Report

Trawsfynydd Site

Project: Trawsfynydd Height Reduction

Title: Pre-Demolition Assessment of Materials Against Clearance Thresholds

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Verification Statement

This document has been internally verified and is fit for purpose. The scope of the verification was to confirm that:

- The scope corresponds with the Contract Module.
- The end points are described.
- All interfaces with other documents are identified
- Relevant exclusions are identified.

AMENDMENTS

To assist in identifying the amendments in each revised issue of this document, a vertical line is displayed in the margin opposite new or revised text. Vertical lines marking previous amendments are deleted at each revised issue of the document.

EXECUTIVE SUMMARY

This report describes the work undertaken by NRS (formerly Magnox) between 2021 and 2024 to characterise those structures that shall be removed by the Height Reduction project at Trawsfynydd. Specifically, these include all built structures above the 6th floor at the lower end of the capping roof and all structures above the recently created 7th floor plus aging pre-cast concrete panels and louvres external to the reactor building.

Characterisation was undertaken to determine the nature, quantities and distribution of any radioactive materials associated with those structures, and thereby facilitate an assessment of their categorisation as either Out of Scope (OoS) in respect of Environmental Permitting Regulations [xxv] or radioactive for the purpose of onward treatment and/or disposal. Characterisation was also undertaken to identify any hazardous materials which may be present and facilitate assessment against Waste Classification Technical Guidance (WM3).

A systematic planning approach was adopted, commencing with a review of the structures' provenance and existing characterisation information. The development of a Data Quality Objectives (DQO) report [xxvii] sub-divided the structures to be removed into a number of zones according to their potential for contamination / hazardous properties and identified that existing characterisation data was insufficient to underpin their removal and onward management. Consequently characterisation plans were prepared and implemented [ii iv vii].

Characterisation activities were deliberately undertaken ahead of the removal of the relevant structures. The dominant mechanism for items to have become radioactive was surface deposition of contamination and hence this early characterisation afforded the best access to those structures, avoiding potential for mixing of materials and enabling recommendations to be made for segregation of materials should it be necessary. Equally, this approach facilitated access to materials with the potential to harbour hazardous properties. Nevertheless, certain structures remained inaccessible during characterisation and it will be necessary to either undertake clearance monitoring where no relevant assessment of radioactivity exists (i.e. zone 3, cranes and gantries) or prioritise reassurance monitoring efforts on structural features where the potential for contamination is comparable to those that could be accessed during characterisation.

Review of characterisation data concluded that the majority of the relevant structures should be categorised as OoS, subject to the observations above regarding accessibility. Furthermore, analytical data for roofing felt and paint throughout the zones indicate they may be regarded as Non-Hazardous Waste for sentencing purposes. It should be noted that a requirement for reassurance monitoring during removal works, in addition to the characterisation work undertaken so far, is consistent with national good practice [xxiv].

Structures in zone 3 remain to be characterised so it is not possible to be conclusive about their provisional categorisation at the time of preparing this report. With the exception of concrete from the R2 north stack where radioactivity exceeding surface clearance levels was discovered [xix], characterisation data indicate the materials throughout the remaining zones are OoS[1]. For the materials in the vicinity of the R2 north stack further targeted characterisation to inform the need for surface decontamination should be carried out in support of OoS sentencing.

[1] Debris from the HLDR has been removed for management as LLW.

Trawsfynydd Height Reduction Project: Pre-Demolition Assessment of Materials Against Clearance Thresholds

Contents

1. Introduction

This technical note summarises the outcome of characterisation work undertaken between 2021 and 2024 in support of the Height Reduction programme at Trawsfynydd. Characterisation specifically considered those materials that will be generated as waste during Height Reduction works, mainly structures above the capping roof plus some external features. An assessment against criteria for the release of materials from control as radioactive materials or wastes for the purpose of disposal is included. Recommendations for further work in support of the further demolition of relevant structures and onward management of the resulting wastes are also included.

2. Project Description

The Trawsfynydd Site Programme requires the construction of new Weather Envelopes to the reduced height reactor buildings to form the Safestores at Trawsfynydd decommissioning Site. The physical height reduction of both reactor buildings is due to commence in 2025. The work associated with height reduction is constrained within the Safestores' building footprints and includes the removal of all built structures above the 6th floor at the lower end of the capping roof (the 6th floor is immediately above the Hot Gas Duct Valve Room), and all structures above the recently created 7th floor which bisects the upper plenum at the higher end of the capping roof. Under this project the aging pre-cast concrete panels and louvres external to the reactor building will also be removed and replaced with a modern weatherproof construction. This involves removal of the following features (illustrated in Appendix A):

1 The existing roofs.
2 Overhead cranes/rails and any remaining plant above the 75' level.
3 External pre-cast concrete cladding panels and supporting steelwork.
4 Framed window units/glazing/profiled metal cladding & louvers.
5 External cast-in-situ concrete walls and floors, above the proposed cut off level (just above Capping Roof level.)
6 Internal walls/ floors & staircases above cut line.
7 Steel strengthening structures added to Boiler Boxes, 131' floor, PC Panel restraining brackets etc.

For both reactor buildings, features 5 and 6 include the following built structures:

a) Charge Hall
b) Fuel Machine Maintenance Bay (FMMB)
c) Hot Gas Duct Cells
d) 131' (Top Duct) Areas
e) Boiler Boxes
f) Boiler Interspaces
g) Shield Fan Rooms,
h) Shield Cooling Discharge Ducts
i) Shield Cooling Stacks

Structures to be removed during the Height Reduction programme are illustrated in Appendix A. The history and provenance of the relevant structures is included in Appendix B: History and Provenance.

In total, the structures to be removed by the Height Reduction Project comprise approximately 3,500 tonnes of metals, and 30,000 tonnes of concrete and other materials. These structures are considered to have relatively low potential for artificial radioactivity, having been the subject of an environmental clean including decontamination works following de-planting in the early 2,000's. There is no provenance of enhanced naturally occurring radioactivity within the structures either. Hence, characterisation was required to critically assess the project strategy for management as non-radioactive waste for the purposes of onward transfer and disposal.

The over-riding mechanism whereby items may have become radioactive is surface deposition of activated reactor core components carried within the primary circuit and released during size-reduction work. Hence contamination would largely remain on the surface of those items. Characterisation effort was deliberately scheduled to take place ahead of the demolition of the above structures in order to optimise access to materials for the purpose of determining the nature and quantity of any radioactivity; inform the approach to segregation activities during decommissioning; minimise handling of decommissioning waste arisings; and ensure the efficient onward routing of wastes. A fuller description of the contaminating mechanisms is provided in Appendix C: Mechanisms for Potential Radioactivity and Level of Radiological Risk.

Characterisation works have also assessed levels of non-radioactive hazards and properties which are relevant for the onward management of decommissioning wastes. This note includes the results of those non-radioactive analyses.

3. Exclusions

An asbestos refurbishment and demolition (R&D) survey has been undertaken in parallel with the characterisation work described in this note. Asbestos characterisation is deliberately excluded from the scope of this note therefore for the purpose of waste classification and onward routing of the resulting demolition wastes it is important that the outcomes presented here are read in conjunction with the Refurbishment & Demolition survey reports [22 No contained in Appendix 19 of the Pre Construction Information Document No TRAWS/L28302/DOC/032].

Gantries and cranes (Zone 3) were deliberately excluded from the scope of characterisation because it was not possible to safely access them *in-situ*. These shall be dismantled and segregated after demolition has started, to be characterised separately: an assessment shall be made at that time against the criteria for their release as Out of Scope (OoS) waste.

Whereas the walls and ceilings in the Charge Halls, Fuel Machine Maintenance Bays (FMMBs), 131' (Top Duct) Areas, Hot Gas Duct cells and Boiler Interspaces were characterised during the 2021 – 2024 campaign, in each case it was generally not possible to safely access structures above 2 metres height[2]. It is therefore advised to carry out further monitoring of the higher structures around the time of demolition to confirm their categorisation for disposal and/or further processing.

Limited surveying and sampling of the internal surfaces of the Shield Cooling Stack was undertaken due to issues with accessibility therefore it is advised that this be the subject of further investigation around the time of demolition.

4. Characterisation Planning

Informed by reviews of the facility provenance and data from prior characterisation activities, a plan was developed for characterisation with the objective of demonstrating whether the structures to be demolished were suitable for clearance as Out of Scope material. Early discussions were held with representatives from the Project, Site Waste Team and Site EHSS&Q Team to confirm the relevance of established characterisation data and the need for more focussed characterisation.

A DQO report [xxvii] was prepared with further consultation and input from the above stakeholders plus members of the Site Restoration Programme, setting out the goals of characterisation and defining the approach to data-gathering and interpretation. Considering the mechanisms for contamination replicated in this report, the DQO report considered that with the exception of a minor volume of structures in close proximity to the RPV where there was potential for activation, all contamination would be present as surface deposits with low penetration into the substrates.

The standard reactor fingerprint, 9G105 'Reactors LLWR' decay-corrected to 2021 [i] was used as a guide to the nature of contamination anticipated throughout the structures and is presented in Table 10. The fingerprint was derived following operations in the reactor buildings, and updated through a waste mapping exercise that takes account of changes in waste forecasts. It was appropriate to check the type of activity in the materials to be removed by the Height Reduction project and not just assume that the established reactor building fingerprint was suitable. Hence, for the purpose of determining the categorisation of decommissioning wastes to be generated by the Height Reduction project, activity assessments have been developed on the basis of provenance and review of analytical data as part of a phased approach. Assessment against clearance thresholds is hence informed by the activities as determined for the various materials, with no expectation that radionuclides will be present at the ratios presented in the fingerprint.

A multi-layered approach to characterisation was devised in accordance with established Company guidance as follows:

- Initiation of characterisation. Schedule and scope of characterisation work reviewed against expectations for a large-scale clearance project. Change control applied.

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[2] Within the Charge Halls, FMMBs and Top Duct Areas scaffolding was erected to enable characterisation work in discrete locations over a 1 metre-wide strip up to a height of around 8 to 10 metres. This did not however cover the full height of those rooms.

- Detailed planning. Agreed the scope of materials to be removed during Height Reduction programme, and baseline routes for their onward management. Established facility provenance and potential for contamination. Characterisation decisions and information requirements confirmed. DQO report developed in consultation with project staff and internal stakeholders developed.
- Radiological Surveys. Radiological survey plan [ii] developed in consultation with stakeholders identified in the DQO report, including the Head of Radiological Protection. Instruments procured and set to work. Areas to be surveyed overlaid with a painted and numbered grid for ease of reference, survey work undertaken, reports and associated metadata (photographs, drawings etc) verified and uploaded to Sharepoint [[iii]].
- Sampling. Sampling plan [iv] developed in consultation with stakeholders identified in the DQO report. Samples of concrete, roofing felt, paint, metal and oil collected then individually packaged, labelled and stored in a dedicated refrigerator pending transfer to the external laboratory for analysis. Comprehensive information on samples recorded on Excel spreadsheet and uploaded to Sharepoint [v] [vi]
- Analysis. Analytical Scope of Work [vii] developed in consultation with stakeholders identified in the DQO report. Used to compete the analytical work via the WCASS III framework. Chain of Custody paperwork prepared with clear instructions for analyses required. Samples transferred to the laboratory using cool boxes to limit warming in transit. A phased approach to analyses was adopted to optimise the effort required to achieve the goals identified in the DQO report.

4.1 Surveying

The radiological survey plan [ii] acknowledged that any contamination in the structures to be cleared would predominantly feature H-3, which cannot practically be measured *in-situ*. It recognised the potential for C-14, Cl-36 and Co-60 and proposed a series of targeted surveys with beta sensitive probes biased toward areas with higher potential for contamination. The BP19 probe was specifically selected because of its relatively good response to low energy (C-14) beta particles and moderate energy beta particles (Cl-36 and Co-60). Additionally, the survey plan proposed gross gamma ray surveys in recognition of potential gamma emissions from Co-60, should it be present at elevated concentrations. By sub-dividing the areas into a systematic grid of 1 x 1 metre squares, surveying would be more consistent, and traceability of results would be enhanced. A process for the collection of information supporting the traceability of survey data was established. For reference, the survey schedule is reproduced in Appendix E: Survey Schedule.

Surveying was undertaken to indicate meaningful variations in the response of appropriate instruments over relatively large areas of the *in-situ* structures, thereby indicating any specific locations of interest for sampling and analysis. Uncertainty in the relative proportions of various radionuclides was anticipated and it was expected that the instruments may not reliably detect the radionuclides of interest at low concentrations commensurate with OoS categorisation (refer to [ii] for calculations). Nevertheless, surveying was an important element of NRS due-diligence in demonstrating that radiation detected was low, uniform and consistent with background levels over the structures to be demolished. In the few cases where surveys identified elevated levels of activity, targeted samples were collected to inform the nature and levels of activity present.

4.2 Sampling

Having notionally sub-divided the structures in both reactor buildings into 6 zones for radiological properties, a statistically relevant number of samples were collected from each of those zones to reliably quantify levels of radioactivity within the corresponding materials [xxvii iv]. Sampling locations were only defined initially in terms of the rooms and materials to be sampled. For ease of reference the sample schedule is reproduced in Appendix F: Sample Schedule. A process for the collection of information supporting the traceability of sampling data was established.

4.3 Analysis

With the exception of specific non-radiological analyses to determine chemical hazard classification, the approach to analysis was to initially analyse relatively large numbers of representative sub-samples for gross alpha / beta activity, C-14 and H-3; and perform high resolution gamma spectrometry (HRGS) on these. Thereafter, the results would be reviewed and used to determine which, if any, of the original samples were submitted for further analyses either as single samples or having been bulked with other samples. The ASoW identified the following further analyses as potentially of interest:

- The significant presence of americium-241 (Am-241) by gamma spectrometry, together with a non-reconcilable gross-alpha activity, may prompt further alpha spectrometric analysis for Am-241 (and associated Curium isotopes), Uranium alpha isotopes, and Plutonium isotopes (i.e., Pu-238, Pu-239/240, Pu-241), including Pu-241 by liquid beta scintillation counting.
- The presence of significant levels of Co-60, Cs-137 and/or Europium (Eu) isotopes, together with a non-reconcilable gross-beta activity, may prompt further analysis for other beta-emitters including Cl-36, Ni-63, Fe-55, strontium-90 (Sr-90), technetium-99 (Tc-99) and Ca-41 depending on the material in question.

5. Characterisation Execution

5.1 Surveying

Surveying work commenced in R1 in May 2022 and continued through R1 and R2 until August. Surveys were carried out in all of the areas identified in the survey plan, with each area having been overlaid with a spray-painted grid of 1 metre x 1 metre squares, each square featuring a unique systematic reference number for the area in question. Access limitations meant that surveys generally were not carried out above 2 metres high, with the exception of the Top Duct Areas, Charge Halls and FMMBs where additional surveys were carried out over a small number of 1 metre wide strips to a height of between 8 and 10 metres. Raw survey reports, supporting drawings and photographic evidence and a summary of survey outputs are saved on Sharepoint [viii, ix, x].

All beta surveys were performed using Thermo Scientific™ BP19 probes around 3mm from the surface of interest evenly scanning the full area of each square metre section, taking approximately 100 seconds to complete. A similar approach was adopted for all gamma surveys which were performed using Ludlum 44-10 probes.

