiological procedures and assessments to show how people and the environment will be protected from the disposal of LA-LLW. The ESC considers various potential exposure scenarios from which people could be exposed to radiation from the disposal of LA-LLW. These are used in the radiological assessments to determine the

radiological capacity of each of the radionuclides to be disposed. This is to ensure they are within the relevant regulatory dose criteria which are set at levels to ensure people and the environment are suitably protected.

The radiological impact must be within the regulatory dose and risk criteria: dose constraints are set for members of the public that may arise from the site during the period of authorisation (300 microsieverts/year (µSv/year)), a risk guidance level after the period of authorisation (20 µSv/year) and dose constraints for human intrusion (3-20 millisieverts/ year (mSV/year)).

The table below shows the exposure scenarios that have been considered in the ESC and the groups that are likely to be exposed:

Exposure Scenario	Exposed Group
Period of Authorisation – Expected to Occur	
Direct exposure	Worker only
Leachate processing off-site	Treatment worker Farming family Fisherman
Release to groundwater	Member of public
Period of Authorisation – Not Certain to Occur	
Dropped load	Worker only
Fire	Worker only
After the Period of Authorisation – Expected to Occur	
Release to groundwater	Member of public
After the Period of Authorisation – Not Certain to Occur	

Recreational user	Member of public
Human intrusion – After the Period of Authorisation	
Agricultural scenario	Member of public
Construction scenario	Member of public
Industrial scenario	Member of public
Housing scenario	Member of public
Subsistence Farming	Member of public

The future disposal inventory is not known in detail because waste streams for disposal will only be identified as a result of commercial agreements. The estimate of radiological impact is based on a 'model inventory' derived from analysis of potentially relevant waste streams identified in the 2016 UK Radioactive Waste Inventory (UKRWI) (Nuclear Decommissioning Authority, 2016). The disposed waste will contain no more than on average 200 Bq/g with a limit on a single item or package (no greater in volume than $2m^3$) within the consignment of 1000 Bq/g. This corresponds to a maximum inventory of 36 TBq assuming that waste has a density of 1.8 te/m^3 and a disposal volume of 100,000 m^3. To ensure that estimated radiation doses would never exceed the regulatory criteria, calculations have been carried out for each exposure scenario and for each radionuclide to determine the radiological capacity for each radionuclide. These are used as the disposal limits for each radionuclide or to calculate disposal limits for combinations of radionuclides in the permit to ensure all disposals are within the regulatory dose criteria.

The radiological capacity is the radionuclide inventory of each radionuclide that can be disposed at the site that would not result in a dose greater than the relevant dose criterion from any of the exposure scenarios. It is therefore the minimum of the values calculated for each exposure scenario. All calculations are inherently cautious ensuring that the prospective dose is overestimated and, because the radiological capacity is proportional to the dose, the radiological capacity is therefore minimised.

The disposal limits in the permit, together with a sum of fractions approach, are used to control disposals to ensure the radiological capacity for each radionuclide and the overall

site limits are within the relevant regulatory criteria. The sum of fractions calculates the fraction of the radiological capacity that has been used by each disposed radionuclide in turn and if that sum of all fractions is ≤1.0 it will ensure that the dose or risk from all disposed radionuclides does not exceed the relevant dose or risk criterion. If the sum of all fractions reach 1 this means the overall site radiological capacity has been reached and no more radioactive waste can be disposed of.

Radiological releases in the leachate, landfill gas or into groundwater have been considered in the radiological impact assessment for each exposure scenario, along with direct exposure to the workers on site. As the disposal limits for each radionuclide have been determined by these assessments there is no requirement for aqueous and gaseous discharge limits to be set in the permit.

We have assessed the ESC as part of our determination of the application and our findings are discussed below in 'Our Assessment' Section.

Justification and Euratom Article 37 (RSR Part A Q9, RSR Part B5 Q2b)

The Justification of Practices Involving Ionising Radiation Regulations 2004' (GB Parliament, 2004) are not part of the environmental permitting regime. But if an application for an environmental permit relates to a practice, as defined in the 'Basic safety standards directive' (BSSD) (EU, 2013), we can only grant a permit if the practice is justified (see appendix 2 of Government policy - radioactive & nuclear substances (GB Parliament, 2015a) for further details).

Justification is not required for this application because waste disposal, such as by burial or incineration, is not subject to specific justification; justification arises from the practice giving rise to the waste.

At the time of the application it was a requirement for the operator of the landfill site to determine if an Article 37 submission was required by the Department for Business, Energy and Industrial Strategy (BEIS). The operator originally stated this was not a requirement, however, we sought opinion from BEIS and it was confirmed they would need to make a submission. BEIS consulted the EA on FCC Recycling (UK) Ltd.'s submission and we requested the submission was revised to take account of a schedule 5 notice for further information in which we required the operator to update their radiological risk assessments. We requested this amendment as the assessments were based on data from the 2010 UKRWI which we considered to be out of date as the UKRWI had been updated in 2016. It should be noted that during the assessment period the 2016 UKRWI was updated to 2019 UKRWI. We accepted the use of the 2016 data as FCC Recycling (UK) Ltd were halfway through their assessments. We would expect FCC to use the most up to date version of the UKRWI in any future updates to the ESC and supporting documents.

The Article 37 submission was made during the transition period of the UK leaving the European Union. Delays to the submission of the amended Article 37 prevented it from being submitted to the European Commission for review prior to the UK leaving the

transition period. This meant the operator was now required to submit a transboundary impact assessment to the Environment Agency (EA) for review and consultation with BEIS.

We reviewed FCC Recycling (UK) Ltd.'s transboundary impact assessment and consider the information used is consistent with the information in the ESC and has been appropriately used for the transboundary assessment. We advertised this on Citizen Space between the 4th February 2021 and 5th March 2021, in addition to directly informing BEIS. We did not receive any comments.

Consultation

Annex 1 summarises the consultation responses and how we have taken these into account.

Our Assessment:

Our guidance for Near-Surface Disposal Facilities on Land for Solid Radioactive Wastes: Guidance on Requirements for Authorisation (NS-GRA) (Environment Agency et al, 2009) sets out the requirements an operator should meet to ensure the disposal of radioactive waste is optimised. We have assessed the application with these requirements in mind. To support the application the operator has produced a revised Environmental Safety Case (ESC) Version 5 (Atkins, 2021a) [1] to demonstrate they have the required management, operational, technical and radiological procedures and assessments in place to meet the requirements of the NS-GRA, other Environment Agency guidance and statutory guidance. The ESC provides the hydrogeological and radiological risk assessments which inform the disposal limits for the site. It also sets out the waste acceptance criteria and procedures used to ensure waste is accepted within these limits.

We have considered FCC Recycling (UK) Ltd.'s application against each of the 14 Requirements in the NS-GRA. Our assessment is summarised below:

Management Requirements

Requirement 1: Process by agreement

The developer should follow a process by agreement (with regulators to find a suitable site) for developing a disposal facility for solid radioactive waste

This requirement is not as relevant to existing landfill operators that hold radioactive substances permits for the disposal of radioactive waste compared to entirely new developments. Lillyhall is an established operational landfill site which is permitted to accept both conventional wastes and HV-LLW radioactive wastes. We have reviewed the design, construction, operation, closure and post-closure management of the disposal facility, see Requirement 8: Optimisation, section below, to ensure the operator can safely manage LA-LLW.

FCC Recycling (UK) Ltd did engage with us prior to making their application to discuss their plans and proposed approach. We also provided advice on the permitting process.

[1] The initial application was supported by version 1 of the Environmental Safety Case (Atkins, 2019). Following our further information requests ((Environment Agency, 2019) and other comments the Environmental Safety Case (Version 5) (Atkins, 2021b) was submitted and was the final version on which we reached our determination.

We consider FCC Recycling (UK) Ltd has met the objectives of Requirement 1 of the NS-GRA.

Requirement 2: Dialogue with local communities and others

The developer should engage in dialogue with the planning authority, local community, other interested parties and the general public on its developing environmental safety case

FCC Recycling (UK) Ltd was granted planning permission (2/13/9007) in 2013 to extend the operational period of the landfill until 2029 with an additional year for restoration to ensure that the former opencast site (Phases 3 and 4) are restored to an acceptable landform and after use and to confirm accepted waste types including LLW. At the time of planning permission being granted the operator was permitted to accept HV-VLLW. Prior to the submission of the variation application, to accept LA-LLW, the operator sought clarification from the planning authority as to whether the variation to the environmental permit would require planning permission. The planning authority have confirmed that the variation to accept LA-LLW would not require planning permission as the activity concentrations are within those for LLW.

Stakeholder engagement was held on the 6th December 2018 to support the current application. Key stakeholders included members of the public, local council and parish representatives and local businesses.

The aim of the stakeholder engagement was to provide information on current permitted LLW activities, reasons to increase the permitted activity limits and details of the permit variation process including the ESC and to answer questions people may have.

We ran a public consultation from 4 March 2019 to 6 May 2019 on Citizen Space. The consultation was also published on gov.uk on 5 March 2019. We informed various government bodies, local authorities, interest groups and other interested parties of the consultation via email and letter. We also attended the operator's stakeholder event in December 2018 and met with the Dean Parish Councillors in April 2019. We received 8 responses from local authorities, Public Health England, COMARE, Low Level Waste Repository (LLWR), Radiation Free Lakeland, and members of the public. We have summarised the consultation responses which are included in Appendix 1 along with our response to the comments. The responses varied from being technical in nature, for example asking specific questions relating to the activity limits and management of the site, to quite general comments on the area. Some of the responses were very detailed and seeking further clarification on points made in the ESC. We also published our summary of the consultation responses on Citizen Space.

We consider that FCC Recycling (UK) Ltd has met the objectives of Requirement 2 of the NS-GRA.

Requirement 3: Environmental Safety Case

An application under RSA 93 (or the Environmental Permitting (England and Wales) Regulations 2010, in this case) relating to a proposed disposal of solid radioactive waste should be supported by an environmental safety case

The operator has submitted a revised ESC (version 5) (Atkins, 2021a) in support of their application to vary the permit to accept LA-LLW. The ESC consists of a set of claims, arguments and evidence to demonstrate the environmental safety of disposals of solid radioactive waste to ensure members of the public and the environment are adequately protected.

We have assessed FCC Recycling (UK) Ltd.'s ESC (version 1) submission (Atkins, 2019) against the requirements of the environment agencies 'Near-surface Disposal Facilities on Land for Solid Radioactive Wastes: Guidance on Requirements for Authorisation' (NS-GRA) (Environment Agency *et a*l., 2009) and the accompanying supplementary guidance related to the implementation of the Groundwater Directive (Environment Agency, 2012). We provided our findings to FCC Recycling (UK) Ltd via email on 17th October 2019 (Glaister, C, 2019) and in a Schedule 5 Notice for further information which we issued on the 11th November 2019 (Environment Agency, 2019). Our assessment also considered the responses we received during the statutory consultation period, see Appendix 1 for consultation responses and how we have addressed these.

Our initial assessment raised a number of questions and a meeting was held on 14th October 2019 between the Environment Agency, FCC Recycling (UK) Ltd and their technical consultants to address these concerns, which ultimately led to a resubmission of the ESC (version 2) (Atkins, 2020a).