5.2 Sampling

The availability of the extant Principal Contractor (Erith) presented a window of opportunity for the collection of samples in May 2022. As the incumbent asbestos-management service provider to the project, Erith's staff were disciplined in collecting and managing samples to preserve traceability and integrity, as well as having a detailed knowledge of potential asbestos contamination in the areas of interest: asbestos was specifically avoided during sampling.

Although surveying was not yet complete, 236 samples from R1 and 229 samples from R2 were collected over a period of 2 months (June to August 2023) using cold-cutting techniques. Each sample was placed within labelled sealed containment and added to a sample refrigerator within the space of 2 hours. Radiological surveys were undertaken using BP-19 and Ludlum 44-10 probes at the point of sampling before and after each sample was collected. Each sampling location was marked for future reference. Information on the samples was collated and saved on Sharepoint [xi, xii]. Because of the timing of the Principal Contractor's availability, it was not possible to plan the location of each sample on the basis of established survey data. A retrospective review was therefore carried out.

Samples were collected and managed as per the Sampling Plan [iv] noting the following aspects of interest for their non-radioactive chemical properties. Some of these samples were also used to determine radiological properties. The precise location of the samples is indicated in references xi and xii.

5.2.1 Roofing Felt

Roofing felt samples were taken to assess activity deposited from the ducts over a period of approximately 30 years during operation of the reactors. An additional weatherproof coating had been overlaid on the roofs in recent years therefore the approach to sampling was to core through all layers, instructing the laboratory to segregate the original felt in each case and analyse it preferentially. Many of the samples contained insulation material that had not been anticipated in the planning stages (refer to Appendix G for illustration) but which would not have been exposed to contamination. Photographs provided by the laboratory on receipt of the samples were used to identify samples which contained only felt; a mixture of felt and insulation material and insulation material only. This information, combined with review of the initial gamma spectrometry results [xiii] enabled the Subject Matter Expert (SME38.03) to identify 15 of the samples to be sub-sampled, deliberately targeting the black roofing felt material as opposed to the insulation.

5.2.2 Dark Staining on Concrete

There was evidence of dark staining in parts of the upper plenum which was considered likely to be oil. A proportion of the concrete samples from these areas were deliberately taken from the areas of dark staining in order to test this assumption.

5.2.3 Batteries

There were no batteries identified in the reactor buildings above the level of the capping roof. There are batteries in a mobile elevated work platform (MEWP) stored in the West corridor of level 3 in R1 which may be removed during Height Reduction works but there is no suggestion that these could have been exposed to radioactivity.

5.3 Analysis

Samples were transferred to the receiving laboratory (Socotec, Didcot) in chilled cool boxes in two batches: R1 samples were transferred on the 6th of October 2023, and R2 samples were transferred on the 26th of October 2023. Chain of Custody forms and laboratory receipt schedules are saved on Sharepoint [xiv, xv].

Samples were homogenised and sub-sampled for H-3/C-14, gross alpha/beta and HRGS analysis. In all cases HRGS was carried out on the raw sample material and the results were shared with NRS in order to assess forward actions in respect of the roofing felt and paint samples.

Due to the low mass per sample, limits of detection for paint samples were relatively high. Paint samples were subsequently bulked in order to reduce the limits of detection.

Gross alpha/beta and HRGS analysis was carried out on the raw material for all concrete and paint samples as per Socotec technical proposal [xiii].

7 samples of the felt from R1 and 8 samples of the felt from R2 were subjected to a 2-stage process to destroy organic material in readiness for assessing gross alpha and gross beta activity. All of the roofing felt samples selected contained the original felt material, which was preferentially segregated for treatment and analysis. Each of the samples was soaked for 16 hours in concentrated nitric acid (70%), followed by a 3 hour boiling in Aqua Regia (1:3 concentrated nitric acid: concentrated hydrochloric acid). This digest/leach was filtered and the gross alpha/beta was measured on the leachate. The remaining residue was washed with water and placed in an oven then over a period of 5 days the temperature was increased to 550^{o} C and left for at least 16 hours. All tar and wood material was completely destroyed by the ashing process, however in the R2 samples a white fibrous residue remained which was suspected to be asbestos, but later shown to be insoluble ash. The R1 samples were prepared

in a calcium sulfate matrix and deposited onto filter papers mounted on steel planchettes for gross counting. The R2 samples were wetted with water to prevent airborne suspension of fibres, and all further processing was suspended.

Oil samples were subjected to a controlled sulfated ashing process in preparation for gross alpha/beta counting.

The raw sample materials were used for H-3/C-14 analysis in all cases.

6. Review of Survey Data

Survey results plus drawings and interpretive spreadsheets are saved in reference areas xvi and xvii on Sharepoint, and are summarised in Appendix I: Summary of Radiological Survey Results [x]. For each square metre grid reference there are two sets of BP19 beta survey data recorded: the integrated count-rate over the square metre, and the highest count-rate within the square metre. The highest 44-10 gamma survey count-rate within the square metre is also recorded. Survey results for Upper Plenums and Boiler Boxes were of particular interest because of their greater potential to harbour contamination.

6.1 Upper Plenums

Survey data for the Upper Plenums were of particular interest as these were considered more likely to have some residual contamination since they were not subject to the previous environmental clean work: this was later confirmed by positive identification of Co-60 by HRGS analysis of samples taken from the Upper Plenums and the High Level Drainage Channels within them (refer to section 7). Data are presented in the following charts for the Upper Plenums in R1 (1802, 1852) and R2 (2802, 2852). Refer to Appendix A for a drawing referencing the locations of the Upper Plenums for R1 (mirrored for R2).

Survey results illustrated in Figure 1 to Figure 9 did not indicate significant variation in count-rates throughout the Upper Plenums. An apparently low series of 44-10 count-rates for the floor in area 2802 prompted a repeat survey (Figure 6 and Figure 7) which reversed the previously seen trend: overall these results were not considered to reliably indicate activity above background levels.

Survey data for other areas throughout the reactor buildings were also plotted graphically, but in most cases did not reveal discernible patterns in the profile of results or significant differences between the integrated count-rate and maximum count-rate obtained with the BP19 probe.