Our comments on the original submission centred on the following:

The use of two different inventories – one presented in the ESC, the other in the Hydrogeological Risk Assessment (HRA) and subsequently used in assessment reports;

How the inventories were derived;

The derivation of, and use of, two different waste densities;

Where assessments have shown dose/risk that exceeds the criteria given in the NS-GRA, generally poor justification of why this should not be of concern (i.e. better justification required).

The revised submission addressed most of our questions, the main ones being the disparity in inventories being used, and the fact that these inventories were based on the 2010 UKRWI. Although the 2019 UKRWI was published while these documents were being updated, this was in the latter stages of the update, and we are satisfied that the approach adopted in the update, which was based on the 2016 UKRWI, is appropriate. We note that in the majority of cases, dose assessment using this updated data has resulted in lower predicted dose and risk across all scenarios.

A number of uncertainties or areas of clarification remained and we did request further information from the applicant (Environment Agency, 2020). We received further responses which resulted in the revised ESC (version 3) (Atkins, 2020b) being submitted in September 2020.

Further review of the ESC (version 3) identified the radiological capacity proposed for Po-210 to be extremely low and lower than expected. We asked the operator to carry out additional work to examine this apparent error (Atkinson, T, 2021a) which they did (FCC, 2021). This further work identified an error in radiological capacity calculations, which in turn resulted in the recalculation of radiological capacities for all radionuclides. An updated ESC (version 4) (Atkins, 2021a) was submitted to us, however, due to data transposition errors and incorrect version control (Atkinson, T, 2021b) this had to be resubmitted to us on 15th June 2021 with these further errors corrected in Version 5 (Atkins, 2021b). This latest version of the ESC was made available on Citizen Space.

Throughout our assessment and determination process we have raised a number of concerns with the operator and their contractors regarding quality assurance, in particular we have raised concerns regarding the use of two different radiological waste inventories and poor document version control. In each instance of quality assurance concerns we have sought all necessary evidence to satisfy us that the information provided and assessments were correct and satisfactory to meet our requirements. We have engaged with the operator and their consultants further in relation to these more recent concerns and have been assured that as a result of issues raised their quality assurance processes have been improved. Following issue of a varied permit we will consider the need to inspect the operator and any contractor support they contract with in relation to their ongoing competency and capability on quality assurance, control of waste disposals and inventory.

We are satisfied that the management, radiological and technical requirements, as set out in the NS-GRA, have been appropriately addressed and consider the ESC meets our expectations for Requirement 3 of the NS-GRA.

Requirement 4: Environmental Safety Culture and Management System

The developer/operator of a disposal facility for solid radioactive waste should foster and nurture a positive environmental safety culture at all times and should have a management system, organisational structure and resources sufficient to provide the following functions:
(a) planning and control of work;
(b) the application of sound science and good engineering practice;
(c) provision of information;
(d) documentation and record-keeping;
(e) quality management.

The operator has summarised the management arrangements in the ESC. These are existing arrangements which are in place to satisfy the requirements of the environmental permits already held by FCC.

In summary the ESC describes the Integrated Management Systems (IMS) and the safety culture. The IMS is subject to regular compliance inspection both internally by suitably qualified and experienced people (SQEP) and externally by independent certification bodies and the Environment Agency. Evidence was provided that the IMS is accredited to ISO14001 and ISO9001.

The Company has the following Management System Policies:

- IMS-1-01-GFCC - Integrated Management System Policy;
- QMS-1-01-GFCC - Quality Management System Policy;
- HSMS-1-01-GFCC - Health and Safety Management System Policy;
- EMS-1-01-GFCC - Environmental Management System Policy.

The operator provided various procedures to support the ESC which we have reviewed. The operator has existing management procedures in place for the receipt and disposal of high volume very low level waste (HV-VLLW). The operator has stated the current procedures will be reviewed for appropriateness for the acceptance of LA-LLW. A pre-operational condition has been included in the permit to ensure this is completed prior to the receipt of LA-LLW. The site safe working procedure which provides details of the current approach to waste receipt, waste disposal and dealing with non-compliant waste packages was provided in Appendix C of the ESC.

The operator has a documented procedure to ensure that records for the IMS are controlled, updated, archived and, where appropriate, destroyed. Records will be kept of all radioactive waste disposals and will include consignor information, mass of consignment, fingerprint, radioactivity, volume and location in the landfill. Records will also be kept of the results of environmental monitoring, including for radioactivity. Our review of the ESC identified that the record retention schedule was not appropriate for radioactive waste records and we requested this was reconsidered in the Schedule 5 Notice for further information. The operator sought advice from us which we provided in an email (Atkinson, 2020). The operator has revised the ESC which now refers out to EA guidance, in the NS-GRA, on records retention.

FCC Recycling (UK) Ltd ensures that all staff have training necessary for the relevant job role. A documented procedure is operated to ensure that:

- All new employees are made aware of their role in the Company;
- Training needs are assessed annually through performance and the Individual Development Scheme;
- Development and training of staff is encouraged through attendance at external conferences and internal seminars where appropriate, self-training and toolbox talks;
- Employees are trained and developed in their roles;
- Training records are maintained.

In support of the revised ESC, evidence of staff training was provided. We also sought further clarification on the relationship between the operator and the consultants that will provide specialist radioactive waste assessment services. We were provided with documents that explained the role of the consultants and evidence of their SQEP capability was also provided. The operator will be supported by consultants to provide a specialist radioactive waste assessment service. The procedure for the disposal of HV-VLLW explains the role of both the operator and consultants in accepting radioactive waste for disposal. This process also involves the peer review of each organisations work.

We have assessed the applicant's competence against the guidance on management arrangements. We have not identified any reasons indicating that the operator is unable to operate in accordance with the permit.

We are satisfied the operator has the necessary management controls in place. It is recognised that these will require further review and possibly be updated to reflect the increase in disposal limits. For this reason we have included a pre-operational requirement in the permit to ensure any necessary changes are implemented prior to the acceptance of LA-LLW. The management controls will also be checked as part of our routine regulatory activities with the site.

We consider the operator has supplied sufficient information to meet Requirement 4 of the NS-GRA.

Radiological Requirements

The operator has conducted various dose assessments, as required by the NS-GRA, in support of this application. The results have been compared against the dose constraint (during the period of authorisation), risk guidance level (after the period of authorisation) and dose guidance level (human intrusion after the period of authorisation), which are discussed in the sections below. The dose assessments are based on the radiological capacity of the landfill site and use various exposure scenarios to calculate the radiological impact on representative members of the public to ensure they are within the relevant dose constraint and guidance levels, as discussed below.

Requirement 5: Dose constraints during the period of authorisation

During the period of authorisation of a disposal facility for solid radioactive waste, the effective dose from the facility to a representative member of the critical group should not exceed a source-related dose constraint and a site related dose constraint

The UK Government and Devolved Administrations have directed the environment agencies to have regard to the following maximum doses to individuals which may result from a defined source, for use at the planning stage in radiation protection:

• 0.3 mSv/y from any source from which radioactive discharges are made; or

• 0.5 mSv/y from the discharges from any single site.

Supplementary guidance to the GRA, resulting from the implementation of the Groundwater Directive (Environment Agency, 2012), specifies an additional dose guidance level of 0.02 mSv y^{-1} for doses arising from groundwater during the period of authorisation.

The period of authorisation includes both the operational period of the landfill and the period of active institutional control, which is the period after landfill operations have ceased but the operator is still required to manage and monitor the landfill site. The landfill will be operational until 2030 and the ongoing management and monitoring is expected to continue until 2090.

The ESC includes detailed radiological impact assessments that consider radiation doses to both workers and the most exposed members of the public during the period of authorisation. The assessments include a range of scenarios where exposure to a potentially exposed group is likely to occur such as a release to groundwater and also where it is not certain to occur, for example a landfill fire. We assessed the relevance of the scenarios and issued a schedule 5 notice for further information requesting the assessment of two additional scenarios:

Fire

We requested that landfill fire was assessed as this is a potential scenario and as such is a potential pathway for radioactivity to enter the environment. FCC Recycling (UK) Ltd subsequently included a fire scenario as an exposure not certain to occur.

Landfill Gas

We noted in our initial review of the ESC that reference was made to the potential for landfill gas to contain radionuclides such as radon, carbon-14 and tritium. However this was not considered as an exposure scenario. In response to the schedule 5 notice FCC Recycling (UK) Ltd have produced a gas assessment and updated the revised ESC (version 3). The assessment concluded that during the period of authorisation the generation of radioactive gases would be mitigated by the flaring of the landfill gas, an established method for managing gas from a landfill site, and exposures would be unlikely and therefore an exposure scenario was not produced. However it was recognised that after the period of authorisation landfill gas will not be actively managed and may accumulate under the capping layer. Therefore there is the potential scenario for members of the public to be exposed to radiological doses from gas migration. The gas assessment has shown the predicted effective annual dose to a person who dwells in a property built on the landfill and is exposed to gaseous emissions of tritium (H-3), carbon (C-14) and radon (Rn-222) is under 0.05 µSv/yr. It has been concluded that the dose implications of gas emissions are insignificant and have not been considered further.

The potentially exposed groups used were considered to be appropriate, with FCC Recycling (UK) Ltd providing justification for their choice of groups.

It must be noted that it is not practical to assess the dose to each individual member of the public and therefore the radiological dose assessments use an individual that would represent someone from a group that would be the most exposed to the source of radiation (also referred to as the representative person). The term representative person has replaced that of critical group. Factors considered when assessing the dose to the representative person include:

Radionuclides being disposed of (source of radiation);

How these can enter the environment (pathways): air, water, land;

Age of representative person - we use four age groups: foetus, 1 year old, 10 year old and adult;

Behaviour of people around the site, for example: member of the public, farming family, fishermen, sewage treatment workers, high consumers of certain foods from the area;

Timescales: during the operation of the landfill; after the landfill has closed; human intrusion into the landfill after it has closed or following erosion.

The table below shows the doses to the exposed groups for each exposure scenario during the Period of Authorisation, compared against the dose criteria:

Exposure Pathway	Receptor	Predicted Total Annual Effective Dose (µSv)	Relevant Annual Effective Dose Criterion (µSv)
Period of Authorisation – Expected to Occur			
Direct exposure	Worker only	65.8	300
Leachate processing off-site	Treatment worker	< 0.1	300
	Farming family	< 25	300
	Fisherman	< 0.1	300
Release to	Member of public	0.8	20
Period of Authorisation – Not Certain to Occur			
Dropped load	Worker only	7.45E-05	300
Fire	Worker only	23	300

In all the scenarios considered, the doses are less than the annual effective dose constraint of 300 µSv and the 20 µSv annual effective dose guidance level associated with leachate migration into groundwater.

The dose assessments are based on data from the UK 2016 Radioactive Waste Inventory (UKRWI) and established modelling techniques. It must be noted that the initial assessments used data from the 2010 UKRWI. We did not consider this data to be the most up to date as the UKRWI was updated in 2016. We issued a Schedule 5 notice for further information (Environment Agency, 2020) requiring the operator to re-assess doses using the 2016 data. The revised assessments, as shown above, have resulted in a reduction to the predicted doses.

We are satisfied the operator has appropriately considered all relevant factors in their assessment of dose during the period of authorisation. We therefore consider the operator has supplied sufficient information to meet Requirement 5 of the NS-GRA.

Requirement 6: Risk guidance level after the period of authorisation

After the period of authorisation, the assessed radiological risk from a disposal facility to a person representative of those at greatest risk should be consistent with a risk guidance level of 10^{-6} per year (i.e. 1 in a million per year)

The 'risk guidance level' is our assessment standard for the natural evolution of the disposal facility. This does not include human intrusion into the landfill, a separate assessment is required for this, see Requirement 7 below. The value of 10^{-6} per year (or 1 in a million per year) is consistent with advice given by the Health and Safety Executive as 'a very low level of risk' and is used as a guideline above which people are prepared to tolerate risks. Public Health England (PHE) recommend a risk coefficient of 0.06 Sieverts (Sv) is used for waste management assessments. This is used to calculate the dose that represents the risk guidance level of 10^{-6} per year which broadly equates to a dose of 20 µSv/yr.

FCC Recycling (UK) Ltd has assessed the radiological risk from the site against a dose of 20 µSv/yr. They consider the time 'after the period of authorisation' to start in 2091 as this is when they expect active management controls (such as leachate and land management) to have ceased. It must be noted that this is not a definitive timeframe as the cessation of management control and permit surrender is dependent on the environmental impact of the landfill site at that time and subject to future updates of the ESC.

Two exposure scenarios were considered after the period of authorisation. These were exposure via drinking water (expected to occur) and bathtubbing (not certain to occur).

Exposure via drinking water:

This scenario is based on the radioactivity in the leachate entering the groundwater which is subsequently abstracted from a well for drinking water. This is considered to be the worst case exposure scenario. Other scenarios considered were the abstraction of groundwater for irrigation or livestock watering. These were not considered further as the abstraction rates required for irrigation and watering would be higher than for a domestic well. This would provide more dilution of the leachate and therefore reduce the activity present.

FCC Recycling (UK) Ltd.'s assessment has considered an extended period of time (several 100,000 years) to ensure that peak radiological concentrations have been captured in their assessment.

Assessment Results – Drinking Water

Period (post waste emplacement)	Annual Effective Dose (μSv)	Requires Further Assessment
~60 - 100	2.5E+00	No
~1,000 – 10,000	5.8E-01	No
~10,000 – 100,000	6.2E-01	No

The assessment shows that the predicted annual effective dose is well below the risk guidance level of 20.

Bathtubbing:

This is where leachate in a landfill cell reaches the surface due to cap failure and leads to land contamination. The bathtubbing scenario was initially screened out from requiring further assessment. However FCC Recycling (UK) Ltd have now included it as a scenario not certain to occur, based on the dose to recreational users (adult, child and infant) who spend time on the land of the former disposal area that may be contaminated by periodic flooding by bathtubbing events.

For this scenario the operator has considered four different variations for exposure:

1. Exposed, uniform contamination distribution – this represents soil contamination that is evenly distributed over the site and extends to a depth of 1 m. There is no overlying uncontaminated soil or other material. It is assumed that the soil has the same activity concentration as that averaged across the contents of a cell, i.e. considering radioactive waste, non-radioactive waste and daily soil cover. No allowance for ‘dilution’ of the activity with cap material is included.

2. Exposed, patchy contamination distribution – as per number 1, but where contamination is restricted to 10% of the area and where occupancy is random (NRPB, 2003).

3. Covered, uniform contamination distribution – as per number 1, but assuming that contamination has not reached the ground surface and that there is a 0.15 m cover of uncontaminated material.

4. Covered, patchy contamination distribution – as per number 3, but where contamination is restricted to 10% of the area and where occupancy is random [NRPB, 2003].

These scenarios consider a number of possibilities where scenario number 1 is very unlikely, but where scenarios 2 to 4 could be considered more realistic, although they are not certain to occur.

Assessment Results – Recreational User (All Scenarios)

Scenario	Annual Effective Dose (µSv)
Exposed uniform	1.6E+02
Exposed patchy	1.6E+01
Covered uniform	2.0E+01
Covered patchy	2.0E+00

The assessment shows that the exposed uniform contamination scenario dose would be 160 µSv/y, nearly an order of magnitude above the risk guidance level of 20 µSv/y. The operator has stated that this is not a particularly realistic scenario as it would be unlikely that the whole site would become contaminated, particularly as not all the cells will have had radioactive waste deposited in them. The operator has suggested more realistic scenarios could be contamination near, but not at the surface and/or patchy contamination (either at the surface or covered). The doses for the remaining scenarios range from 2 to 20 µSv/y which are within the risk guidance level of 20 µSv/y.

The operator has assessed the radionuclides that provide the biggest part of the dose. The dose for each of the scenarios is dominated by Caesium-137 (Cs-137). The exposed uniform contamination scenario dose has been assessed as 160 µSv/y, occurring immediately after the period of authorisation in 2091. For bathtubbing to occur the landfill cap would have to fail immediately after the period of authorisation. This would be unlikely as during the period of authorisation, expected to end in 2090, the operator will be required to monitor and manage the landfill site and we must be satisfied that the landfill would not pose a risk to the public and the environment. Therefore failure of the landfill cap immediately after the period of authorisation is extremely unlikely. The operator has also assessed the dose accounting for the radioactive decay of Cs-137 and after 90 years the dose would have reduced from 160 µSv/y to 20 µSv/y (within the risk guidance level). This is a more realistic dose as the integrity of the cap is expected to be maintained for 100 years. It must be noted that the period of authorisation is expected to end in 2090, however, depending on the monitoring and management requirements this could extend beyond 2090. If this situation does arise we would expect the operator to review their ESC and associated radiological risk assessments.

We are satisfied that FCC Recycling (UK) Ltd has considered appropriate exposure scenarios and has provided adequate justification for these and that the impact is below

the risk guidance level. We therefore consider the operator has supplied sufficient information to meet Requirement 6 of the NS-GRA.

Requirement 7: Human intrusion after the period of authorisation

The developer/operator of a near-surface disposal facility should assess the potential consequences of human intrusion into the facility after the period of authorisation on the basis that it is likely to occur. The developer/operator should, however, consider and implement any practical measures that might reduce the chance of its happening. The assessed effective dose to any person during and after the assumed intrusion should not exceed a dose guidance level in the range of around 3 mSv/year to around 20 mSv/year. Values towards the lower end of this range are applicable to assessed exposures continuing over a period of years (prolonged exposures), while values towards the upper end of the range are applicable to assessed exposures that are only short term (transitory exposures)

After the period of authorisation active management of the landfill site will have ceased and there will be the potential for people to utilise the land. Our guidance requires the assessment of potential human intrusion scenarios into the landfill on the basis that there is no prior knowledge of the landfill or the waste that has been disposed there.

Our guidance states the assessments should use a dose guidance level which ranges from 3 mSv/year to 20 mSv/year. This is to take in to account prolonged exposures at the lower end of the dose guidance level, for example houses being built on the site and short term exposures, such as construction works, at the upper end.

FCC Recycling (UK) Ltd have assessed the impact on human intrusion based on four scenarios:

- Agricultural – this assumes the land will be used for agricultural purposes and thus potential exposure to contaminated ground and the ingestion of contaminated crops.
- Construction – this scenario is based on the land being redeveloped and the impact of potential exposures to the workers. This scenario also includes consideration of mineral extraction as part of the landfill site is underlain by coal measures.
- Industrial and housing scenarios are also included to account for industrial or residential uses of the land and potential exposures to workers and residents.

We reviewed these scenarios and requested the operator also considered subsistence farming as this is also a credible future scenario. The operator has included subsistence farming in Revision 3 of the R7 Intrusion document (Atkins, 2021d), which supports the ESC (version 5). We are satisfied they are representative of possible future situations that could influence human intrusion in to the landfill site.

To reduce the dose impact of human intrusion into the landfill site the operator has proposed that most of the radioactive waste will be buried to depths greater than 5 meters to minimise exposures by future human intrusion.

The assessment has used a conservative approach based on the scenarios above and the average activity concentration of the waste – 200 Bq/g. An exposed, uniform

contamination distribution has been considered in the assessments. This assumes the soil contamination is evenly distributed over the site and extends to a depth of 1 m. There is no overlying uncontaminated soil or other material. The soil is assumed to have the same activity concentration as that averaged across the contents of a cell, i.e. considering radioactive waste, non-radioactive waste and daily soil cover. The cap has been lost or that waste material has been distributed evenly across the site. No allowance for 'dilution' of the activity with cap material or surrounding soil is allowed for.

The results of the assessment are shown in the table below:

Assessment results summary

Exposure Scenario	Public Receptor	Effective Dose (mSv)	Effective Dose Criterion (mSv)
Agricultural scenario	Member of public	5.2E-01	<5 (prolonged exposure)
Construction scenario	Member of public	5.3E-01	15-20 (transient exposure)
Industrial scenario	Member of public	5.8E-02	<5 (prolonged exposure)
Housing scenario	Member of public	3.0E-01	<5 (prolonged exposure)
Subsistence Farming	Member of public	8.2E-01	<5 (prolonged exposure)

The doses were assessed to be between 0.058 mSv and 0.82 mSv, below the dose guidance levels of 3-20 mSv/ year.

The operator has also assessed the dose from the disposal of packages with a maximum activity concentration of 1000 Bq/g. This is based on the dose from the construction scenario, 0.53 mSv, being five times higher from a package to give a result of 2.7 mSv/year. This is also below the dose guidance levels.

FCC Recycling (UK) Ltd has used a conservative approach to the dose assessments and doses have been shown to be below the dose guidance levels. We consider FCC Recycling (UK) Ltd has satisfied the objectives of Requirement 7 of the NS-GRA.

Requirement 8: Optimisation in the management and disposal of radioactive waste

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 as low as reasonably achievable (ALARA), taking into account economic and societal factors

The NS-GRA requires an operator to assess how waste disposals can be optimised to ensure the radiological risks to members of the public and the environment are appropriately managed and within the relevant regulatory dose criteria. Optimisation of the management and disposal of radioactive waste means the operator must use the best available techniques (BAT) to ensure radiological risks are kept as low as reasonably achievable (ALARA). For a landfill operator a number of factors must be considered: Waste acceptance criteria, how the site is used and the design, construction, operation, closure and post-closure management of the site. The optimisation requirement overlaps with a number of other requirements set out in the NS-GRA (Requirements 11, 12 and 13), which are discussed in more detail in the relevant sections.

We have assessed how FCC Recycling (UK) Ltd will optimise their activities from an existing landfill perspective and throughout the ESC they have shown how they will ensure their operations will keep radiological risks to members of the public ALARA. FCC Recycling (UK) Ltd have specifically considered optimisation in terms of the design and management of the landfill site. However it is worth noting waste acceptance criteria is separately addressed under Requirement 13 of the NS-GRA, see the relevant section below. The radiological assessments provided to meet Requirements R5 to R7 of the NS-GRA also provide relevant information to show how the radiological capacity has been optimised in terms of the choice of exposure scenarios that are both certain to occur and those that are not certain to occur and the impacts on the representative person. We have considered these factors in terms of acceptability of the exposure scenarios and that the calculated doses are within the relevant dose and risk criteria. These are discussed in the relevant sections above.

FCC Recycling (UK) Ltd has explained how the design and construction of Lillyhall landfill site is based on the principle of engineered containment to minimise exposure to the waste and ensure the containment of any leachate that is generated. The engineering standards are a specific requirement in the existing installations permit (EPR/GP3037SJ) and are set out in a Construction Quality Assurance (CQA) Plan which is approved by the Environment Agency and subject to our ongoing regulation.