Figure 1: 1802 BP19 survey data

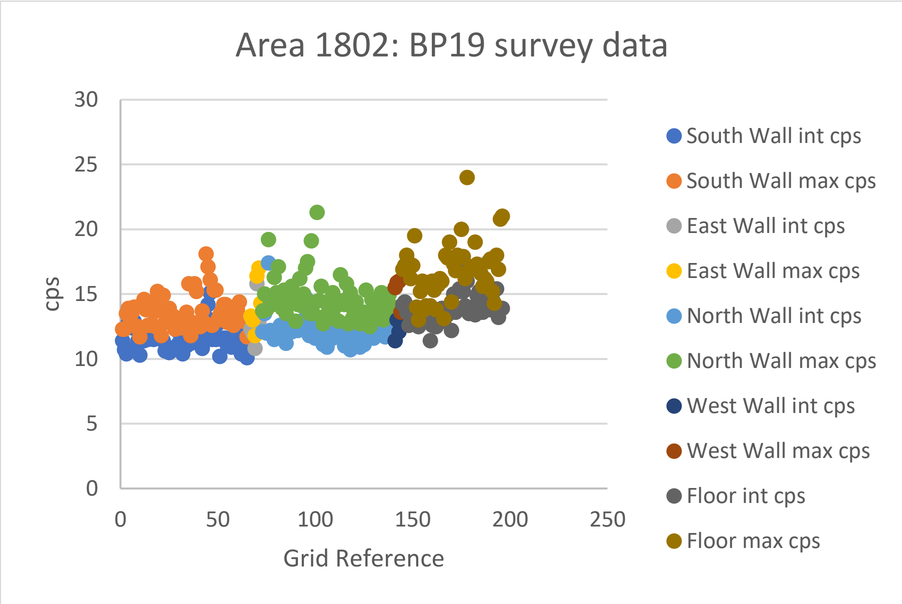


Figure 2: 1802 44-10 survey data

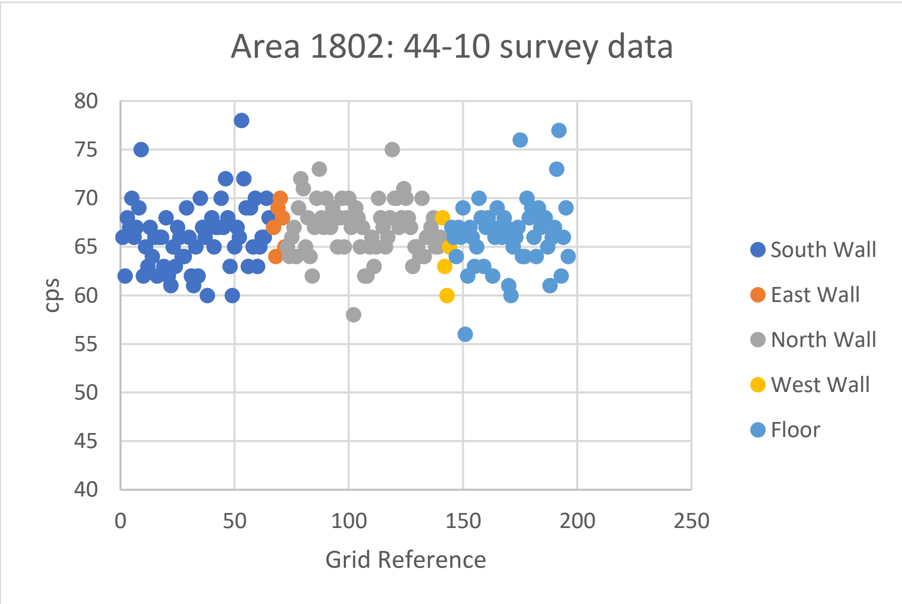


Figure 3: 1852 BP19 survey data

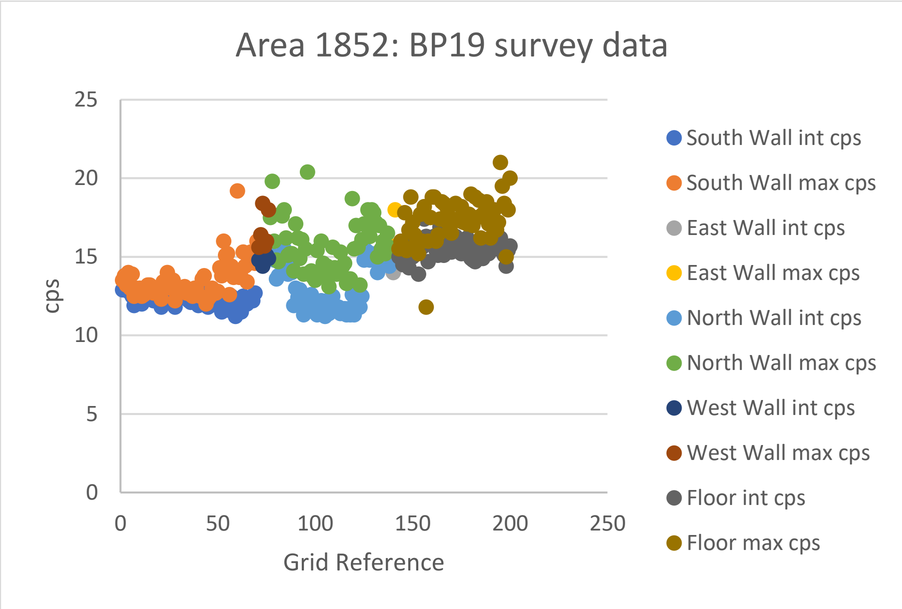


Figure 4: 1852 44-10 survey data

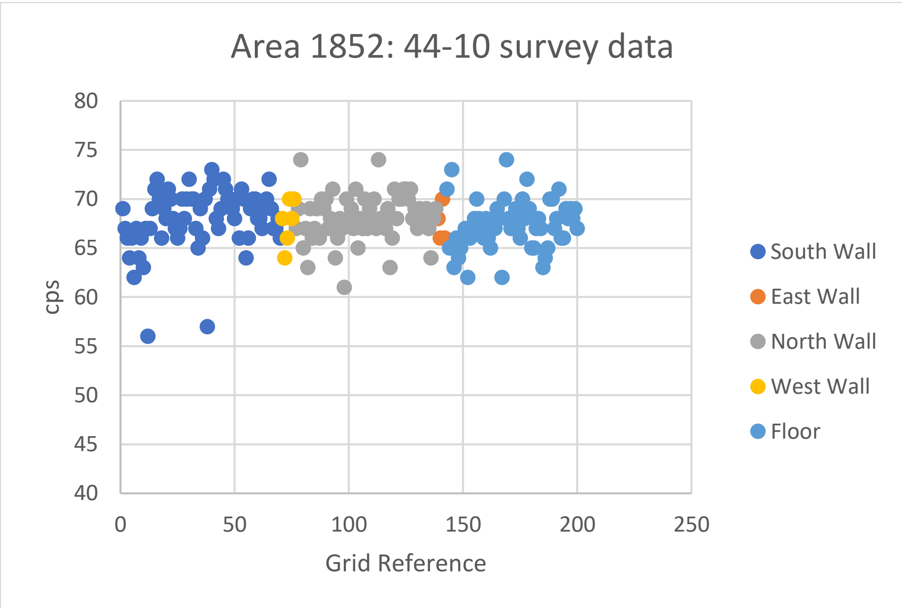


Figure 5: 2802 BP19 survey data

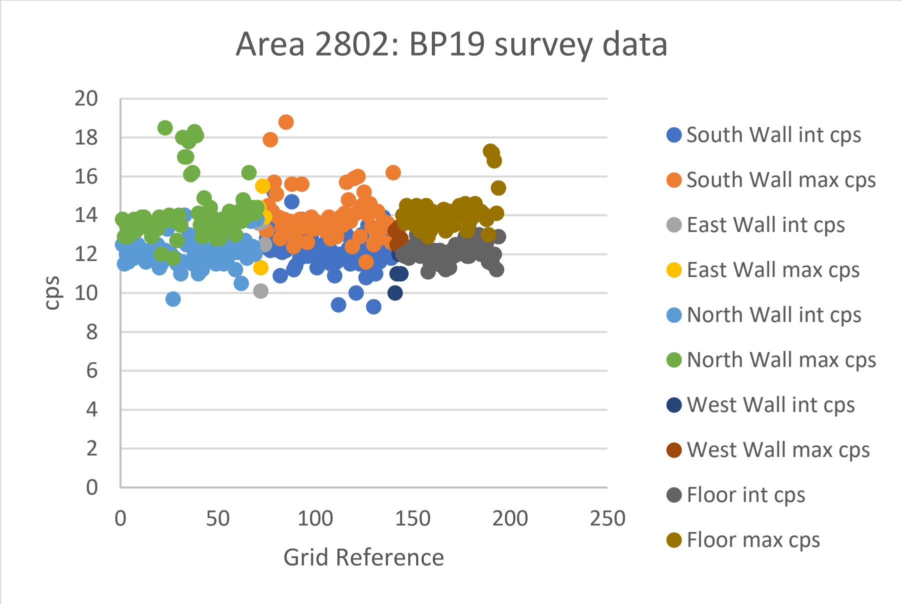


Figure 6: Original 2802 44-10 survey data

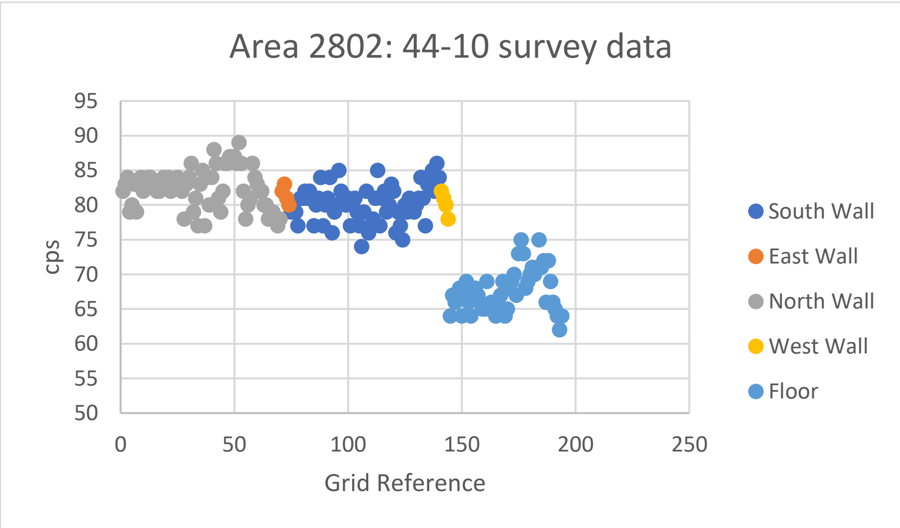


Figure 7: Repeat 2802 44-10 survey data

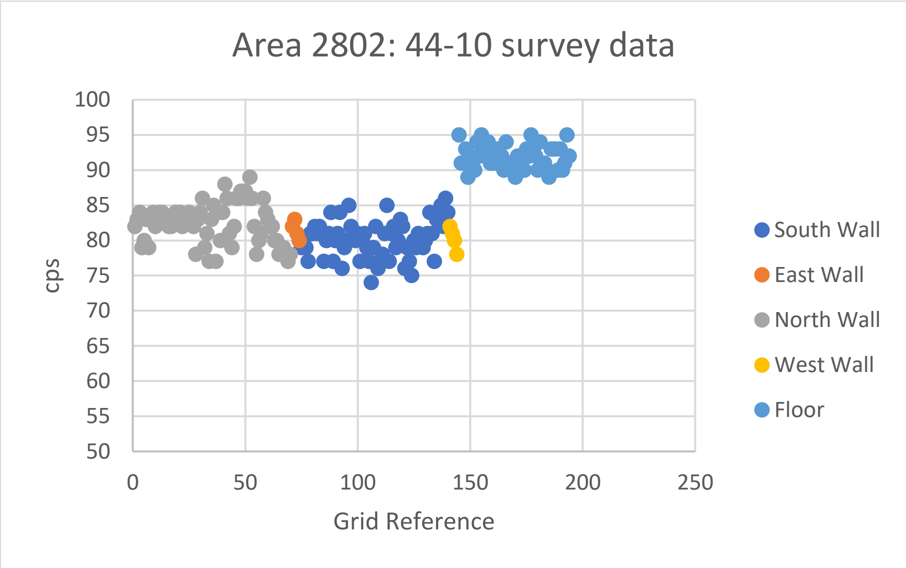


Figure 8: 2852 BP19 survey data

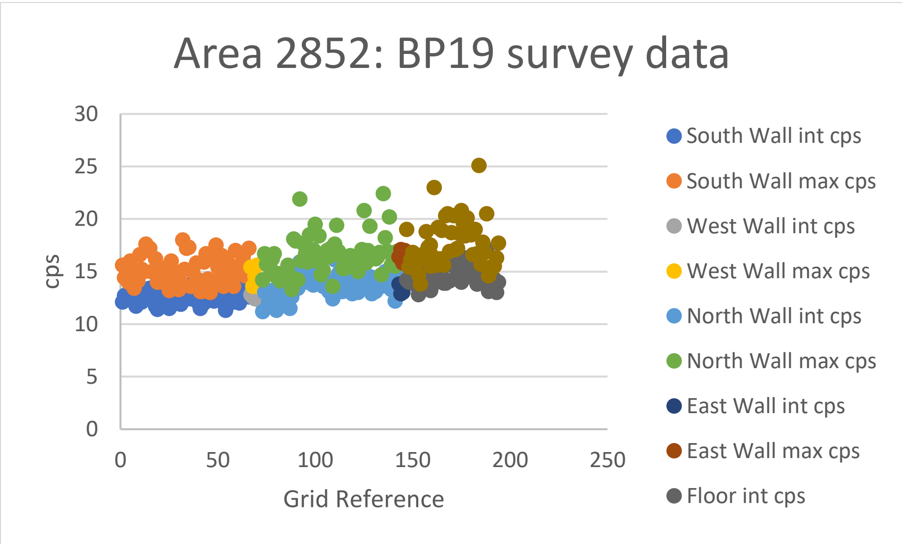
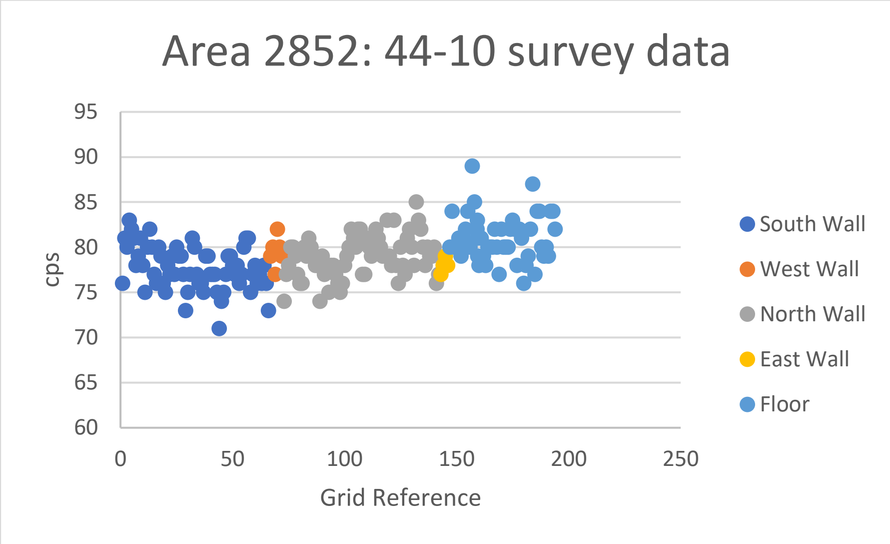


Figure 9: 2852 44-10 survey data



6.2 Boiler Boxes

For the R1 north side boiler boxes, the 44-10 results tended to be higher toward the centre of each of the walls: this was most notable in area 1751, Boiler Box 4 (refer to Figure 11).

Figure 10: 1751 BP19 survey results

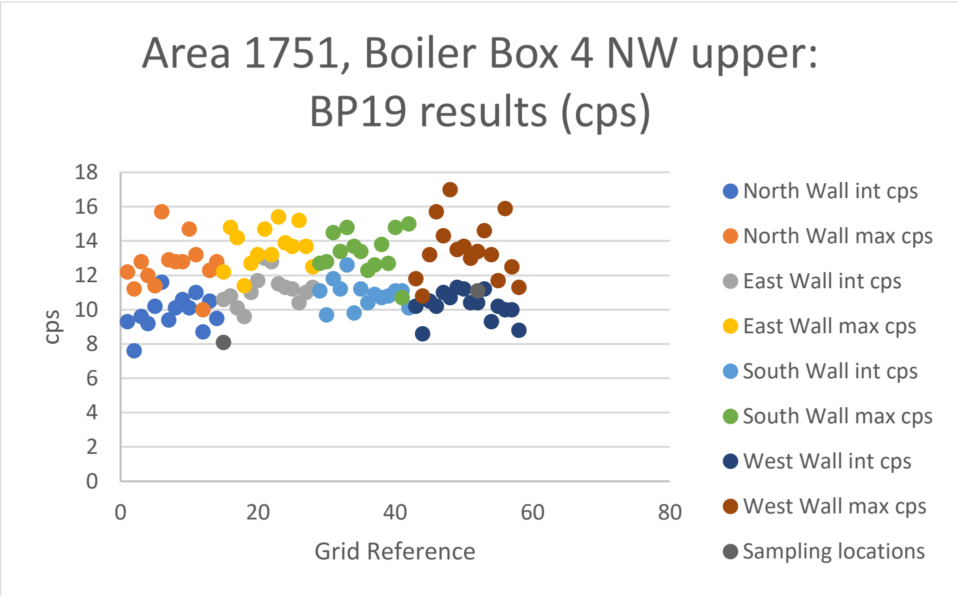
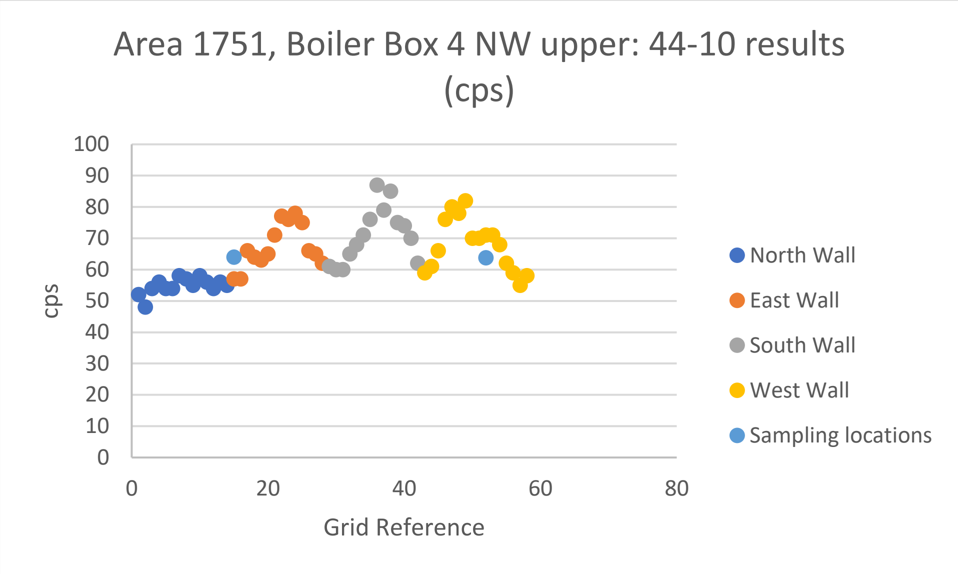


Figure 11: 1751 44-10 survey results



Two concrete samples corresponding to grid squares 15 and 52 were taken from within area 1751. Survey data at the sampling locations are presented in Table 1 below however these results were not significantly different from results for adjacent grid squares.

Table 1: Data on samples from Boiler Box 4, Area 1751

Sample Number	Grid Reference	BP19 at workface before taking sample	Ludlum 44-10 at workface before taking sample
TRA/HR/2022/1751/123/C	15	8.1	64
TRA/HR/2022/1751/124/C	52	11.1	63.8

All of the survey data were collated for R1 zone 4 to take a large-scale view on variations in detector response. Zone 4 includes the 131' Areas (otherwise known as the Top Duct Areas); the 6 Boiler boxes above the level of the capping roof; and the 6 Hot Gas Duct Cells, i.e. areas with the potential to have contamination arising from historical size-reduction of the top ducts and boilers or gas leaks during reactor operations. The collated zone 4 data are presented in Figure 12 to Figure 16**Error! Reference source not found.** below. The data were collected over both sets of Top Ducts Areas; the 6 x Boiler Boxes; and the 6 x Hot Gas Duct Cells. With the exception of 4 x 1m x 8m strips in both of the Top Duct Areas, all of the measurements were taken over grids 2 metres above floor level only.

There appears to be a dip in both the integrated and maximum BP19 count rates between points 600 to 900, which corresponds to all of the boiler boxes except the south-west boiler box (1509).

Noticeably, this pattern is not replicated in the 44-10 results which are relatively stable throughout zone 4 except for four distinct increases corresponding to the four 1m x 8m strips in Top Duct Area 1901; the four 1m x 8m strips in Top Duct Area 1951; the south wall and part of the east and west walls in the north west boiler box (1751); and the south and part of the east and west walls in the north central boiler box (1752). These locations were further investigated as described in sections 6.3 and 6.4.

Excluding the survey results for the 1m x 8m strips, area 1751, area 1752 and the nine relatively low survey results from the 44-10 dataset for R1 zone 4, gives results for 1,048 data points that are randomly distributed with a mean of 62.4 cps and a standard deviation of 3.5 cps (see Figure 12). When plotted as a histogram (refer to Figure 13) the data tend toward a symmetrical distribution with a slight low-end tail suggesting random uncertainty in the counting results only and no distinct peaks in count-rate that would suggest discrete areas requiring further investigation. Of these data points, 54 lie outside of the mean plus or minus 2 standard deviations.

There are nine 44-10 data points at around 40 cps which correspond to locations on the floor covered by steel floor plates where the steel appears to be partially shielding any gamma radiation emitted by the concrete.

Figure 12: Zone 4 44-10 survey results

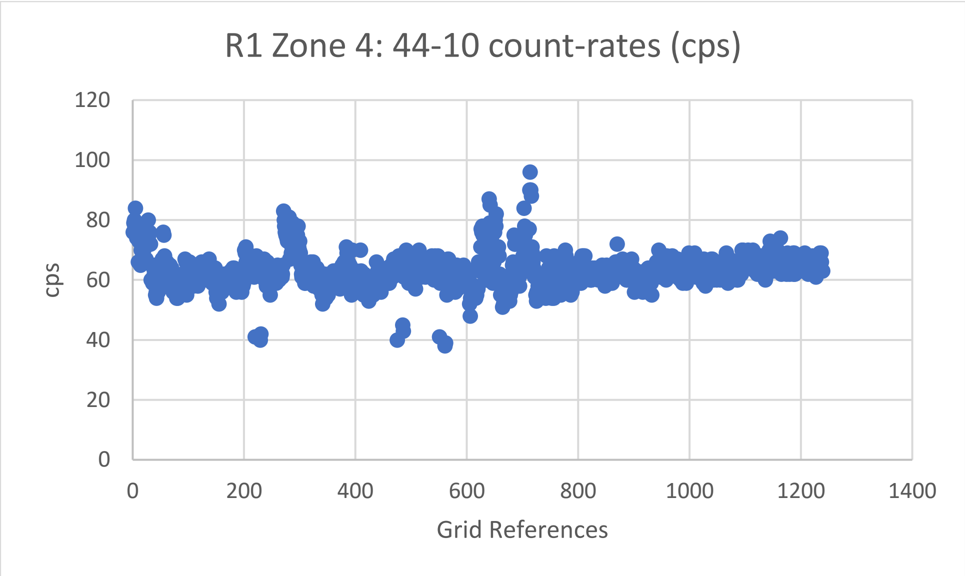
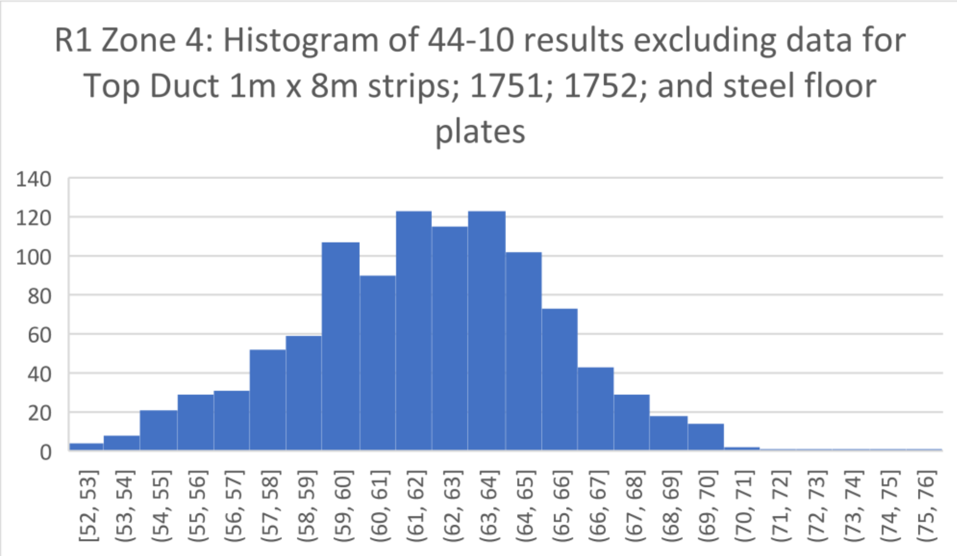


Figure 13: Histogram of Zone 4 44-10 count-rates excluding notable high and low count-rates



A similar near-symmetric distribution of maximum count-rates is observed for BP19 survey results, albeit with a slight high tail (refer to Figure 14). Again, these data did not indicate discrete areas requiring further investigation.

Figure 14: Histogram of Zone 4 BP19 count-rates

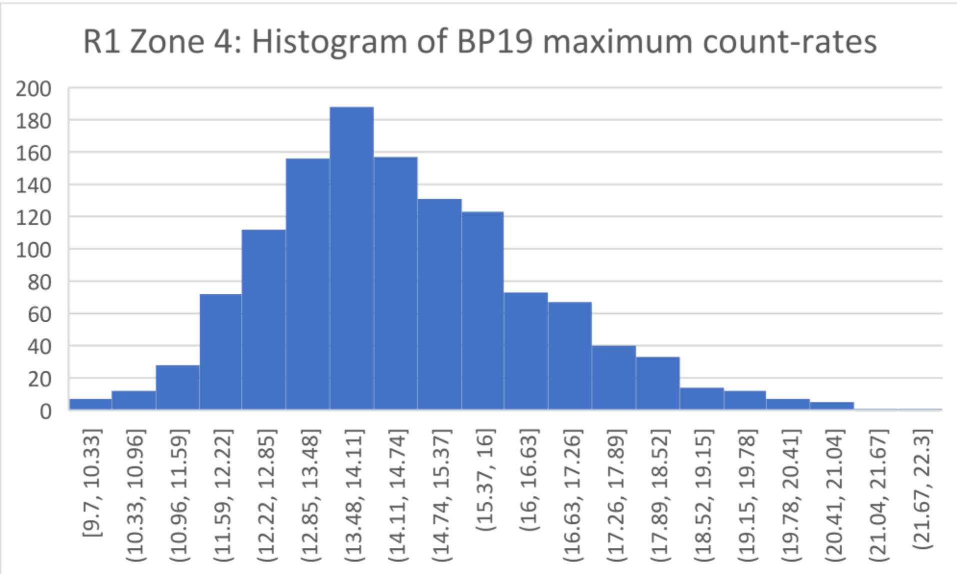


Figure 15: Zone 4 BP19 integrated count-rates

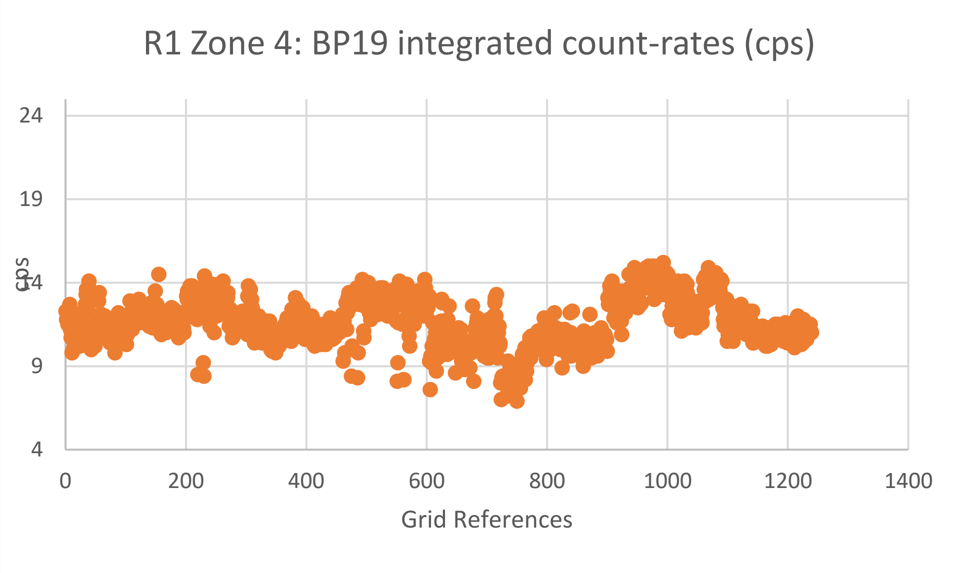
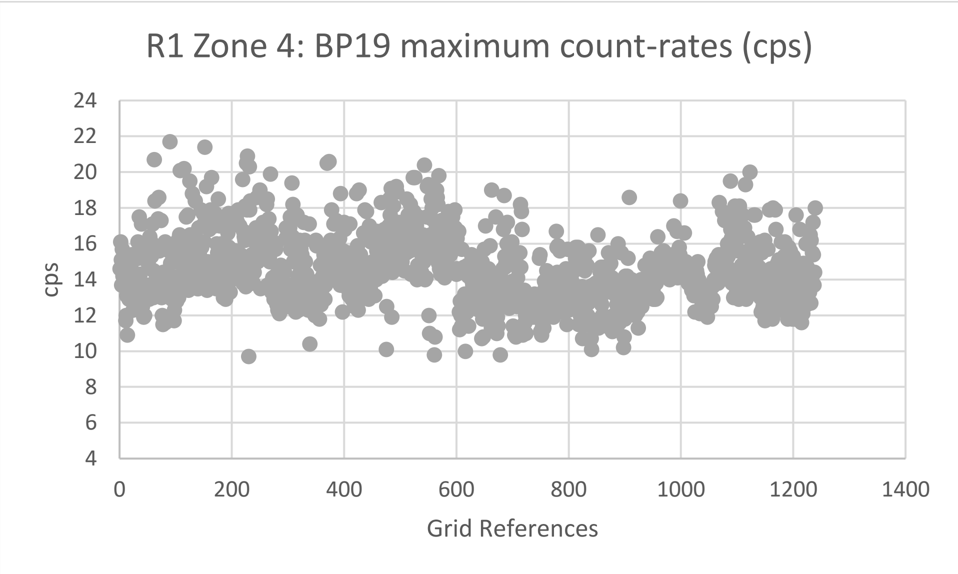


Figure 16: Zone 4 BP19 maximum count-rates



6.3 *In-situ* Gamma Spectra

Low resolution gamma spectrometry measurements were acquired at locations within R1 zone 4 to assess the nature of radioactivity at points where the 44-10 probe recorded elevated count-rates (see Table 2). All measurements were acquired using a GR-130 probe held static at 30 cm from the surface for an acquisition time of 60 seconds. In all cases, the GR-130 spectral analysis feature was unable to identify any peaks, however a slight peak at 1439keV was observed, corresponding to the 1460keV gamma ray emitted by K-40 which is naturally occurring within the concrete. The GR-130 energy calibration is maintained using the supplied Cs-137 stabilisation source. In summary, *in-situ* gamma spectrometry measurements did not identify evidence of anthropogenic radionuclides at the locations where the 44-10 probe survey recorded elevated count-rates.

Table 2: Locations where elevated gamma count-rate was investigated by in-situ gamma spectra

Area Code	Grid Reference	Corresponding entry on the x-axis of Figure 12 illustrating 44-10 count-rate
1901	A1 (within one of the 1m x 8m columns)	1
1951	B1 (within one of the 1m x 8m columns)	279
1751	One measurement in the centre of the south wall	Within the range 633 to 646
1752	Five measurements on south wall, being ○ Centre ○ Top left corner ○ Top right corner ○ Bottom left corner ○ Bottom right corner	Within the range 695 to 709

6.4 Further investigation of locations with higher recorded count-rates

Those areas where elevated gamma count-rates were observed were investigated further by targeted sampling (swabs and physical samples) – refer to Table 3 for further information. Specifically, the targeted sampling sought to assess whether elevated count-rates might be due to contamination on the walls.

For grid squares where gross gamma count-rates were elevated the process was:

- Re-survey using 44-10 probe to locate the precise location of the highest count-rate
- Wipe the whole of the grid square using a taki rag to assess removable activity on the surface of the concrete then measure the taki rag using the on-site high resolution gamma spectrometry system
- Take a sample of concrete from the point of highest count-rate then measure the concrete sample using the on-site high resolution gamma spectrometry system

For the two grid squares with a relatively high difference between maximum and integrated count-rates using the BP19 probe the process was:

- Re-survey using BP19 probe to locate the precise location of the highest count-rate
- Wipe the whole of the grid square using a taki rag to assess removable activity on the surface of the concrete then measure the taki rag using the on-site high resolution gamma spectrometry system
- Take a sample of concrete from the point of highest count-rate then measure the concrete sample using the on-site high resolution gamma spectrometry system

- Send the concrete sample to the laboratory for phase 1 analysis (high resolution gamma spectrometry, gross alpha, gross beta, H-3, C-14) plus Cl-36, Fe-55 and Ni-63 analysis.

BP19 count-rates were generally randomly distributed with no significant outliers throughout the areas surveyed. The highest point of difference between maximum and integrated BP19 count-rate occurred in grid square 50 within top duct area 1901, which was of interest.

On-site gamma spectrometry measurements on the taki swabs and concrete samples were undertaken on HRGS detector # 1 using a 250 ml bottle calibration over 30,000 seconds per sample. Sample results were treated as semi-quantitative due to differences in the geometry and density of the taki swab compared to the liquid calibration standard and allowing for inhomogeneity in the distribution of activity. For ease of reference, the on-site gamma spectrometry results are reported in Table 3 alongside the areas where re-survey work was undertaken.

Co-60 was only measured above limits of detection in the taki swabs in one case (area 1951 grid square A1) and the reported activity (0.62 Bq/sample) was higher than the values of the limits of detection for the other taki swabs (typically around 0.25 Bq/sample). No other anthropogenic radionuclides were measured in any of the taki swabs. Low levels of NORM not associated with credible sources of anthropogenic contamination were observed [xviii].

No anthropogenic radionuclides were measured above limits of detection for the concrete samples.

Laboratory analytical results associated with re-sampling are discussed in section 9.

Table 3: Further actions to investigate elevated count-rates

4-digit area code	**Grid Square**	**Prompt for investigation**	**Co-60 measured by on-site HRGS for taki swab (Bq/sample)**	**Co-60 measured by on-site HRGS for concrete sample (Bq/g)**
1751	36	Recorded gross-gamma count rates are higher toward the centre of each of the walls in 1751. Highest count-rate on south wall recorded in grid square 36.	<0.4201 (beam) <0.2481	<0.01066
1751	49	Recorded gross-gamma count rates are higher toward the centre of each of the walls in 1751. Highest count-rate on west wall recorded in grid square 49.	<0.2703	<0.007847
1752	52	Recorded gross-gamma count rates are higher toward the centre of each of the walls in 1752. Highest count-rate on west wall recorded in grid square 52.	<0.2439	<0.01199
1752	41	Recorded gross-gamma count rates are higher toward the centre of each of the walls in 1752. Highest count-rate on south wall recorded in grid square 41.	<0.2416	<0.009352
1901	A2 (part of the 1m x 8m strip)	Vertical 1m x 8m strips in top duct area 1901 had elevated gross gamma count-rates compared to the rest of the walls. Relatively high count-rate in grid A2, which was easily accessible.	<1.4035	<0.009675

4-digit area code	Grid Square	Prompt for investigation	Co-60 measured by on-site HRGS for taki swab (Bq/sample)	Co-60 measured by on-site HRGS for concrete sample (Bq/g)
1901	50	Of all the BP19 results throughout R1, the highest difference between integrated and maximum count-rate (9.8 cps) was observed in grid 50 on the south wall.	<1.386	<0.007732
1951	A1 (part of the 1m x 8m strip)	Vertical 1m x 8m strips in top duct area 1951 had elevated gross gamma count-rates compared to the rest of the walls. Relatively high count-rate in grid A1, which was easily accessible.	0.6186	<0.01038
2771	27	Of all the BP19 results throughout R2, the highest difference between integrated and maximum count-rate (11.8 cps) was observed in grid 27 on the south wall.	<1.066	<0.007407
2752	27	Recorded gross-gamma count rates are higher toward the centre of each of the walls in 2752. Highest count-rate on west wall recorded in grid square 27.	<1.295	<0.01159
2071	6	Single isolated spike in gross gamma count-rate compared to the rest of the stairwells.	<0.05766	

6.5 Radiological survey: Concluding remarks

A systematic campaign of radiological surveys was undertaken throughout the structures above the level of the capping roofs in R1 and R2 to a height of 2 metres. In the Charge Hall and Top Duct Areas surveys were extended to a height of between 8 and 10 metres in isolated strips where it was feasible to use zip-up scaffolding. The surveys were carried out using gamma-sensitive probes (44-10) to detect any Co-60, and beta-sensitive probes (BP19) to detect any Cl-36 and/or C-14 with due consideration to activity deposition mechanisms (see Appendix C: Mechanisms for Potential Radioactivity and Level of Radiological Risk). The results of the surveys have been appropriately recorded in Sharepoint references viii and ix.

The purpose of the surveys was to establish the location and relative activities of contamination throughout the structures (if any) and thereby inform judgemental sampling to confirm the nature and extent of activity. The building fingerprint which was used to underpin sentencing of operational wastes was used as a guide to probe selection, but with no expectation that the nature of contamination would be consistent over such a large surface area and allowing for variation in the efficiency of the environmental clean process.

For most of the areas surveyed, the BP19 and 44-10 survey results were randomly distributed about a mean value that varied slightly from area to area with no discernible pattern. In a few select areas however, there was a clear pattern in the gross gamma count-rates that prompted further investigation. Additionally, one area in R1 and one area in R2 were selected for further investigation on the basis that they had the largest difference between maximum and integrated BP19 count-rates.

In-situ gamma spectra acquired at the most significant locations of enhanced gamma count-rate, i.e. within Top Duct Areas 1901 and 1951, and Boiler Boxes 1751 and 1752 did not show any evidence of anthropogenic activity [xviii]. Similarly, high resolution gamma spectrometry measurements of taki wipes from selected grid squares showed negligible evidence of anthropogenic activity. Assuming a 10% pick-up factor, the highest taki swab result for Co-60 translates as 0.62 Bq/m^2 x 10/10,000 = 0.00062Bq/cm^2 which is a factor of 1,600 below the 1 Bq/cm^2 surface clearance threshold for Co-60 defined in RP113 [xix] appropriate to buildings for demolition. Co-60 is the most likely gamma-emitting artificial radionuclide to be encountered from reference to the building's provenance, and no other anthropogenic radionuclides were detected.

On the basis of on-site HRGS of taki swabs and concrete samples, those areas of elevated gross gamma count-rates do not appear to contain artificial activity on the surface of the materials surveyed. It is more likely that the elevated count-rates are the result of local increases in background radiation, possibly resulting from the sections of the boilers which remain in their original locations, and sections of boilers and hot gas ducts which were removed ahead of installing the capping roof and have been stored in the Boiler House Interspaces ever since.