Waste is disposed into cells which are constructed on a cell by cell basis. The ESC specifically refers to radioactive waste disposals in cells 7-10. However after further discussion with the operator it was confirmed that LA-LLW will also be over tipped onto completed cells 4B, 5, 5A and 6A, which are adjacent to cells 7-10 (Atkins, 2021c). Over tipping onto completed cells is standard landfill practice to ensure the final profile of the landfill site, set by the local planning authority, can be achieved. The inclusion of these cells has not impacted on the dose assessments as these have been based on the

remaining volumetric capacity of the site. The calculated non-engineered remaining site void space of the landfill is 891,053 m^3 and the radiological impact assessments have been based on LA-LLW disposals of 100,000 m^3 which equates to approximately 10% of the total amount of waste that can be disposed on site.

The site is operated in a cellular manner to minimise leachate generation. After each disposal operation (i.e. by the end of each working day), the waste will be covered with a layer of soil or clay. Prior to final capping a temporary cap is used to cover the cells where the disposal of waste has temporarily ceased or pending placement of the final cap. The final cap is comprised of low permeability layers overlain with restoration materials which will prevent exposure to the waste and minimise rainwater ingress into the landfill.

Leachate and landfill gas management systems are installed to ensure adequate controls are in place. Leachate migration is controlled by the engineering of the landfill to ensure containment and the installation of a leachate collection system which involves the collection of leachate at the base of disposal cells, drainage to abstraction pumps and extraction of the leachate. Leachate is currently biologically treated at the onsite Leachate Treatment Plant prior to discharge to sewer whereby it reaches the Parton Treatment Works, operated by United Utilities.

Landfill gas is also collected and extracted and managed either through flaring the gas or power generation.

There is an existing surface water and groundwater monitoring regime in place for both chemicals and radioactive species. This is discussed further under Requirement 14.

Existing operational and management controls are in place which will optimise the radioactive waste disposals:

The waste is covered daily to prevent waste from becoming wind-blown and minimising the creation of dust. Soil or Quaternary clay will be used for the cover material which will make up 3% to 20% of the disposal volume. This will reduce both the disposal capacity and the potential for the mobilisation of dusts in air, and will also provide a sorption substrate for any radionuclides released from the waste.

The disposal of putrescible wastes is restricted. This will minimise the creation of radiological gaseous emissions by mitigating the potential for microbial activity and the associated gaseous releases from microbial action and the risk of fire within the landfill site.

Leachate is currently processed in the on-site treatment facility which will also minimise the radioactivity going to Whitehaven Parton Wastewater Treatment Works (WwTW). This will also minimise exposure to the representative person during the period of authorisation - a member of a farming family who applies sewage solids to agricultural land.

The design of the site profile post-closure will ensure the restored surface will encourage surface water runoff, preventing the development of puddles and reducing infiltration and the generation of more leachate. 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 human intrusion disturbing waste or the prospect of housing development at the site.

To further optimise the disposals FCC Recycling (UK) Ltd have proposed to implement additional waste management controls and emplacement strategies for the radioactive waste:

The waste will be co-disposed with non-radiological wastes. The radioactive waste will be mixed with the non-radioactive waste which will effectively reduce the impact of potential exposures.

Some radioactive waste will be packaged with the packaging acting as a barrier, therefore reducing the radiological impact on the leachate from the site in the short term.

Operational constraints will be in place to restrict the placement of waste in a landfill cell, placing non-radioactive waste to a specified depth at the base (2 meters), sides (2 meters) and top (1 meter) 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. The operator has also proposed that most radioactive waste will be buried to depths greater than 5 meters to minimise exposures by future human intrusion.

We have included a pre-operational requirement in the permit for the operator to develop a waste emplacement strategy which must be embedded into the site's management system and associated procedures before any disposal of LA-LLW take place.

Established landfill engineering practices, existing operational controls and additional waste emplacement strategies demonstrate that optimisation has been adequately considered, thereby ensuring the required level of protection of people and the environment. We consider the operator has satisfied the objectives of Requirement 8 of the NS-GRA.

Requirement 9: Environmental Radioactivity

The developer/operator should carry out an assessment to investigate the radiological effects of a disposal facility on the accessible environment both during the period of authorisation and afterwards with a view to showing that all aspects of the accessible environment are adequately protected

The operator is required to demonstrate that non-human species and habitats are protected from radiological disposals at the site.

There is currently no internationally established criteria for determining radiological protection of the environment. The European research project, 'Framework for Assessment of Environmental Impact (FASSET)' Project concluded that the threshold for statistically significant effects on organisms is about 100 microgray per hour (μGy h^{-1}). Allowing for the dose rate from natural background, which is at most about 60 μGy h^{-1}, we have adopted a value of 40 μGy h^{-1} as the level below which we consider there will be no adverse effect on non-human species (Environment Agency, 2009).

The operator has assessed the impacts on non-human species based on a number of likely scenarios during the period of authorisation and after the period of authorisation, using the Environment Agency's Initial Radiological Assessment Tool (IRAT) for releases to sewer and the ERICA tool which is used to assess radiological impacts on non-human

biota (plants and animals). Impacts on non-human biota are typically assessed at the population level, based on reference organism types, although for protected species or habitats, more detailed impact assessments may be required.

The operator's assessment was based on exposures to representative animal and plant species that may inhabit the site or may be exposed to radionuclides as a result of their transport off-site both during and after the period of authorisation.

The nearest conservation sites to Lillyhall are the River Derwent and Bassenthwaite Lake Special Area of Conservation (SAC) and the River Marron (a tributary of the River Derwent), which is also designated as a Site of Special Scientific Interest (SSSI). The River Marron is the closest SSSI to the site, located around 2.5 km to the east of the site. The flow of groundwater at the site is from east to west and therefore there is no pathway by which leachate entering groundwater could reach these designated receptors. These conservation sites have therefore been excluded from further assessment.

During the period of authorisation leachate processing off-site and leachate migration to groundwater was assessed, as treated leachate is sent to Whitehaven (Parton) Wastewater Treatment Works (WwTW) which discharges to the Irish Sea. The estimated marine biota (plant and animal life found in a region) dose rate (to the worst affected organism) was 0.0002 µGy/h. This is below the 40 µGy/h screening value and therefore no further assessment was required.

Leachate migration to groundwater for both the period of authorisation and after the period of authorisation was assessed using the ERICA assessment tool. During the period of authorisation, leakage from the cells and migration of radioactivity into groundwater is considered to result from defects in the geomembrane liner which is underlain by a 2 meter clay layer. After the period of authorisation, leakage from the cells and migration of radioactivity into groundwater is considered to be a result of complete failure of the geomembrane liner. The ERICA tool uses 13 default freshwater reference organisms, however reptile was disregarded as there are no native species in the UK. The calculated dose rates (µGy/h) for the 12 freshwater reference organisms were below the 40 µGy/h threshold for all the organisms and the highest calculated dose rate was for insect larvae at 0.55 µGy/h. Therefore no further assessment was required.

After the period of authorisation the ERICA assessment tool was used to calculate the potential of plants and animals to be directly exposed to the waste. The tool was used to derive dose rates for all radionuclides for the 13 terrestrial reference organisms. An additional user-defined organism was also included – a large burrowing mammal as these are considered to be more sensitive to radiation exposure. The calculated dose rates for terrestrial biota were below the 40 µGy/h threshold for all but one of the reference organisms – lichen and bryophyte which was 47 µGy/h. The operator has concluded that despite exceeding the threshold further detailed dose assessment was not required. The operator has justified their decision based on the International Commission on Radiological Protection (ICRP) Derived Consideration Reference Levels (DCRLs) for wild grass (40 to 400 µGy/h), which includes small plants. The dose rate to lichen and bryophytes is at the low end of the ICRP ICRL.

The operator has also considered the fact that the assessment of dose impacts on biota is based on populations rather than individual plants and animals. Guidance provided by the International Atomic Energy Agency (IAEA), (IAEA, 2018a) based on ICRP advice is that radiological impact assessments on plants and animals should aim to protect the ecosystem from exposures to radiation and the impact on plant and animal populations in those ecosystems. The IAEA recommend an assessment area for dose assessments of between 100 and 400 km^2, with radionuclide activity concentrations being averaged across this area. The area of the cells that will receive radioactive wastes for disposal is around 0.073 km^2, which is several orders of magnitude lower than the suggested area for population-level assessments. Therefore the operator has concluded that dose rates across the population would be considerably lower than that calculated in this assessment.

We have assessed the operator's justification for this and based on the comments in the ESC we are satisfied no further assessment is required.

It must be noted that we did request the operator revise their radiological assessments. The data initially used to derive the radiological inventory for the site was based on UKRWI 2010 data despite this having been updated in 2016. We requested the operator to recalculate their assessments based on the most up to date information which also included the biota dose assessments. This work was completed and an updated ESC and associated assessments were re-issued (Atkins, 2020 b).

We are satisfied that the operator has appropriately considered radiological impacts on non-human biota and has met the requirements of Requirement 9 of the NS-GRA.

Technical Requirements

Requirement 10: Protection against non-radiological hazards

The developer/operator of a disposal facility for solid radioactive waste should demonstrate that the disposal system provides adequate protection against non-radiological hazards.

The operator is required to demonstrate that the landfill will provide protection against non-radiological hazards. The landfill site is permitted to accept asbestos which is disposed of in a stable non-reactive cell. All other hazardous substances, as defined in Technical Guidance WM3: Waste Classification – Guidance on the classification and assessment of waste, are not permitted at this landfill site.

A hydrogeological risk assessment (HRA) has been produced to support the landfill installations permit and provides the evidence to show that leachate from the landfill will not pose an unacceptable risk to groundwater at any stage of its lifecycle.

The HRA and related assessments inform the groundwater control levels and compliance limits for the landfill. They also enable the operator to determine the engineering standards and other operational controls necessary to protect groundwater.

The operator's WAC for non-radioactive waste will also be included in the WAC for radiological wastes preventing the acceptance of hazardous materials such as flammable or corrosive substances.

The operator has demonstrated they have conducted the necessary assessments of the non-radiological hazards and along with the design, engineering and operational controls in place they have demonstrated that the landfill provides adequate protection against non-radiological hazards.

Therefore we consider the operator has satisfied the objective of Requirement 10 of the NS-GRA.

Requirement 11: Site investigation

The developer/operator of a disposal facility for solid radioactive waste should carry out a programme of site investigation and site characterisation to provide information for the environmental safety case and to support facility design and construction

FCC Recycling (UK) Ltd have not carried out a specific site investigation for this application as there is existing data on the geology and hydrogeology underlying the site. It is a requirement for the landfill installations permit to produce a Hydrogeological Risk Assessment (HRA), as discussed above in Requirement 10. To support this HRA site investigations were conducted which included the drilling and installation of a number of boreholes for site investigation and monitoring purposes, to assess the status of the underlying geology and hydrogeology.

The operator has used this information to produce a hydrogeological conceptual site model, which has been submitted in support of this application. This model summarises the results of the hydrogeological characterisation and assessment to determine the effect of radionuclides on the underlying groundwater, and their subsequent migration off-site. The model uses leachate leakage from the failure in the landfill engineering as a potential source of contamination. This characterisation data is used to inform the radiological risk assessments as discussed in Requirements 5-7 above.