Overall, radiological surveys using gamma and beta-sensitive instruments did not indicate evidence of localised activity. This may be due to there being very low levels of activity associated with those materials and/or the nature of any activity not being amendable to detection (e.g. low energy beta emissions). Self-shielding by the structures to be characterised is not considered to be a significant factor since any activity present will predominantly be surface-bound.

It was not possible to survey certain features within the scope of the Height Reduction project due to access limitations, namely the cranes and gantries; and structural concrete above 2 metres within the Charge Halls, Fuelling Machine Maintenance Bays, Top Duct Areas, Boiler Boxes and Hot Gas Duct Cells. Surveying and/or sampling of these features at or around the point of demolition should pay close attention to horizontal surfaces such as ledges where contamination could have settled over time.

7. Review of Laboratory Analytical Results for samples acquired during 2022

314 of the samples collected from R1 and R2 during summer 2022 were submitted for analysis by a third-party laboratory in accordance with the DQO report and ASoW. The results for phase 1 analysis of these samples, as defined in the ASoW [vii], are discussed below.

7.1 High Resolution Gamma Spectrometry (HRGS) Results

Laboratory HRGS results for the samples are saved on Sharepoint in reference xx. Although there are too many results to conveniently include within this report, charts illustrating the spread of data are included in Figure 17 to Figure 20 below. Minimum detectable activities (MDAs) are represented as zero values.

Variation in natural activity is relatively even across the concrete samples for K-40 and the Th-232 and U-238 (post Ra-226) decay chains (Figure 17 to Figure 19). As predicted, there was negligible natural radioactivity detected in the paint, felt, oil and metal samples. Figure 19 indicates certain samples having higher levels of Bi-214, and these are almost all associated with the upper plenum (expanded on in Figure 20).

Figure 17 Variation in K-40 with sample type

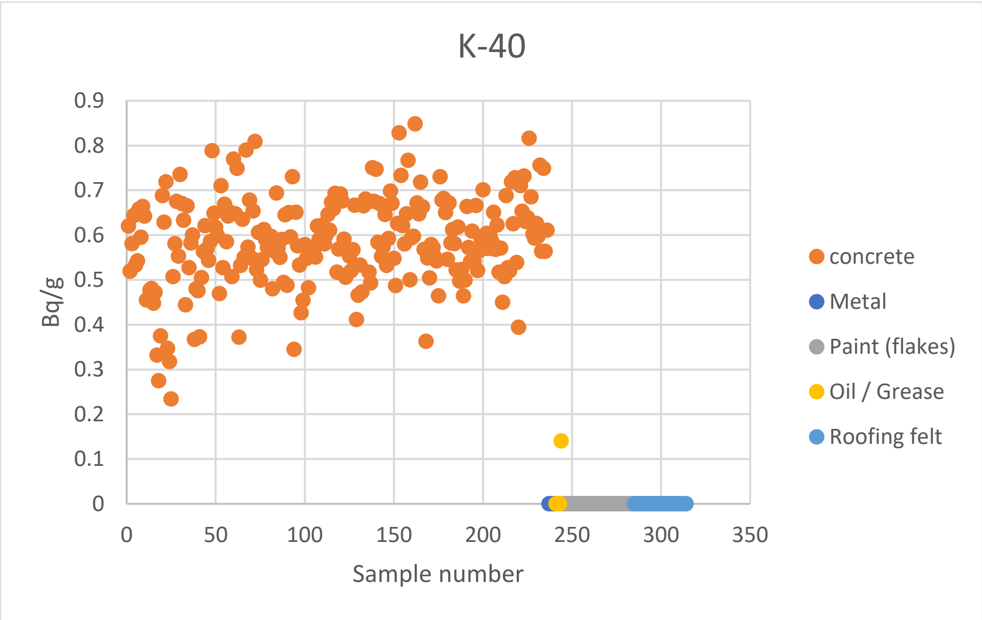


Figure 18 Variation in Ac-228 with sample type

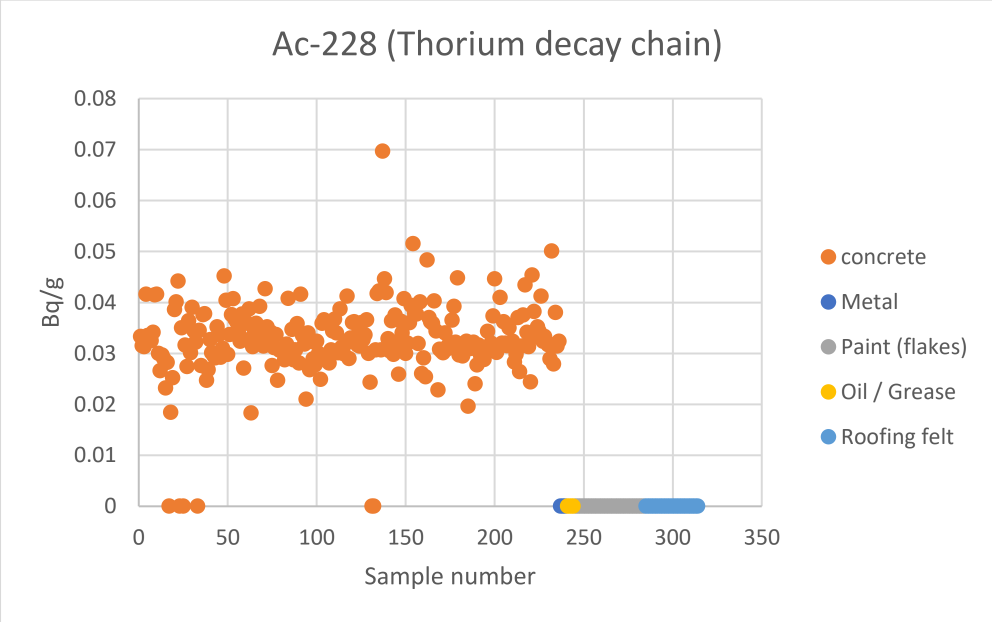


Figure 19 Variation in Bi-214 with sample type

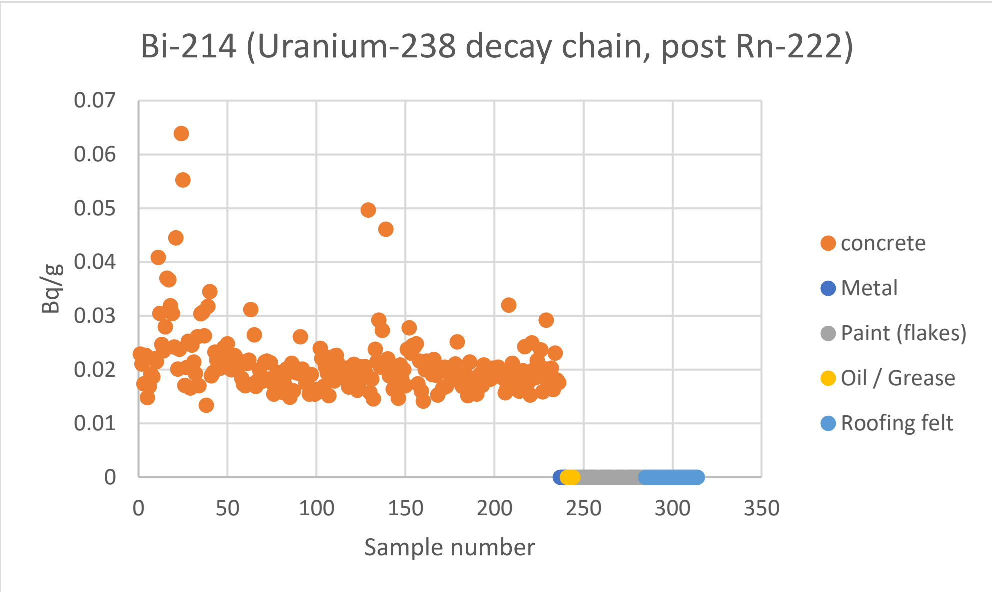
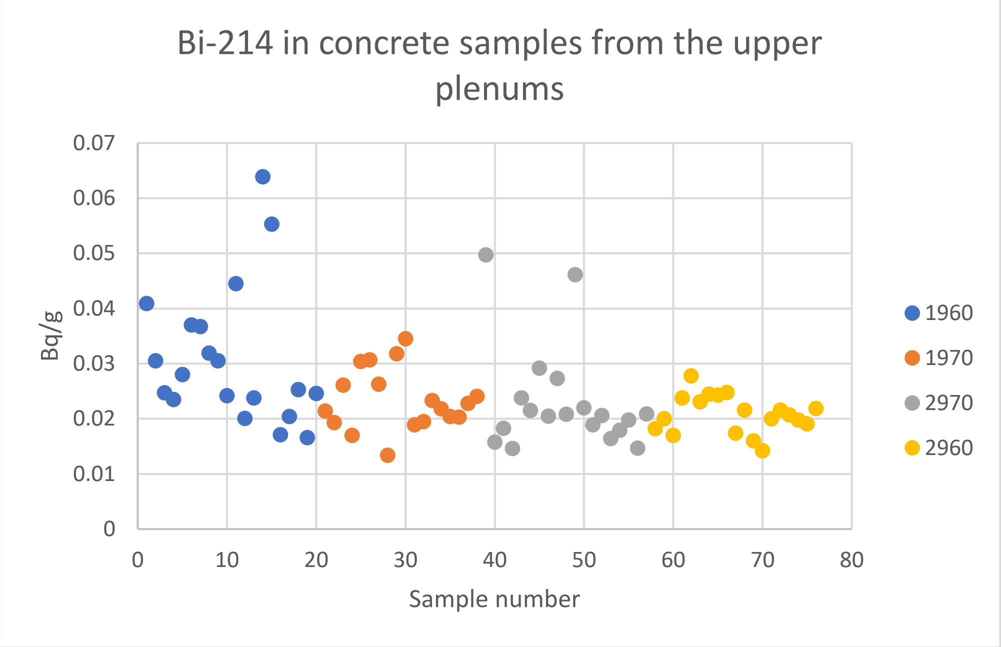


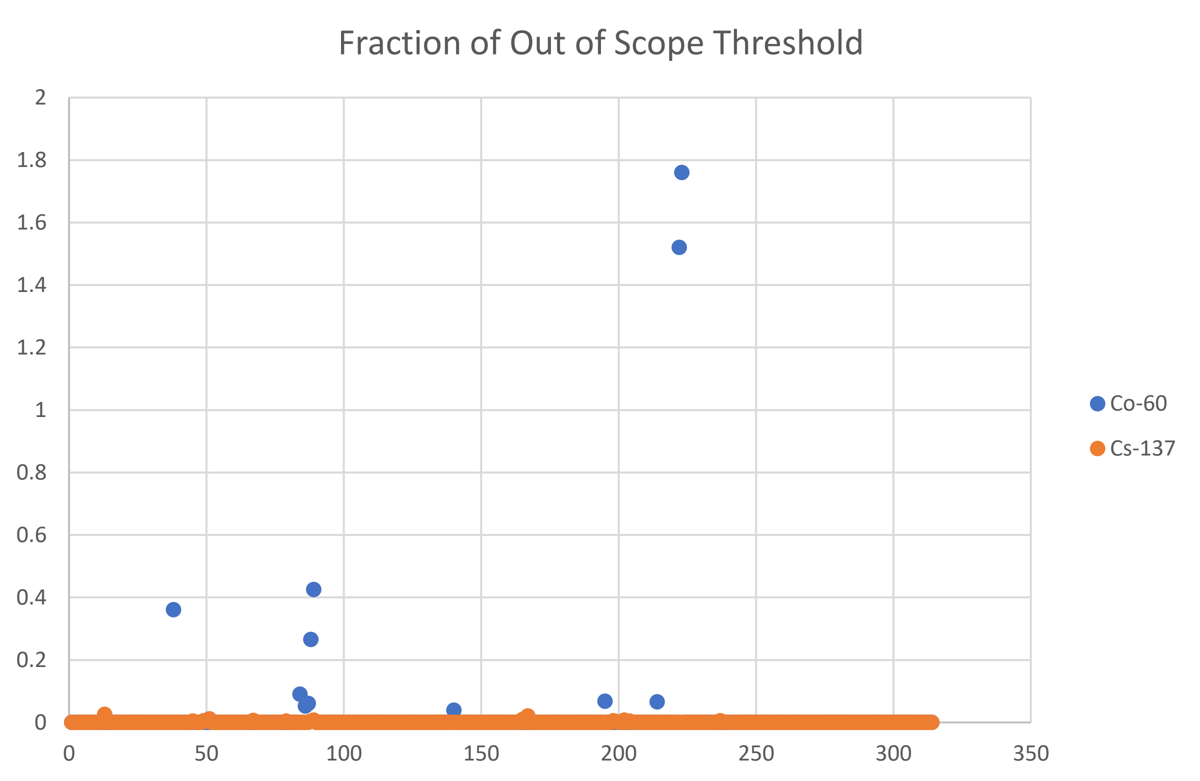
Figure 20 Bi-214 in concrete samples from the upper plenums (colour coding indicates the 4-digit codes assigned to the upper plenums in R1 and R2)



No anthropogenic radionuclides other than Co-60 and Cs-137 were detected above limits of detection in the samples. Figure 21 illustrates the measured values expressed as the fractions of the respective clearance thresholds, i.e. 0.1 Bq/g and 1 Bq/g.

Clearly, Cs-137 is well below the levels of regulatory interest, which is to be expected given that the contaminating source term in this case is derived from activation of core graphite and in-core furniture, and fuel failures at Trawsfynydd were relatively uncommon.

Figure 21 Cs-137 and Co-60 results, presented as the fraction of the respective clearance thresholds i.e. 1 Bq/g and 0.1 Bq/g



Positive measurements of Co-60 by HRGS are described in Table 4 below. The two highest instances of Co-60 (0.152 and 0.176 Bq/g) are associated with concrete samples from the high-level drainage channel (HLDC) within the upper plenum, area 2970 in R2. Most other instances where Co-60 was positively detected were also associated with concrete samples from high-level drainage channels.