The operator has discussed the site's underlying geology and hydrogeology in the context of potential pathways and impacts on people and the environment, which are summarised below:

Site Geology and hydrogeology:

The geology of the site is underlain by superficial deposits comprised of Glacial Till, which was previously described as Boulder Clay. The thickness of the Boulder Clay varies across site from 2 -18 m. The bedrock geology underlying the site comprises the Lower Pennines Coal Measures (LCM).

The LCM is classified as a Secondary A Aquifer which is capable of supporting water supplies at a local scale (i.e. a private water supply). There is also an abstraction borehole located downgradient of the site. Based on this information the operator had stated that groundwater abstraction downgradient of the site cannot be discounted. Groundwater monitoring data indicates that groundwater in the LCM is confined by the Glacial Till in areas south of the site but that water levels are below the level of the Glacial Till in the areas underneath the proposed cells. Groundwater contours indicate that groundwater is flowing from east to west across the site under the area of the proposed cells.

In the original ESC the operator identified that there are known historical coal works underlying the north east of the site however they did not provide enough information to satisfy us that they had appropriately considered the potential impact of the coal works on the underlying groundwater. In a request for further information (Environment Agency, 2019) we asked the operator to consider the location of the coal works and the potential impact on the groundwater. The operator responded to our request and updated the ESC (Atkins, 2020). The coal works records indicate that these coal workings do not extend below the area of the proposed cells. Due to their age, it is not thought likely that further subsidence at the site is likely. Groundwater levels show groundwater flow to the west, and the workings are located to the east of the proposed cells. Therefore, in the absence of a driving head gradient, it is considered unlikely that the historical coal workings are currently exerting a control on groundwater flow or will act as a preferential migration pathway to receptors. We also requested the operator to consider potential impacts if the coal works were re-instated. This is discussed further in the pathways section. We are satisfied the operator has addressed our request for further information on the location and impact from the coal works.

The site characterisation has identified 5 faults in the LCM. Faulting has the potential to influence groundwater behaviour and flow in the LCM. The faulting could create fractures

in the bedrock which could hydraulically connect the sandstone beds and thus create vertical pathways for groundwater flow. The operator has considered the potential of these faults creating a pathway for leachate to reach the groundwater. This is based on measured groundwater levels across the site, which appear to be similar and may indicate that groundwater underlying the site is behaving as a single, continuous groundwater body, as opposed to a multi layered aquifer system. The operator has taken a precautionary approach to calculate the mixing and dilution of leachate seepage from the cell base with the groundwater. The groundwater flow through the LCM has been estimated based on the top 5 meters of the LCM. However fracturing and the creation of vertical pathways for groundwater flow could extend through a significant thickness of the LCM, greater than a depth of 5m, therefore increasing groundwater flow and the mixing zone. An increase in the size of the mixing zone and groundwater flow would increase the dilution capacity compared to that of a mixing zone of 5m.

Hydrogeological conceptual model:

A conceptual site model has been presented which considers the source, pathways and receptors of any radioactivity that could enter the environment. For the purpose of the dose assessments provided in the ESC the concentration of radionuclides in leachate, and the fate and transport in groundwater have been calculated. Distribution coefficients (Kd) were applied to quantify the partitioning of radionuclides into waste.

Source:

The operator has determined the potential source of radioactivity entering the environment is via leakage of landfill leachate from the engineered containment of each of the proposed cells that have received radioactive waste. During the period of authorisation, any leakage from the cells is likely to result from defects in the geomembrane liner. Complete failure of the geomembrane liner and bathtubbing (where leachate overtops the landfill cap) are scenarios considered for the time after the period of authorisation.

Pathways:

The operator has considered surface water features that may influence or interact with the underlying groundwater or that may be impacted by a discharge from the landfill site. Distington Beck is the closest surface water body to the landfill site and the operator has discounted the Beck as a receptor as the groundwater is not considered to be a feed source into the Beck due to the depth of groundwater and the thickness of Glacial Till. Bathtubbing has also been discounted as any discharge on the surface of the landfill will be expected to infiltrate the surrounding land rather than run-off into the Beck.

The operator has considered the underlying geology and hydrogeology of the site and has considered the migration pathway of leachate leakage from cells via the unsaturated zone and the saturated zone. The unsaturated zone comprises the 1 m low permeability liner, 2m attenuation layer and any additional thickness of superficial Glacial Till or LCM which may exist underneath each cell. The porosity of the clay liner and Glacial Till has been assessed.

The saturated zone pathway will consist mainly of lateral flow within groundwater within the LCM. Faulting and fractures may provide vertical pathways for groundwater flow in the saturated zone. Groundwater water level data has been used to create groundwater contour plots which indicate that the groundwater flows east to west within a mixing zone in the upper 5 meters of the LCM. Faulting may provide pathways for rapid vertical migration of leachate, however this would result in a larger mixing zone and a greater degree of attenuation of the radionuclides. Therefore, any vertical flow will further dilute leachate seeping out of the site. Calculations of the hydraulic gradient and the permeability of the LCM aquifer and attenuation through dispersion and decay within the saturated zone have been completed.

Leachate seepage has also been modelled for both the period of authorisation and the time after the period of authorisation. This modelling suggests that bathtubbing may occur due to the low permeability of the clay basal liners. Bath-tubbing is where the infiltration of rainfall in to the waste results in leachate levels reaching the surface of the landfill. As leachate levels are actively managed during the period of authorisation, this would only occur after the period of authorisation phase, see Requirement 6 above.

In response to the request for further information the operator has considered the potential for the reopening of the coal works. Reactivation of coal mining activities, or general exploitation of the local mineral resource, on or around the site may open up new pathways for contaminant migration and exposure. Mining, coalbed gasification or ground source heat abstraction of mine water is likely to require some degree of dewatering or abstraction of groundwater. Large scale groundwater abstraction will result in a cone of depression and potentially the reversal of natural groundwater flow directions toward the abstraction points. Hydraulic fracturing or excavation/mining of coal measures underlying the site will create high permeability potential pathways. A significant degree of dilution and mixing of contaminated groundwater within the abstracted water would be expected, as a result of radial and vertical flow toward the abstraction well. Dewatering associated with coal mining will reduce groundwater levels, increasing the thickness of the unsaturated zone and ensuring that there is no hydraulic connectivity between groundwater in the LCM and leachate in the proposed cells.

Assumptions made in this assessment:

The operator has taken a conservative approach to this assessment by making various conservative assumptions. The site is currently permitted for leachate levels of up to 3 m above the base of the cell. The operator has a leachate management plan in place to ensure leachate is managed at or below this level. For the purpose of this assessment a constant head of leachate of 3 m has been assumed during the period of authorisation, in order to demonstrate whether the permitted leachate levels present a risk to the environment.

After the period of authorisation, when the site is no longer within regulatory control, a worst case scenario has been assessed assuming the waste will become fully saturated, as control of leachate levels will no longer be required and there will be 100% failure of the engineered containment of the landfill site. In reality this is considered to be unlikely as the

geomembrane cap emplaced over the waste following the period of authorisation and the restored surface water drainage system at the site are likely to prevent infiltration into the waste. This scenario was investigated for the purposes of estimating a maximum level of potential leachate leakage, however, full failure of both geomembrane cap and composite geomembrane liner is considered unlikely to occur simultaneously as the result of a single event. It is considered more likely that degradation of the liner will occur gradually, over a period of time of the order of 100s of years. Therefore, seepage rates will likely increase from the estimates calculated for the period of authorisation, slowly increasing over time.

For the purposes of the fate and transport calculations, the activity of the waste is assumed to remain constant with time. The ingrowth of radionuclides and production of daughter products is not considered. This is a conservative approach, as over time the activity in the waste will decrease due to radioactive decay.

We have reviewed the hydrogeological conceptual model and consider the operator has adequately characterised the site to appropriately determine the source of radioactivity entering the environment and pathways by which radioactivity could enter the environment. We are satisfied this meets the objective of Requirement 11 of the NS-GRA.

Requirement 12: Use of site and facility design, construction, operation and closure

The developer/operator of a disposal facility for solid radioactive waste should make sure that the site is used and the facility is designed, constructed, operated and capable of closure so as to avoid unacceptable effects on the performance of the disposal system

The design, construction and operational controls have been considered for a number of the NS-GRA requirements (Requirement 4, Requirement 8, Requirement 10, Requirement 13) and we are satisfied the operator will manage the site appropriately to ensure the landfill performs as a containment landfill site ensuring the adequate protection of people and the environment.

We will expect the ESC to be updated if any significant changes occur to the design, construction or operations of the landfill site or significant new information becomes available. There is also a permit requirement to periodically review the ESC to ensure it reflects the management and operational arrangements at that time. We have included an improvement requirement in the permit to ensure the ESC is reviewed within a specified time period. In line with other disposal permits we have set this review period for every 10 years from the effective date of permit issue. This period will remain subject to review based upon current information. The final ESC must show that the requirements in our NS-GRA that apply to the period after the end of regulation have all been met. We will only agree to release a site from radioactive substances regulation if we are satisfied that radioactive waste disposal has ended and that the site is in a state that will ensure people and the environment are protected.

Financial provision in place to ensure the continued management of the landfill site post closure. This is required as part of the installations permit to ensure the appropriate funds are available to meet the costs associated with the construction work for final site closure; surveillance and monitoring of the site during the post-operational period; maintenance of the site infrastructure; administrative, environmental monitoring and technical support work.

We are satisfied that the operator has met the objectives of Requirement 12 of the NS-GRA.

Requirement 13 Waste Acceptance Criteria (RSR Part B5 Q7)

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

We have reviewed how FCC Recycling (UK) Ltd has developed their waste acceptance criteria (WAC) for increasing the radiological limits in their current permit. The radiological limits are based on their application to vary the current permitted limit of 4 Bq/g (40 Bq/g for tritium) to 200 Bq/g.

The waste acceptance procedure is set out in the ESC and explains how the operator proposes to assess and receive waste for disposal to ensure the radiological and non-radiological characteristics of the waste meet the requirements of the permit. This is based on two aspects: the radiological capacity of the landfill site and the management of waste acceptance to ensure the radiological disposal limits are not exceeded and the non-radiological properties of the waste are considered.

Radiological capacity management:

The radiological impact of the landfill site is based on a modelled radiological inventory derived from the analysis of potentially relevant waste streams identified in the 2016 UK Radioactive Waste Inventory. The operator has calculated the maximum radioactive inventory for the site based on LA-LLW making up approximately 10% of waste disposed on site. The maximum radioactive waste inventory for the site has been calculated as 36 TBq based on a waste density of 1.8 tem^{-3} and the disposal of 100,000 m^3 of LA-LLW with a maximum average consignment activity limit of 200 Bq/g with a limit on a single item or package (no greater in volume than $2m^3$) within the consignment of 1000 Bq/g.

The operator has derived radiological capacities for each individual radionuclide based on the results of radiological risk assessments which have assessed the doses, from each individual radionuclide, to the potentially exposed groups in various exposure scenarios. The radiological capacity is the maximum activity that can be accepted for each individual radionuclide to ensure the dose is within the specified dose criteria and risk guidance levels.

The dose calculations for each exposed group and exposure scenario produce different results for the same radionuclide due to the differences in the dose criteria and risk guidance levels, the timing of the exposure and the way in which the exposure occurs. A conservative approach to determining the radiological capacity has been used. The radionuclide with the lowest activity, and therefore the lowest dose impact, has been determined as the radiological capacity, the highlighted numbers in the table below illustrates this (taken from section 7.4.2 of the ESC version 5).

An example of radiological capacity based on regulatory dose rates to a subset of exposure groups considered by the operator:

Radionuclide	Radiological Capacity (TBq)				
	Sewage Worker	Farming Family	Coastal Fisherman	Groundwater Abstraction	Landfill Fire
	During PoA	During PoA	During PoA	During PoA	During PoA
H-3	7.28E+07	5.43E+04	2.39E+08	1.35E+05	6.42E+04
C-14	1.96E+06	3.22E+01	4.51E+02	4.52E-01	2.86E+03

We have set disposal limits in the permit based on the radiological capacities discussed above. This is to ensure the estimated radiation doses will not exceed the dose criteria and risk guidance levels and disposals are managed within the maximum radioactive waste inventory for the site.

As radioactive waste can include a number of different radionuclides the operator must determine the amount of activity, from each radionuclide, that has been disposed of to the landfill site to ensure compliance with the disposal limits and that the radiological capacity of the site is not exceeded. This will be managed by using the 'sum-of-fractions' approach. This involves dividing the activity of each radionuclide that has been disposed by its radiological capacity to provide a number between 0 and 1. This is repeated for each radionuclide that is disposed of at the landfill site. The sum of all the fractions must be less than 1, if the sum of all the fractions reach 1 this means the radiological capacity of the site has been reached and no more waste can be accepted for disposal. The sum of fractions equation is illustrated below:

$$\sum_{Rn} \frac{I_{Rn}}{L_{Rn}} \leq 1$$

Where I_{Rn} is the disposed activity of each radionuclide and L_{Rn} is the radiological capacity for that radionuclide.

We have assessed and accept FCC Recycling (UK) Ltd.'s proposed approach for managing radiological capacity and the proposed limits have been included in the permit.

Management of waste acceptance:

FCC Recycling (UK) Ltd has an existing waste acceptance criteria (WAC) document for the acceptance of HV-VLLW. We have included a pre-operational requirement in the permit to ensure the WAC, and other relevant procedures, are updated to reflect the requirements of the ESC submitted in support of the application to vary the permit. The WAC must be updated prior to any waste being accepted on to site for disposal.

The WAC has been developed to ensure the producers of LA-LLW waste have all the necessary information to allow LA-LLW to be accepted for disposal. This includes controls on the radiological and the non-radiological physical, chemical and biological properties of the waste to ensure compliance with the limits and requirements of the site's environmental permits. Also see Requirement 10 Protection against non-radiological hazards.

We have also included a pre-operational requirement for future development in the permit to ensure the operator assesses the impact of accepting wastes containing high activity particles or discrete items prior to receipt of such wastes. We consider there is the potential for such wastes to be disposed of at a landfill site and as this has not been specifically addressed in the ESC we will require the operator to undertake an appropriate assessment prior to disposal of such wastes.

We have reviewed the operator's procedure for accepting radioactive waste which covers the process from the initial waste enquiry from a customer through to the assessment of the waste. The operator will also be supported by consultants through the provision of specialist radioactive waste assessment support.

We are satisfied that the ESC demonstrates that the operator has developed appropriate waste acceptance criteria to ensure LA-LLW can be safely disposed of at the Lillyhall Landfill Site. We consider the objective of Requirement 13 of the NS-GRA has been met.

Requirement 14 Monitoring (RSR Application Form Part B3 Q5)

In support of the environmental safety case, the developer/operator of a disposal facility for solid radioactive waste should carry out a programme to monitor for changes caused by construction, operation and closure of the facility.

The operator has an existing monitoring regime in place for radioactive and non-radioactive chemical species, as required under the radioactive substances and landfill installations permits respectively. As radioactive waste has not been accepted at the Lillyhall landfill site since the permit was issued in 2011 we agreed with the operator that their radioactive monitoring regime could be paused, this is documented in the monitoring and control plan (FCC Recycling (UK) Ltd, 2017). To update the background data, monitoring was resumed in 2015 and again put on hold at the end of 2016. The operator

agreed with the Environment Agency that monitoring will resume before radioactive waste is received on site (Pailing, 2021). We have decided to include a pre-operational requirement in the permit to ensure the operator undertakes radioactive monitoring prior to receipt of radioactive waste. The purpose of this is to provide up to date background information prior to the receipt of radioactive waste. We do not expect the data to differ from previous monitoring results however it has been four years since the data was last gathered and it is appropriate for this to be updated to reflect the current conditions around the site.

The ESC sets out the monitoring regime and the site's monitoring and control plan was also provided in support of the claims made in the ESC. We accepted the operator's proposals with the exception of one query regarding uranium. The original ESC stated that natural uranium would be monitored in surface water but not for groundwater. We requested further clarification on this and the operator confirmed this was an error in the ESC and uranium will not be specifically monitored in surface water. The monitoring and control plan states all samples will be analysed for total alpha and beta, tritium and gamma spectrometry with all detected radionuclides being reported.

There are eleven boreholes installed around the perimeter of Stage 3 of the Lillyhall Landfill Site to monitor the level and the quality of the groundwater both up gradient and down gradient of the site.

The monitoring and control plan sets out in more detail the monitoring regime for radionuclides entering the environment. The results from the sampling and analysis will be compared with the baseline data compiled prior to radioactive waste disposals. Samples will be taken from groundwater, leachate, sewage sludge and surface water at various frequencies throughout the year. Grass and herbage surrounding the site will also be sampled and analysed. All samples will be analysed for: total alpha and beta/gamma activity; tritium and gamma spectrometry with a requirement that all radionuclides that are detected are reported.

We also requested further information regarding the sampling and analysis of leachate from cells 7-10, yet to be constructed, as the original ESC did not address this. The operator has updated the ESC to explain that leachate from each new cell containing radioactive waste will be sampled and analysed in accordance with the monitoring plan.

The operator has yet to determine appropriate trigger levels for radionuclides, which will provide an early indication of any environmental impact from the landfill site. The ESC states the operator will set trigger levels to take into account results from the initial baseline surveys and these will be recorded in a formal procedure and agreed with the Environment Agency. If significantly elevated concentrations are measured on any occasion, a more detailed set of measurements would be undertaken to determine the contributions from different radionuclides. We have included an improvement requirement in the permit to ensure the operator addresses this.

The operator has stated the monitoring will continue during the post-closure period of 60 years. However we will expect appropriate levels of monitoring to continue until the permit is surrendered.

Based on the operator's response we are satisfied they have a suitable monitoring programme in place to monitor the performance of the landfill and meets the objective of Requirement 14 of the NS-GRA.

Growth duty:

We consider the requirements and standards we have set in this permit are reasonable and necessary to protect the environment and optimise the protection of people, and are consistent with our 'growth duty'. This also promotes growth amongst legitimate operators because the standards applied to the operator are consistent across businesses in this sector and have been set to achieve the required legislative standards.

Decision

We conclude that that the operator can operate in accordance with the permit conditions to meet statutory requirements and the requirements of Government policy. We therefore grant the application, subject to the conditions of the permit.

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Annex 1: Consultation and advertising responses

Summary of responses to advertising and consultation and the way in which we have taken these into account in the determination process:

Comment Summary	Environment Agency Response
Topic: Tritium limit & drinking water borehole	
Radiation Free Lakeland commented that the proposed limit of 200 Bg/g for tritium was 5 times higher than in the current permit. They presented various papers which state tritium is more hazardous than previously thought and stated: 'The most comprehensive report on tritium was published by the UK Government's senior Advisory Group on Ionising Radiation (AGIR, 2008). This report strongly recommended that tritium's hazard (i.e. its radiation weighting factor) should be doubled from 1 to 2. However other scientists (Fairlie, 2008; Fairlie, 2007a; Fairlie, 2007b; MelintESC u et al, 2007; Makhijani et al, 2006) have presented evidence for even larger increases in tritium's radiotoxicity, including the US EPA (2006) which recommended a 2.5 fold increase in hazard. Instead of reducing the activity limit allowed by 2.5 the operators of Lillyhall landfill are asking for a fivefold increased activity limit.'	We are aware of the debate regarding the radiation weighting factor for tritium. The International Commission on Radiological Protection (ICRP) reviews the scientific evidence when defining radiation weighting evidence and in its 2007 recommendations (ICRP, 2007) took account of the evidence at that time. It concluded that a radiation weighting factor of 1 for tritium continues to be appropriate for general radiological protection purposes, which our radioactive substances permitting falls under. The Health Protection Agency (HPA) (now Public Health England, PHE) reviewed the application of the 2007 ICRP recommendations to the UK (HPA, 2009). HPA noted the Advisory Group on Ionising Radiation report and the advice on the radiation weighing factor for tritium. HPA concluded that it agreed with ICRP's view that the radiation weighting factor of 1 should continue to be applied for tritium. It is worth noting that the risk of early fatality to members of the public from disposals of tritium to the Lillyhall landfill site at the increased activity concentration limit are much less than 1 in a million per year. Hence, even if a higher radiation weighting factor of 2.5 was used, the risks to members of the public would still be acceptable.

Radiation Free Lakeland commented the Lillyhall landfill site is just 200 metres from a potable fresh water supply.	In relation to public drinking water boreholes and water abstraction, the operator has amended the assessment to reflect that the scenario of groundwater abstraction during the Period of Authorisation is 'certain to occur' and that this risk is assessed. This has been assessed against the standards described in the Guidance on Requirements for Authorisation for Near Surface Disposal Facilities.
Radiation Free Lakeland are opposed to this variation.	Noted.
Topic: Matters outside the Environment Agency's remit	
Workington Town Council Planning Committee queried why this site has been selected for this type of waste rather than other facilities in the area that already have the appropriate systems and staffing in place.	We do not influence or regulate site selection. This decision is made by the operator in consultation with the local planning authority. We can only take account of issues within the relevant environmental regulations or inside the remit of the Environmental Permitting Regulations 2016. The local planning authority would be responsible for granting permission for change of use under planning law. The National Planning Policy Framework published in 2019 (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/810197/NPPF_Feb_2019_revised.pdf) confirms that the planning system should not duplicate controls that exist under pollution control regimes and, where a planning decision has been made, the planning issues should not be revisited through the permitting regimes operated by pollution control authorities, such as the Environmental Permitting regime administered by the Environment Agency.
Workington Town Council Planning Committee expressed concerns that 26% of the waste comes from outside of the area and would like to seek clarification as to why this	The 2007 Government policy on LLW management is explicit in stating that the proximity principle needs to be taken into account when consigning sites take waste management decisions. The policy also states that the proximity principle needs to be weighed against other

waste has to be disposed at this site rather than at facilities closer to its location of origin.	factors when considering options. This will inevitably mean that sometimes the preferred option may not be the nearest to the site of origin of the waste. There are currently three other landfill sites permitted to accept low activity LLW in England. These are CLESA at Sellafield in Cumbria, which only accepts waste generated on the Sellafield site; Clifton Marsh in Lancashire and Kings Cliffe in Northamptonshire. Having these sites has reduced the amount of waste being disposed of to the LLWR in Cumbria, which is a long distance from some nuclear sites. If a number of landfill sites are authorised for the disposal of low activity LLW this will help, in part, to address the proximity principle.
Workington Town Council Planning committee are keen that the surrounding community should be properly compensated for having to accept this type of radioactive waste.	This is a matter for the operator to discuss with the local community.
Dean Parish Council commented that the consultation did not address transport issues.	The Office for Nuclear Regulation regulate the transport of radioactive wastes from nuclear sites along with the planning authority under the planning regime. We can only take account of issues within the relevant environmental regulations or inside the remit of the Environmental Permitting Regulations 2016.
A member of the public commented on the increased volume of waste to be disposed of at the site and that the extra volume of waste is making Allerdale a 'nuclear dumping ground'. They stated that this was 'not good publicity for future businesses to invest in this area'.	The potential effect on future investment in the area is not in the Environment Agency's remit and we cannot comment on this.
Topic: Further clarification on the information submitted by the applicant	