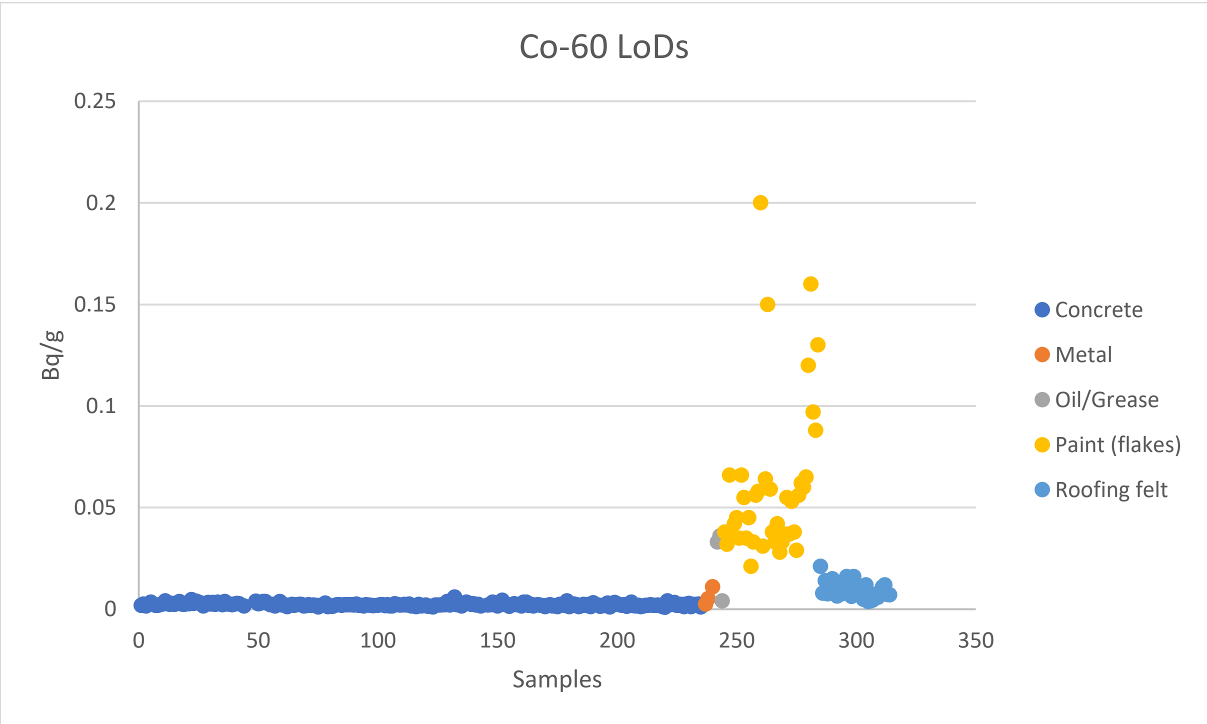
Table 4: Samples where Co-60 was positively identified by HRGS

Sample Ref	**Matrix**	**Location**	**Specific location**	**Co-60 (Bq/g)**
TRA/HR/2022/1605/232/O	Oil / Grease	R1 Shield Cooling Fan Room - South (upper)	FM auxilliary crane hook - on capping roof	0.036
TRA/HR/2022/1970/083/C	Concrete	R1 South Side Upper Plenum	Survey Grid 101	0.0090
TRA/HR/2022/1970/085/C	Concrete	R1 South Side High Level Drainage Channel	N/A	0.00525
TRA/HR/2022/1970/086/C	Concrete	R1 South Side High Level Drainage Channel	N/A	0.0060
TRA/HR/2022/1970/087/C	Concrete	R1 South Side High Level	N/A	0.0265

		Drainage Channel		
TRA/HR/2022/1970/088/C	Concrete	R1 South Side High Level Drainage Channel	N/A	0.0425
TRA/HR/2022/1605/196/C	Concrete	R1 Shield Cooling Fan Room - South (upper)	Survey Grid 43	0.00386
TRA/HR/2022/2652/132/M	Metal	R2 Hot Duct Cell - South Cct 8 (lower)	Bolt to gas duct	0.0067
TRA/HR/2022/2970/050/C	Concrete	R2 Upper Plenum	Survey Grid 45	0.0065
TRA/HR/2022/2970/061/C	Concrete	R2 North Side High Level Drainage Channel	N/A	0.152
TRA/HR/2022/2970/062/C	Concrete	R2 North Side High Level Drainage Channel	N/A	0.176

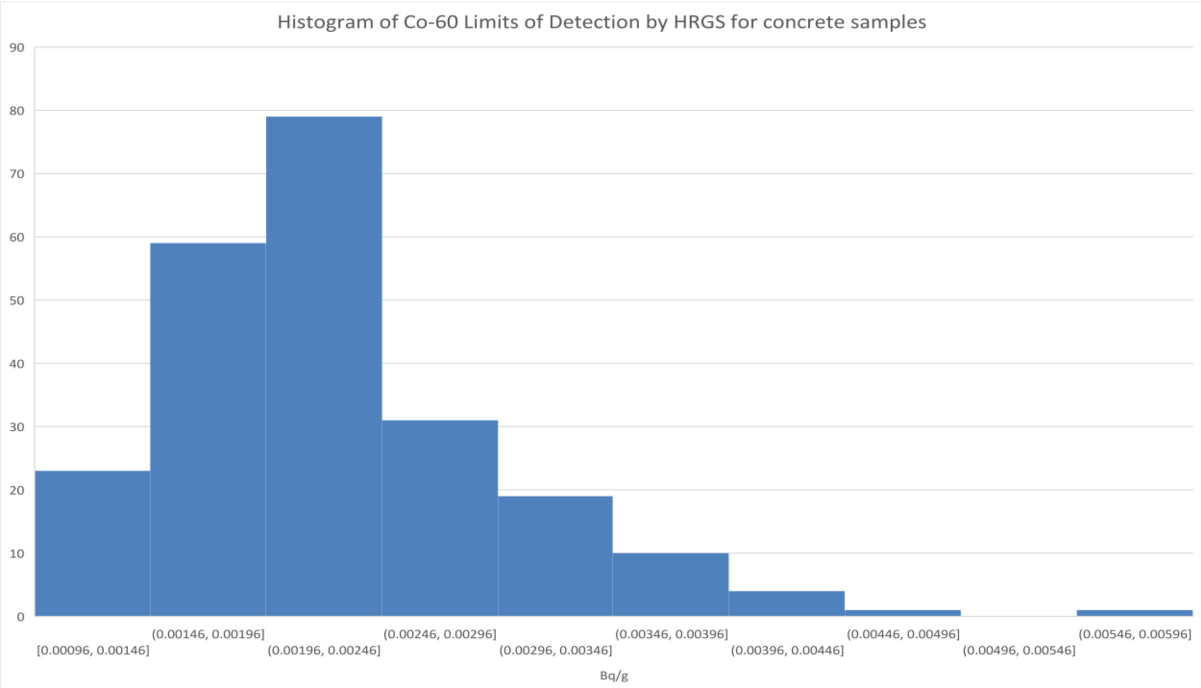
Co-60 was detected at 0.0067 Bq/g in the metal sample, which is close to the limit of detection for metal (average 0.006 Bq/g). Co-60 was also detected at 0.036Bq/g in one grease sample which is close to the limit of detection for grease (0.024 Bq/g).

Figure 22: Limits of detection for Co-60 by material type (raw samples, no bulking applied)



The positive Co-60 activities for the concrete samples not associated with HLDCs (0.0090, 0.00386 and 0.0065 Bq/g) are all close to the limit of detection, refer to the Figure 23 below for the profile of limits of detection.

Figure 23: Co-60 LoDs for concrete samples



For those samples where Co-60 was not measured above limits of detection (LoDs) the values of the LoDs were generally well below the threshold for clearance (0.1 Bq/g). LoDs expressed in Bq/g for paint scraping samples were relatively high however due to their low mass, illustrated in Figure 22.

Paint scraping samples were consequently bulked according to their originating location and reanalysed by HRGS successfully reducing the limit of detection and demonstrating that Co-60 activity in the bulk paint samples is sufficiently low to be of no regulatory interest (see Table 5).

Table 5: HRGS results for paint bulks

Paint Bulk #	**Samples included in the bulk**	**Co-60 result (Bq/g)**
1	TRA/HR/2022/1670/175/P	<0.0054
	TRA/HR/2022/1670/176/P	
	TRA/HR/2022/1670/177/P	
	TRA/HR/2022/1670/178/P	
	TRA/HR/2022/1670/179/P	
2	TRA/HR/2022/2670/175/P	<0.0052
	TRA/HR/2022/2670/176/P	
	TRA/HR/2022/2670/177/P	
	TRA/HR/2022/2670/178/P	
	TRA/HR/2022/2670/179/P	

7.2 Gross Alpha / Beta

7.2.1 Concrete, Paint, Metal and Oil Samples

Gross alpha and beta activities for the concrete, paint, metal and oil samples are presented in Figure 24, Figure 25 and Figure 26.

Positive measurement results were obtained for most samples, with MDAs only being reported for some paint samples and the metal samples. For metals, the average MDAs were 0.17, 0.20 and 0.29 Bg/g (gross alpha, gross beta (as C-14) and gross beta (as Co-60) respectively). For paint, the average MDAs were 0.20, 5.29 and 0.49 Bq/g (gross alpha, gross beta (as C-14) and gross beta (as Co-60) respectively). Most gross alpha and gross beta results were relatively low and near-normally distributed (see Figure 27, Figure 28 and Figure 29).

Inferred alpha activities from reference to the gamma spectrometry results (uranium and thorium decay series) compared reasonably well with the measured gross alpha figures: the ratios of inferred/measured activities for the dataset had a median value of 0.81.

There was one relatively high gross alpha result which related to concrete sample TRA/HR/2022/1610/182/C which was taken from a position at 1 metre height and 27.1 metres from the east wall of the R1 Charge Hall, adjacent to the 1762 Hot Duct Cell (see Figure 24).

Figure 24: Gross alpha activities (Bq/g) excluding the felt samples and minimum detectable activities

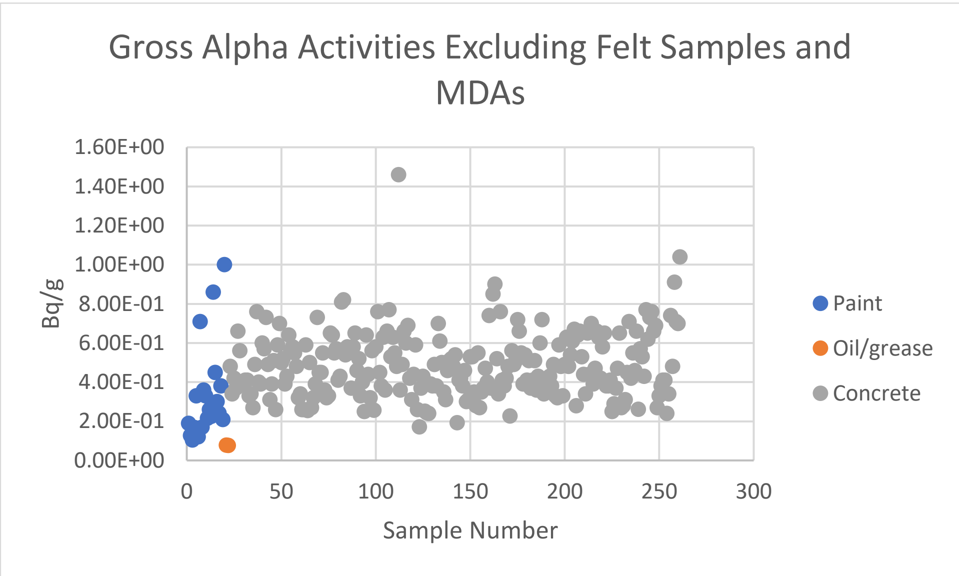


Figure 25: Gross beta activities as Co-60 (Bq/g) excluding the felt samples and minimum detectable activities

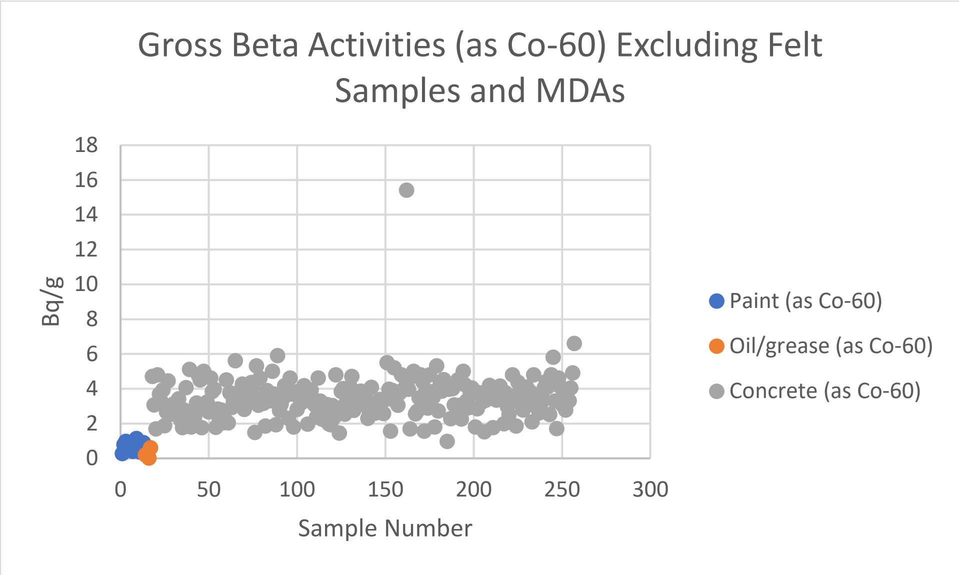
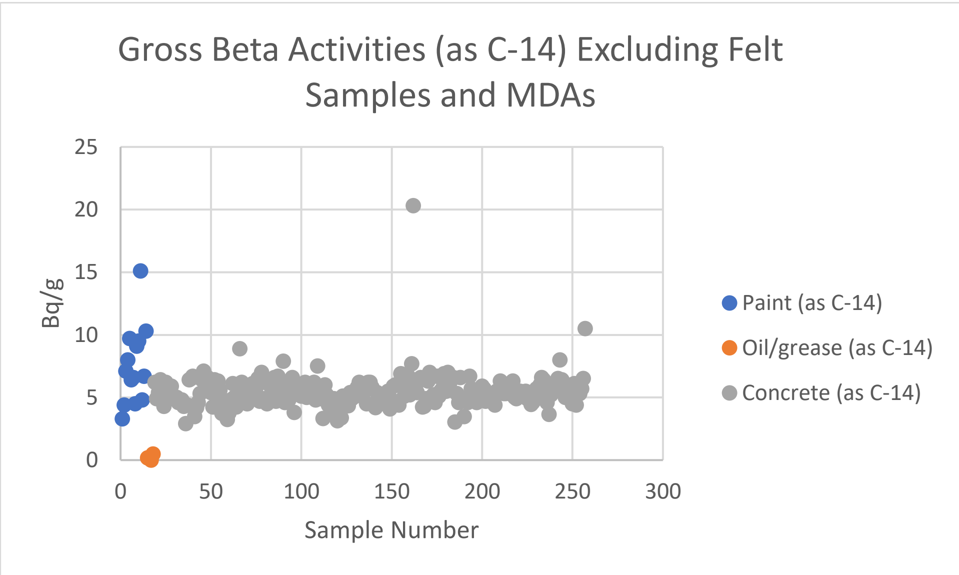


Figure 26: Gross beta activities as C-14 (Bq/g) excluding the felt samples and minimum detectable activities



Gross beta results were reported against C-14 and Co-60 as calibrants. Inferred beta activities from reference to the gamma spectrometry results (uranium and thorium decay series plus K-40 and Co-60) compared poorly with the gross beta activities measured as Co-60: the ratios of inferred /measured activities for the data set had a median value of only 0.24, suggesting a systematic bias likely due to the selection of calibration setting for the gross beta measurements. The lack of reconciliation for the gross beta measurements was investigated further for specific samples whose results were considered as outliers.

The gross beta activity (as C-14) reported at 15.1 Bq/g was obtained for paint sample TRA/HR/2022/2610/163/P which was taken from the north wall of the central bay in the R2 Charge Hall. The gross beta figures of 20.3 Bq/g (as C-14) and 15.4 Bq/g (as Co-60) were obtained for sample TRA/HR/2022/2970/062/C which was taken from the west side HLDC of R2.