COMARE have commented on a number of paragraphs within the Environmental Safety Case (ESC), based on seeking further clarification and highlighting mistakes they have noticed. Each comment is listed below in points 1-16:	We have addressed each comment individually below:
1. Paragraph 16 & 17. Paragraph 16 refers to planning permission 2/12/9007 condition 4, while Paragraph 17 refers to permission 2/13/2007 condition 4. Is this a typographical error or are two different documents being referred to? These do not seem to form part of the supporting documentation.	It is a typographical error. This was not submitted as part of the application but we have since received it
2. Paragraphs 26 and 27 appear contradictory.	We requested further clarification on the figures provided, and note that more up to date information is available in subsequent iterations of the UK Radioactive Waste Inventory. The operator has reworded paragraphs 26 and 27 to reflect the use of the 2016 UKRWI data. The paragraphs are no longer contradictory.
3. Paragraph 38 tells the reader that the radiation dose to the Cumbria Average Group is 2.1 mSv y^{-1}; however, the evidenced reference, paragraph 12 (the EA permit) contains no data on the CAG.	The operator has updated the ESC (vs 3 and subsequently vs 5) which includes the correction of all referencing errors.
4. Paragraph 62 mentions 12 cells, while Fig 5 shows a cell 11, not mentioned in the text.	This refers to the existing cells (shown in red on Figure 5). However, we have received clarification that the application is for cells 4B, 5, 5A, 6A, 6B, 7, 8, 9, 10

5. Paragraph 171 notes record retention for 10 years. This should extend to site controlled lifespan.	The operator has updated the ESC (vs 3 and subsequently vs 5) which has amended the wording of paragraph 171 (now paragraph 177 in ESC vs 5. The paragraph now refers to EA guidance on records retention.
6. Paragraph 186 the use of a public dose limit being applied to onsite workers is confusing, which is also noted in document R5.	The operator has updated the ESC (vs 3 and subsequently vs 5) which includes an amendment to paragraph 186 (now 192 in ESC vs 5) to compare the doses against the relevant regulatory criteria.
7. In Paragraphs 195 and 196, doses are close to limits even for the more optimistic assumptions, while it is noted that other scenarios give rise to much higher doses.	The operator has updated the radiological assessments in ESC (vs 3 and subsequently vs 5) with data from the 2016 UKRWI. This has resulted in a reduction in the predicted doses which have been amended in paragraphs 195 & 196 (now paragraphs 193 & 194 in ESC vs 5).
8. Paragraph 265 refers to section 3, but it is actually section 2.2.	The operator has updated the ESC (vs 3 and subsequently vs 5) which includes the correction of all referencing errors.
9. Paragraph 266 makes the suggestion that “When contaminants are transported in groundwater or discharged to sewer, for example, it is likely that substantial mixing will occur so members of an exposed group are exposed to radionuclide concentrations in environmental media that are a function of some average of those in the landfill. However, for certain cases, it is more reasonable to consider the radiation dose to be proportional to the average activity concentration over some smaller volume of the landfill.” A reference would be very helpful here.	The operator has proposed to remove this paragraph on the basis that modelling to determine the radiological capacity for a range of exposure scenarios is presented elsewhere in the ESC and supporting assessments. We are satisfied the supporting assessments include all relevant references associated with the scenarios assessed.

10. Paragraph 268 introduces the pSv – is this correct?	The operator confirmed this was an error and should have been µSv. The ESC has since been updated and this paragraph is no longer relevant as the section of the ESC has been rewritten.
11. For Paragraph 270, the supporting documentation for tables 10 and 11 could not be identified.	We requested that this paragraph was modified due to a lack of clarity. The operator has updated the ESC (vs 3 and subsequently vs 5) and modified paragraph 270 and tables 10 & 11 (now paragraph 284 and table 7-2 in ESC vs 5).
12. Paragraph 272 is incorrect.	We requested the operator to provide the correct equation. The operator has updated the ESC (vs 3 and subsequently vs 5) and has removed paragraphs 272 and 273 and replaced with more explanation (now paragraphs 285-287 in ESC vs 3, now 284-286 in ESC vs 5).
13. Paragraph 289 references Paragraph 435. There is no Paragraph 435. Paragraph 294 references Paragraph 436. There is no Paragraph 436.	The operator has updated the ESC (vs 3 and subsequently vs 5) which includes the correction of all referencing errors.
14. Paragraph 304 states that samples will be collected on two occasions – presumably 'per year'?	We requested that the operator clarifies this statement with the timescale over which these samples will be collected. The operator has updated the ESC (vs 3 and subsequently vs 5) which includes the addition of 'per year' (now paragraph 317 in ESC vs 5.
15. Appendix A, is not discussed in the document except for a brief mention in Paragraph 41.	We have made a number of comments to the operator about Appendix A and its contents both in relation to the main body of the ESC and to the supporting documentation. The operator has updated the ESC (vs 3

	and subsequently vs 5) which includes the correction of all referencing errors.
16. Appendices B, C, D & E are not included in the document, and reference is not made to the title of the documents that contain the appropriate data.	Appendices B, C, D and E were provided as part of the submission and made available on Citizen Space.
PHE Comments on R5 - Period of Authorisation Rev A - Final Table 2, page 7 refers to “Section 2.12 and Section 3 of the main report [FCC, 2018d]” which is given as ESC: Disposal of Low Activity Low Level Radioactive Waste (LA-LLW) at the Lillyhall Landfill Site, 2018. However, these are not the correct sections and Section 2.12 does not exist. Appendix D, page 32 – footnote refers to “activity concentrations given in Section X of the main report”. Section X should refer to the correct Section in the main report and it needs to be made clear what the main report is.	The operator has updated the ESC (vs 3 and subsequently vs 5) which includes the correction of all referencing errors.
PHE Comments on R6 - After Period of Authorisation Rev A -Final Table 3, page 13 refers to the time periods “60 to 100 years” and “1000 to 10,000 years”. We believe that it should be “100 to 10,000 years”.	The operator has updated R6 to include the suggested time periods. Table 3 is now on p. 10 in the updated document.
PHE Comments on R7 - Intrusion Rev A Final are listed below in points 1-4:-	We have addressed each comment individually below:
1. Section 1.2 states that “A number of exposure scenarios were initially identified and assessed on a risk	We believe that this comment relates to a misunderstanding, and that the reference to Table 1

rating considering the likelihood of occurrence and the impact of that occurrence. These are shown in Table 1." However, the risk ratings are not shown in Table 1. Table 1 has a footnote indicated but no note is present in the table.	relates to the exposure scenarios, not the risk rating. The risk rating is shown in Appendix A of the main ESC.
2. The scenarios given in Table 1 do not correspond with those considered.	The ESC does state that the scenarios identified in Table 1 could be bounded by broader exposure scenarios from the National Radiation Protection Board (NRPB) W36 publication (NRPB, 2003) which are; agriculture, construction, industrial and housing.
3. The justification for using Tc-99 as a surrogate for C-14 and Ca-41, which is discussed in Section 2.1.1.3, should be more strongly made.	We requested clarification and the operator has provided an additional technical note (R7 Clarification). As part of an information request the operator was required to revisit their dose assessments using data from the 2016 UKRWI. A revised assessment (revision B) was produced which resulted in lower doses and a different radionuclide inventory, with Ca-41 no longer being present. This work also resulted in the removal of the sensitivity analysis as the worst case intrusion doses were very low and the Tc-99 dose per unit contamination was not applied. We consider the operator has adequately addressed this comment.
4. Section 2.1.1.5 on the sensitivity analysis should be expanded to consider other assumptions that may lead to a conservative estimate of doses, for example the assumptions that the land is used by a subsistent farmer who grows all his own food and that no dilution of the waste has occurred.	We agreed with this suggestion and requested this section is expanded. However, we note that it would be disproportionate to consider all assumptions/scenarios that may lead to a conservative estimate of dose. The operator has produced an additional technical note (R7 Clarification) to address this comment. A subsistence farmer assessment has been considered. The operator has summed the intrusion doses for the agricultural and housing scenarios. This is a pragmatic approach and the resultant doses are still below the dose criteria for human intrusion (3-20 mSv). We are satisfied the operator has addressed this comment.

Topic: Management	
Workington Town Council Planning Committee would like assurances that staff on site would receive appropriate training to work with the new waste material safely.	The physical form of the wastes types received will not differ from those the site can already accept. However the amount of radioactivity that the waste contains may be higher. This will necessitate some additional training. FCC ensures that all staff have training necessary for the relevant job role. A documented procedure is operated to ensure that: • Training needs are assessed annually through performance and the Individual Development Scheme; • Employees are trained and developed in their roles; Training records are maintained. • The management of LLW will be subject to appropriate Health Physics controls and supervision by an accredited Radiation Protection Supervisor (RPS). • Evidence has been provided that staff have received the necessary training. There are also specific procedures in place for the disposal of the low level waste. • The site also have access to and will consult with a Radiation Protection Advisor as necessary. The management system, which includes training and suitably qualified people are a requirement of the permit. This has been assessed as part of our determination of this application.
COMARE's Authorisation Working Group: The approach taken in section 6.4.2 is heavily dependent upon the declaration of radioactive content made by the consignor and is not clear on how waste containing a mixture of radionuclides will be considered.	Consignors of waste are required by their permit to provide accurate information to the consignee in accordance with the requirements of the waste receiving sites. The site will be expected to ensure accurate information is received from consignors and that any consignment meets the site Conditions for Acceptance – this will contain the total activity of a list of radionuclides the waste receiving site can accept. We, or other relevant environment agencies, regulate these transfers of waste between the consignor and consignee. We will expect both consignors and consignees to work closely together to ensure accurate and appropriate information is made available.

COMARE's Authorisation Working Group: Paragraph 52 and others throughout the document. This Paragraph and others explain thorough and exemplary procedures that will be put in place with regard to operational and passive management once the facility is operational. There is no inclusion of any overview of how this will be reported on or audited.	The management system is accredited to ISO14001 & 9001 and will be subject to external auditing for re-accreditation. The Executive Committee of FCC defines and refines a set of overall Management System Objectives, which are used by managers as the framework for all subsequent objective setting and measurement. These objectives are designed to promote continual improvement. Management reviews are carried out following a defined agenda and at a regular frequency to ensure that the IMS remains effective and is continually improved. The management of the site will be subject to audit /inspection as part of our regulatory interactions to assess compliance against the conditions of the permit.
Topic: Disposal limits, volumes, waste streams	
Workington Town Council: The committee wanted to know why the original limit was set at the lower level and what measures have been taken for it to be safely raised. At this point, the committee felt that there was no clear evidence that the site is more suitable than when it was originally designed.	It is the operator's decision what disposal limits they apply for. As part of the application to vary the permit the operator has submitted a radiological risk assessment as part of their Environmental Safety Case which considers the impacts of the disposals on a number of receptors during the operational life of the landfill and after it has ceased operations. Based on the proposed disposal limits this radiological risk assessment must demonstrate that specified dose and risk constraints are met both during and after the Period of Authorisation. These dose and risk constraints are detailed in Environment Agency guidance available at: https://www.gov.uk/government/publications/near-surface-disposal-facilities-on-land-for-solid-radioactive-wastes Therefore the original limits were based on the acceptability of the operators original application for those limits, the new higher limits are based upon a new application for these higher limits and do not necessarily relate to any changes in the suitability of the site.