Figure 27: Gross Alpha

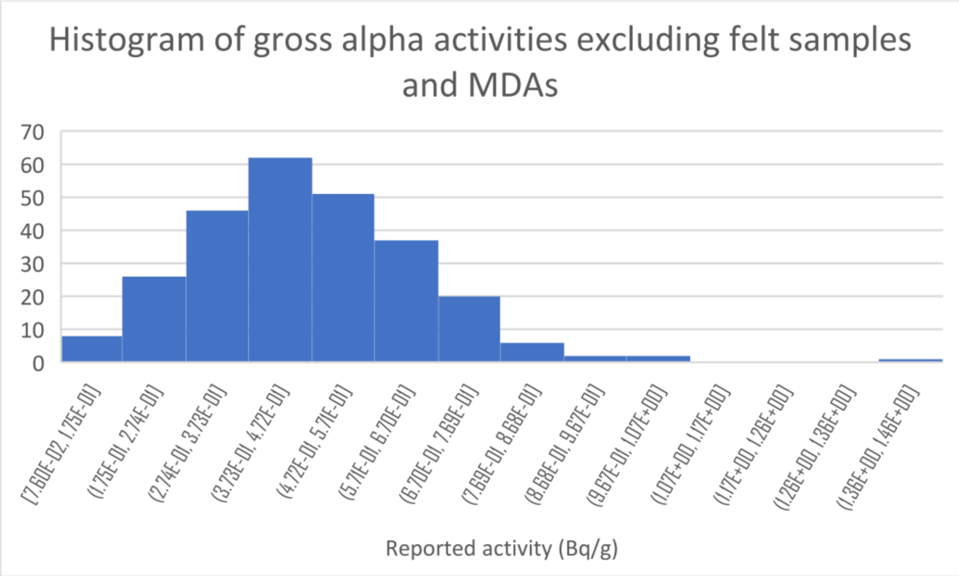


Figure 28: Gross Beta (calibrated as C-14)

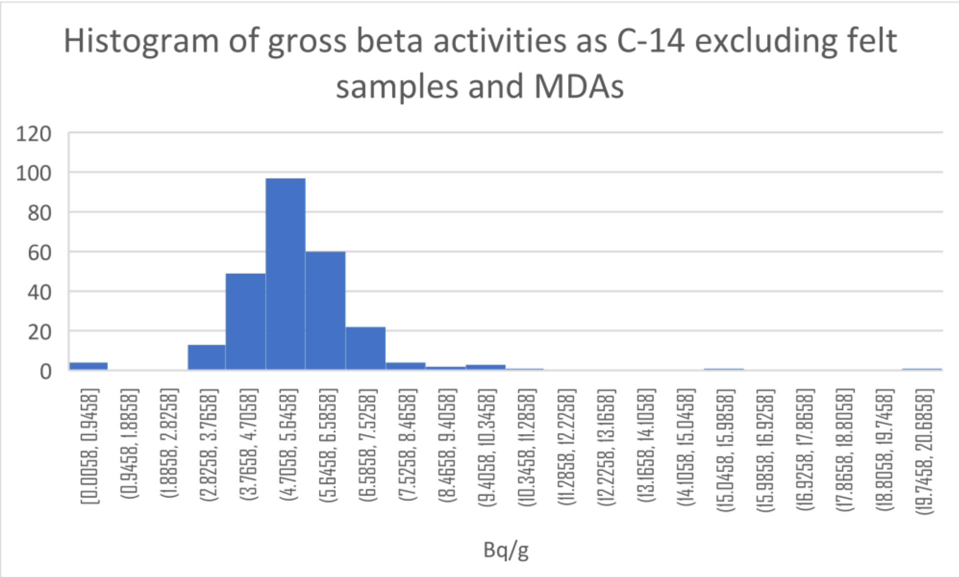
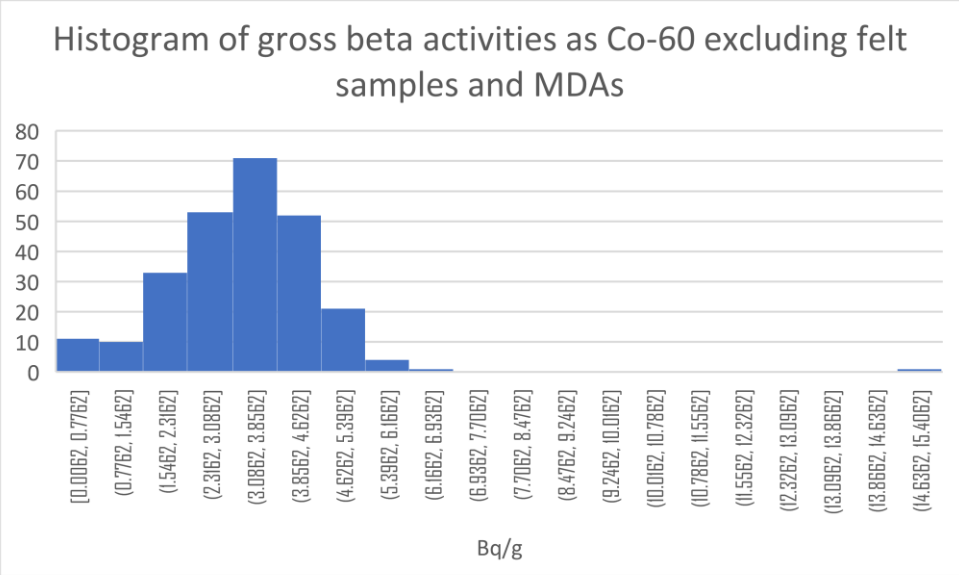


Figure 29: Gross Beta (calibrated as Co-60)



7.2.2 Roofing Felt Samples

The roofing felt samples were managed separately to determine gross alpha and beta activities. In total, 15 samples were randomly selected: 7 from R1 and 8 from R2. Their processing is described under Characterisation Execution (Section 5). Fibres, suspected of being chrysotile asbestos were observed in the R2 samples and for safety reasons no further work was carried out on them: these were later shown to be insoluble ash. Gross alpha/beta activity was measured on the ashed R1 sample residues. Gross alpha and beta activities for the felt samples are presented in Figure 30,

Figure 31 and Figure 32. Minimum detectable activities (MDAs) are shown as zero values on the charts. Gross alpha and beta results for the roofing felt samples were all low and did not indicate a significant pattern of activity that would prompt further analysis.

Figure 30: Gross alpha activities in felt samples

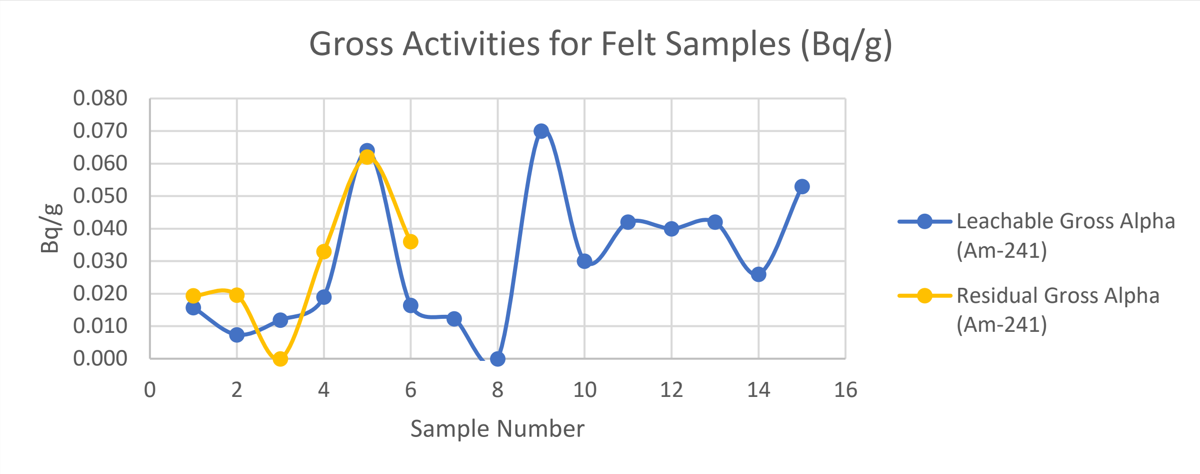


Figure 31: Gross beta activities (as C-14) in felt samples

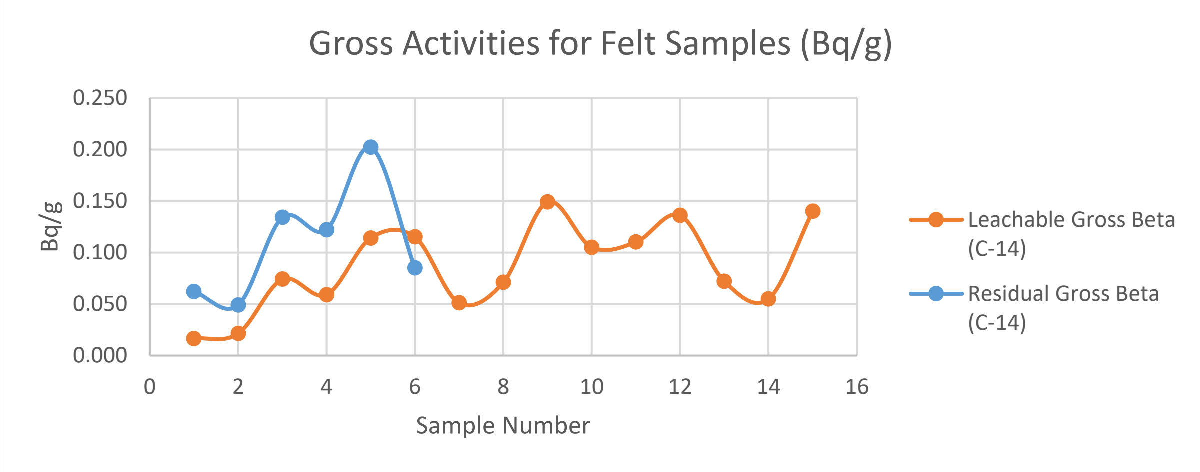
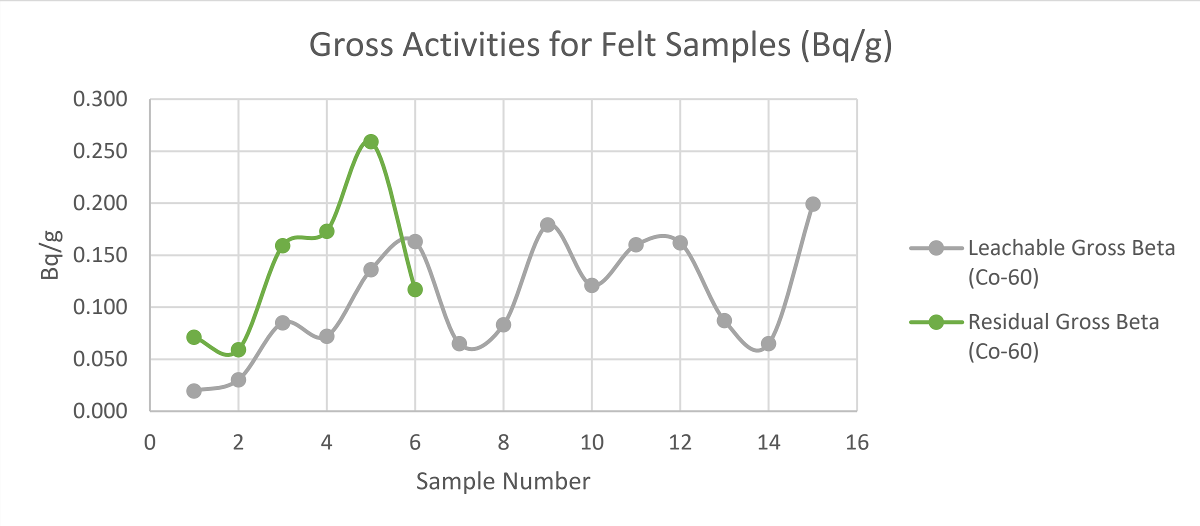


Figure 32: Gross beta activities (as Co-60) in felt samples



7.3 Tritium (H-3) and Carbon-14 (C-14)

H-3 and C-14 results for all sample types are presented in Figure 33 and Figure 34 respectively. Minimum detectable activities (MDAs) are shown as zero alues on the charts. The average and maximum H-3 MDAs were 0.24 Bq/g and 0.67 Bq/g.

In all cases, H-3 and C-14 activities are well below the thresholds for clearance: 100 Bq/g for H-3 and 10 Bq/g for C-14. MDAs are suitably low. There are 4 x samples where H-3 activities are significantly higher than the others, between 2.2 and 5.2 Bq/g and these are associated with samples taken from area 1970, specifically around the HLDC of the R1 south stack. The two slightly elevated C-14 results (0.6 and 0.67 Bq/g) were associated with samples taken from area 1960, the R1 north Upper Plenum: their reported activities are well below the clearance threshold for C-14 and these samples aren't associated with any other elevated activities.

Figure 33: H-3 activities (Bq/g)