A member of the public felt that the increase in disposal limit was too high.	The Environmental Safety Case, incorporating a radiological risk assessment, provided by the operator as part of their submission, assesses the dose and risk posed by disposals at the proposed limits against specific dose and risk constraints detailed in Environment Agency guidance available at: https://www.gov.uk/government/publications/near-surface-disposal-facilities-on-land-for-solid-radioactive-wastes. We are satisfied with the assessment presented and that it shows that doses and risks are consistent with the criteria in this guidance. We can therefore issue a permit with the disposal limits applied for and assessed against in the Environmental Safety Case.
COMARE's Authorisation Working Group was interested to know the current annual waste volume received at the site.	The site has not received any radioactive waste under the current EPR permit. In the past they have received radioactive waste under Exemption Orders relating to the Radioactive Substances Act 1993. These include Naturally Occurring Radioactive Material (NORM) waste streams produced by the oil and gas industry. The main disposals under such Exemption Orders are summarised in Table 5 of the Environmental Safety Case.
COMARE also asked how might the volumes increase if the application is approved (i.e. what proportion of waste going to LLWR might be diverted)? This is germane also to the transport implications.	The proposals are that the entire remaining non-engineered capacity of cells 4B, 5, 5A, 6A, 6B, 7, 8, 9, 10 are utilised for the disposal of Low Level Waste. This equates to 891,053 m^3 or c.1.60 million tonnes of waste, assuming a waste density of 1.8 te/m^3 (1800 kg/m^3). However, in practice, the volume of low activity LLW waste that could be accepted will be less than this maximum capacity figure due to an annual limit in the permit of 26000 m^3 and the use of the sum of fractions. Volume will additionally be taken up by the acceptance of non-radioactive waste, void space and daily coverage of the waste. Therefore, the maximum possible diversion of waste from LLWR is 26000 m^3 per year, although this is subject to considerations such as Best Available Techniques, commercial aspects, volumes of suitable radioactive waste available for disposal over the operational lifetime of the landfill and the presence of other Low Level Waste landfills which may be utilised for disposals.

COMARE's Authorisation Working Group suggested examples of the other facilities accepting Low Level Waste should be provided.	The submission received is from a commercial entity, and it may not be in their interests to consider alternative disposal facilities. However, disposals of waste at any facility will be subject to BAT considerations on the part of the consignor, which will include options for disposal at all sites with relevant permits for those wastes.
COMARE's Authorisation Working Group: Paragraph 32 states that "Based on our analysis of waste streams potentially suitable for disposal at the Lillyhall landfill site it is believed that the average activity concentration across all waste streams so disposed would be a few tens of Bq g^{-1}". The assertion is repeated in Paragraph 265 but there appears to be no explicit justification for the statement.	The operator has referenced the 2016 UKRWI as the source of this information.
COMARE's Authorisation Working Group: Paragraph 81 states "The depth and placement of restoration soils above the protective geotextile cap layer have been modelled as 10% of the total waste disposals (i.e. 100,000 m^3 in total). There is considerable uncertainty relating to forecast arising of LA-LLW and it is considered that this assumption is likely to be cautious as annual disposals of LA-LLW for certain years could be much less than this, or far greater." More explanation is needed given that the disposals could be either much less than this, or far greater. It is not evident how this provides reassurance of a conservative approach.	The operator has updated paragraph 81 (now paragraph 79 in ESC vs 5) to explain that 10% is considered a reasonable assumption based on the amount of waste to be disposed, the area of the landfill and the depth to which the restoration soils will be placed. We are satisfied the operator has explained the reason for the modelling.

COMARE's Authorisation Working Group: In Paragraph 125 et seq the derivation of the inventory presented, based on an analysis of 281 potentially relevant waste streams, is not clear. How were the 'potentially relevant' sources selected to calculate the average activity concentrations shown in table 4? Also in table 4, the total inventory appears to be calculated as 1.335 x $10E^{9}$ times the average content per gramme – is this correct if the average density is 1.8te/m^3?	We requested further information on the derivation of the inventory, including why this is based on the 2010 UKRWI rather than the current iteration. The operator has updated the ESC using the 2016 UKRWI data. With regard to table 4 total inventory and density the operator has now presented the information to show the total inventory is based on an average density of 1.8te/m^3.
COMARE's Authorisation Working Group: Paragraph 206 describes an individual package permitted to have an activity of 1000 Bq/g^{-1} as a 'disposal bag or 210l drum', but Paragraph 317 suggests that it could be 'a consignment' – which is correct?	We requested clarification. The operator has updated the ESC (vs 3 and subsequently vs 5) which includes amendment of paragraph 317 (now 329 in ESC vs 5) to state 1000 Bg/g maximum activity concentration per individual package.
Topic: Habitats and food chain impact assessments	
COMARE's Authorisation Working Group: In Paragraph 234, it not clear how the doses to biota were estimated.	This comment is noted. The assessment methodology is described in more detail in Appendix E Radiological Assessments: R9 Environmental Radioactivity.
COMARE's Authorisation Working Group: In the summary for Environmental Protection (page 6) the report states that "The ESC demonstrates that for the amount determined, for all reasonably foreseeable circumstances, doses	We requested the operator to update the radiological risk assessments using the 2016 UKRWI data. This resulted in the reduction of predicted doses with the exception of bryophytes and lichens. The dose for this group was 47 µGy/h. However the operator has justified this and we therefore consider the doses to be acceptable. The

or risks remain below the relevant dose and risk guidance levels defined by the EA for humans and for biota." However, the doses for biota in one scenario exceed DCRLs and for the public the doses are close to the limits after authorisation (Table 7).	operator has updated the ESC (vs 3 and subsequently vs 5) to include these amendments.
COMARE's Authorisation Working Group: In the case of intrusion, the estimated doses for lichen and bryophytes exceed the Environment Agency threshold by a factor of 2 and are within the relevant ICRP DCRL band which suggests some chance of deleterious effects of ionising radiation occurring to individuals within a population. Taking account of the small area impacted the author's state that "impacts across the population are therefore considered to be extremely unlikely". This conflicts with the statement in the non-technical summary of "reasonably foreseeable circumstances" and implies that the intrusion scenario is not reasonably foreseeable (see note above).	The operator has provided further detailed justification on the terrestrial biota. These figures were also reviewed in line with the updated radionuclide inventory in the updated ESC (vs 3 and subsequently vs 5). The operator justifies this on the basis that IAEA [2018] suggest an assessment area of between 100 and 400 km^2, with radionuclide activity concentrations being averaged across this area. The area of the cells that will receive radioactive wastes for disposal is around 0.073 km^2, which is several orders of magnitude lower than the suggested area for population-level assessments. Typical dose rates across the population would therefore be considerably lower than that calculated in this assessment. Furthermore, the evaluation of dose rate for lichen and bryophyte relies on the application of a concentration ratio relating the activity concentration within the reference organism to that in soil. With the absence of root systems, the overall appropriateness of a soil to organism concentration ratio for lichen and bryophyte can be questioned. As such we do not think this implies that intrusion is not reasonably foreseeable and the justification instead relates to the small area of the site in relation to the area recommended by the IAEA for assessment of potentially deleterious effects on populations.
The Food Standards Agency have undertaken a risk assessment to estimate the potential dose to the public via the food chain. The assessment showed that the dose to the public via the food chain, calculated using conservative	Noted.

assumptions within their screening methodology, is below the Environment Agency acceptable dose criteria for the site of 20 microsieverts per year (µSv/y). The Food Standards Agency had no objections to the application.	
A member of the public was concerned about the local watercourse and the impact on it if the waste was to enter it.	Distington Beck runs adjacent to the site. Clean surface water is collected in a series of lagoons, including a settlement lagoon, prior to discharge to Distington Beck. The surface water management plan was developed in accordance with the existing landfill Environmental Permit and was approved by the Environment Agency. A small area in the south of the site (away from the proposed cells) shows groundwater contours indicating flow toward Distington Beck. However, this is thought to be unlikely to affect groundwater flow directions under the proposed disposal cells. Due to the depth to groundwater and the thickness of Glacial Till in the area of the Beck it is not thought to be in hydraulic continuity with groundwater. Therefore, Distington Beck is not considered a likely receptor. There is a programme of environmental monitoring around the site which includes taking samples from the beck. The results would show if the landfill site was having an impact on the stream.
Topic: Dose calculations	
PHE commented the calculated doses for human intrusion are inconsistent. For example, in the ESC the doses are given as 0.09 and 4.04 effective dose (µSv) in Table 8 and as 0.09 and 4.04 mSv in Paragraph 204. The text on page 7 of the ESC “The maximum annual dose from potential future situations where the waste is unintentionally brought to the surface is 4.04 µSv compared to	ESC (vs 3 and subsequently vs 5) has been updated to amend these inconsistencies. Changes to the ESC have resulted in new table and paragraph numbers. Table 8 is now Table 6-4 and paragraph 204 is now 216. An additional scenario has also been added to the table in version 5. The operator has also revised their radiological assessments based on 2016 UKRWI data and therefore the effective doses have changed.

the EA acceptable dose criteria of 3 mSv per annum." should be amended.	
PHE have suggested it would be useful if there was more discussion on the assumptions made in the assessment likely to lead to an overestimation of doses if it exceeds 3 mSv y^{-1}, for human intrusion after the period of authorisation.	This comment has been noted. Further information is provided in the supplementary document 'R7: Human Intrusion After the Period of Authorisation'.
PHE - The calculations of the inventory to be disposed are difficult to follow, for example the calculation of the totals in Table 4, page 38 of the ESC are not explained clearly.	Further explanation has been provided in the updated ESC (vs 3 and subsequently vs 5).
PHE - Comments on the ESC table 4, page 38 - It is not clear how the potential total inventory or the total activity concentrations were derived.	The table (now table 3-1) has been updated and further explanation provided in the updated ESC (vs 3 and subsequently vs 5).
PHE – comments on R7 A.1 page 14 activity concentrations are given and the footnote refers to Section 3 of the ESC but that does not appear to be relevant.	The ESC (vs 3 and subsequently vs 5) has been updated and as a result section numbers have changed. Section 3, paragraph 133, is now relevant to the footnote.
Topic: Consultation process	
Dean Parish Council have no objections to the application but made the following comments on the consultation process: They felt they were not consulted in a timely manner.	Dean Parish Council were notified of the consultation. We met with the Parish Councillors on the 3rd April 2019 and had a question and answer session with them. Representatives from the Environment Agency, FCC and the planning authority were present at this meeting to answer any questions. We extended the consultation to provide enough time for the Parish Council to provide a

	response to the consultation. A site visit, for the parish councillors, was also arranged on the 26th April 2019.
LLWR are in support of the application	Noted.

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