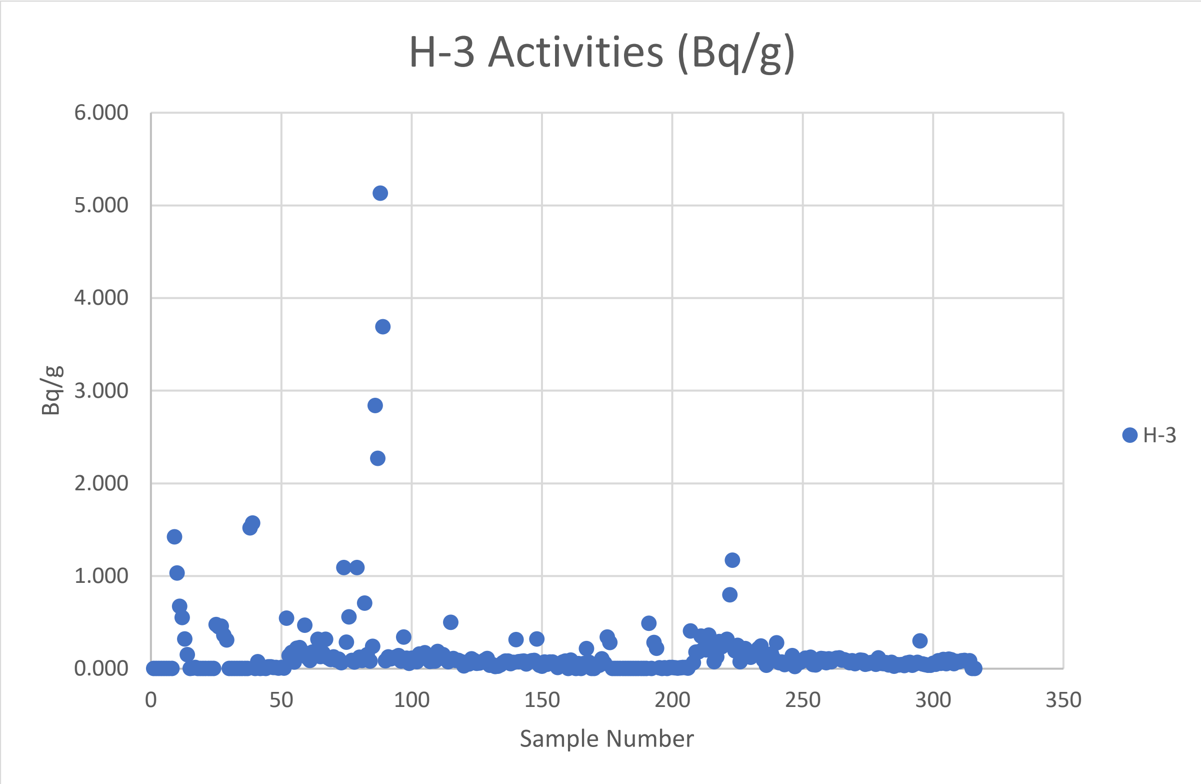
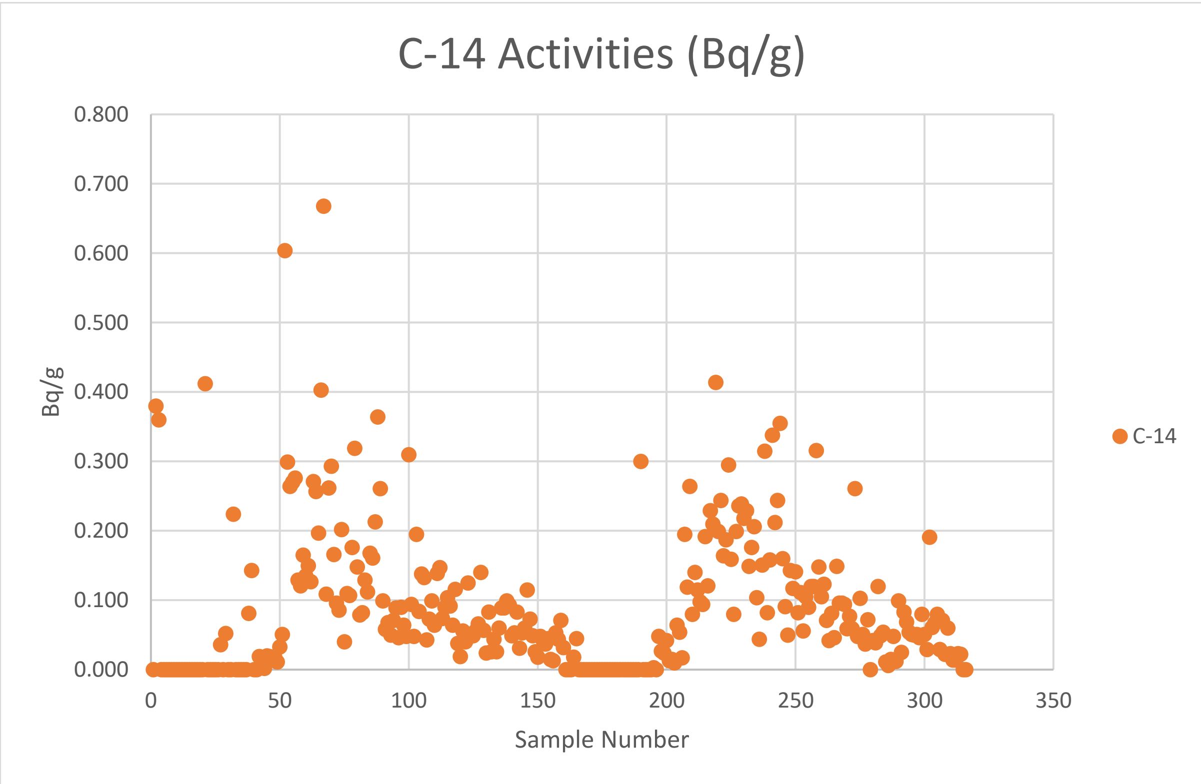


Figure 34: C-14 activities (Bq/g)



7.4 Non-radiological Analytes

Samples were analysed to determine whether the roofing felt contained coal tar that would require it to be classified as Hazardous Waste for the purpose of disposal. The laboratory segregated the black material from samples of the roofing felt and tested for the standard 16 PAHs identified as priorities for assessment by the US EPA plus coronene by gas chromatography mass spectrometry (GC-MS); and phenols (as tri-methyl, di-methyl and methyl phenols plus phenol itself) by high performance liquid chromatography ultraviolet spectroscopy (HPLC UV). In all cases, individual analytes within the PAH suite were all determined below limits of detection with the exception of one result at 1 mg/kg for benzo[a]anthracene (BaP). On the basis that total PAH was consistently below 200 mg/kg and BaP was <10% of the total PAHs the roofing felt was not deemed to contain coal tar and hence a Non-Hazardous waste classification (European Waste Code 17 03 02 Bituminous Mixtures Other than those mentioned in 17 03 01) is recommended [xxi].

A selection of fourteen of the concrete samples were taken from areas with dark staining, suspected to be oil. In addition to radiochemical tests, these were also tested for the standard 16 PAHs and for total petroleum hydrocarbons (TPH, C6 – C40). In all cases, individual PAH analytes were determined below limits of detection. Results for TPH analysis varied between 32 and 4,900 mg/kg (i.e. a maximum of 0.49%). All of the samples tested were considered Non-Hazardous for oil because nine of them had BaP/TPH ratios of <0.01% and the other five had TPH results far below the threshold of 1,000 mg/kg [xxii].

10 of the concrete samples were chosen to test acid-soluble sulfate content. The results varied between 2690 and 7210 mg/kg. The relevance of this to on-site applications for the concrete to be removed by the Height Reduction project remains to be determined.

12 paint samples were analysed for their lead content. Results varied between 60 and 410 mg/kg (i.e. a maximum of 0.04%). At these levels, the lead content of the paint is considered Non-Hazardous.

7.5 Summary of Phase 1 Analytical results

The majority of the samples did not indicate anthropogenic activity above limits of detection (LoD) by gamma spectrometry and LoDs were suitably lower than the corresponding clearance thresholds defined within EPR. In a few cases, anthropogenic activity was positively measured by gamma spectrometry in building materials, however this was mostly close to LoD and well beneath EPR clearance thresholds. The exception was the area around the HLDC in 2970 where concrete samples contained Co-60 slightly in excess of the 0.1 Bq/g limit under EPR.

Tritium results were mostly distributed around a low limit of detection: maximum tritium activity concentrations, observed in area 1970 were only 5% of the EPR clearance threshold.

There were more positive measurement results for C-14 than tritium, with the highest of these corresponding to area 1960, the R1 north upper plenum. The highest of the C-14 results was 7% of the EPR clearance threshold.

With certain exceptions, gross alpha and gross beta results were low and near-normally distributed, therefore not prompting further investigation. Slightly elevated activities were associated with a small number of samples only. Notably, the highest gross beta figure was associated with area 2970 where gamma spectrometry had identified Co-60 in excess of the EPR threshold.

Over the majority of the safestore structures within the scope of the Height Reduction project, phase 1 analysis was consistent with the project's expectation of categorisation as Out of Scope. Samples from the HLDC on the R2 south stack were above Out of Scope thresholds, and elevated activity (albeit relatively low levels of tritium) was observed on the equivalent location of the R1 north stack. The stacks were anticipated within the DQO report to have higher potential for contamination.

8. Further sampling and analysis work prompted by review of phase 1 analytical data and survey results

Further sampling was carried out in response to the review of phase 1 analytical results which identified localised activity in the vicinity of the R2 North HLDC. Table 6 and Table 7 describe the sample types and where they were collected. On-site HRGS results are interpreted to be semi-quantitative only due to differences between the calibration geometry and the form of the samples. The HRGS results were used as an early indication of the likely nature and quantities of activity in the samples and to inform transport and receipt of the samples by the laboratory.

Whereas phase 1 analysis had positively identified Co-60 and Cs-137 activity in samples from the upper plenum and area around the HLDC in location 2970, no further analysis was undertaken on those particular samples. Instead, the new samples of debris (a granular material) recovered from each of the 4 sides of the 2970 HLDC were submitted for phase 1 and phase 2 analysis on the basis that:

- The contaminating mechanism would have been the same (i.e. surface deposition of activation products carried in the air extracted from the void between reactor pressure vessel and bioshield). This also would have been the same for the upper plenum and shield cooling fan rooms.
- Surface deposited radionuclides on the inner walls of the stack would have been gradually washed down to the HLDC where they would have concentrated. Indeed, activity concentrations in the debris were higher than in the concrete samples of the stack walls.
- Having established the presence of contamination in and around the HLDC the purpose of further analysis was to determine the nature of the activity, and the higher concentrations of activity in the debris would provide lower relative uncertainties in the measurement data.

Table 8 presents the analysis techniques requested on the new samples in the vicinity of area 2970, plus additional samples that were collected in response to apparent elevated count rates during initial radiological survey throughout the zones (refer to Table 3). The rationale for additional analysis is also presented in Table 8.

Additionally, further analyses were requested for selected samples following review of their phase 1 analytical results. The samples selected for additional analysis, the analytical techniques requested and their rationale are presented in Table 9.

Table 6: Further Sampling (Area 2970): Samples of materials

Sample	**Positively identified anthropogenic activity measured by on-site HRGS (Bq/g)**
Debris from 2970 HLDC (west Side)	Co-60: 1.792 Cs-137: 0.04602
Debris from 2970 HLDC (east Side)	Co-60: 9.077 Cs-137: 0.0832 Eu-154: 0.03393
Debris from 2970 HLDC (north Side)	Co-60: 5.006 Cs-137: 0.1567 Eu-154: 0.02833
Debris from 2970 HLDC (south Side)	Co-60: 1.493 Cs-137: 0.0605
Concrete from area 6 to 8 " above the HLDC where the highest count-rate was recorded after re-surveying	Co-60: 0.363
Concrete from 2970 grid square 45 at site of previously collected sample TRA/HR/2022/2970/050/C	Co-60: 0.03454

Table 7: Further Sampling (Area 2970): Swabs

Sample	**Positively identified anthropogenic activity measured by on-site HRGS (Bq/sample)**
Taki swab from 2970 HLDC (north side)	Co-60: 60.6
Taki swab from 2970 HLDC (east side)	Co-60: 99.02
Taki swab from 2970 HLDC (south side)	Co-60: 23.87
Taki swab from 2970 HLDC (west side)	Co-60: 19.6
Damp filter paper swab from area 6 to 8 " above the HLDC where the highest count-rate was recorded after re-surveying	Co-60: 5.472
Damp filter paper swab from exposed concrete at the location of previous sample in 2970 grid square 45 TRA/HR/2022/2970/050/C	Co-60: < 0.175
Taki swab from 2970 grid square 45 TRA/HR/2022/2970/050/C	Co-60: 5.689

Table 8: Phase 1 and phase 2 analysis required for additional samples

Rationale	Sample type	Location	Sample ID	HRGS	Gross beta & alpha*	H-3 & C-14	Cl-36	Fe-55 & Ni-63	Sr-90
In-situ surveys indicated elevated gamma counts. Need to confirm if there is anthropogenic activity associated with the concrete.	Concrete	Boiler box 1751 grid square 36	TRA-HR-2022-1751-AS1-C	✓					
		Boiler box 1751 grid square 49	TRA-HR-2022-1751-AS2-C	✓					
		Boiler box 1752 grid square 52	TRA-HR-2022-1752-AS3-C	✓					
		Boiler box 1752 grid square 41	TRA-HR-2022-1752-AS4-C	✓					
		Top duct 1901 grid square A2	TRA-HR-2022-1901-AS5-C	✓					
		Top duct 1951 grid square A1	TRA-HR-2022-1951-AS7-C	✓					
		Boiler box 2752 grid square 27	TRA-HR-2022-2752-AS8-C	✓					
		NW stairs 2071	TRA-HR-2022-2071-AS12-C	✓	✓	✓	✓	✓	
	Taki rag	Boiler box 1751 grid square 36	TRA-HR-2022-1751-AS1-T	✓					
		Boiler box 1751 grid square 49	TRA-HR-2022-1751-AS2-T	✓					
		Boiler box 1752 grid square 52	TRA-HR-2022-1752-AS3-T	✓					
		Boiler box 1752 grid square 41	TRA-HR-2022-1752-AS4-T	✓					
		Top duct 1901 grid square A2	TRA-HR-2022-1901-AS5-T	✓					
		Top duct 1951 grid square A1	TRA-HR-2022-1951-AS7-T	✓					
		Boiler box 2752 grid square 27	TRA-HR-2022-2752-AS8-T	✓					
		NW stairs 2071	TRA-HR-2022-2071-AS12-T	✓	✓	✓	✓	✓	
In-situ surveys indicated elevated beta counts. Need to establish the nature of beta activity.	Concrete	Top duct 1901 grid square 50	TRA-HR-2022-1901-AS6-C	✓	✓	✓	✓	✓	
		Shield cooling fan room 2771 grid square 27	TRA-HR-2022-2771-AS9-C	✓	✓	✓	✓	✓	
	Taki rag	Top duct 1901 grid square 50	TRA-HR-2022-1901-AS6-T	✓	✓	✓	✓	✓	
		Shield cooling fan room 2771 grid square 27	TRA-HR-2022-2771-AS9-T	✓	✓	✓	✓	✓	
In-situ surveys indicated this is an area of potential	Concrete	Location 6 to 8 “ above high level drainage channel 2970 east side	TRA-HR-2022-2970-AS10-C	✓	✓	✓	✓	✓	
	Taki rag		TRA-HR-2022-2970-AS10-T	✓	✓	✓	✓	✓	
	Swab		TRA-HR-2022-2970-AS10-S	✓					

Rationale	Sample type	Location	Sample ID	HRGS	Gross beta & alpha*	H-3 & C-14	Cl-36	Fe-55 & Ni-63	Sr-90
contamination. Need to establish the nature of contamination.									
Co-60 positively identified in concrete from this location.	Concrete	2970 Upper plenum grid square 45 at site of previously collected sample TRA/HR/2022/2970/050/C	TRA-HR-2022-2970-AS11-C	✓					
	Taki rag		TRA-HR-2022-2970-AS11-T	✓					
	Swab		TRA-HR-2022-2970-AS11-S	✓					
To provide data for deriving a contamination fingerprint	Miscellaneous debris	High level drainage channel 2970 north side	TRA.HR.2022.2802.north.debris	✓	✓	✓	✓	✓	✓
		High level drainage channel 2970 east side	TRA.HR.2022.2802.east.debris	✓	✓	✓	✓	✓	✓
		High level drainage channel 2970 south side	TRA.HR.2022.2802.south.debris	✓	✓	✓	✓	✓	✓
		High level drainage channel 2970 west side	TRA.HR.2022.2802.west.debris	✓	✓	✓	✓	✓	✓
			Totals	**30**	**12**	**12**	**12**	**12**	**4**

Table 9: Phase 2 analysis required for pre-existing samples

Sample identifiers ending: C = concrete; O = oil; M = metal; P = paint

Rationale	Sample location	Sample ID	Cl-36	Fe-55 / Ni-63	Actinides	Lead (Pb)
Samples with positive measurements within Phase One analysis						
Co-60 positively detected by HRGS. Want to determine levels of any other radionuclides that might be present in order to make an assessment against EPR limits	R1 South Shield Cooling Discharge Stack (upper drainage channel)	TRA/HR/2022/1970/085/C TRA/HR/2022/1970/086/C TRA/HR/2022/1970/087/C TRA/HR/2022/1970/088/C Combine equivalent masses of these samples and conduct phase 2 analysis on the bulk sample	✓	✓		
	R1 Shield Cooling Fan Room - South (upper)	TRA/HR/2022/1605/232/O	✓	✓		
	R2 Hot Duct Cell - South Cct 8 (lower)	TRA/HR/2022/2652/132/M		✓		
High Bi-214 in upper plenum samples	R1 North Upper Plenum	TRA/HR/2022/1960/057/C	✓	✓	✓ [3]	

[3] Uranium isotopes (U-234, U-235/236, U-238)

<table>
<tr><th>Rationale</th><th>Sample location</th><th>Sample ID</th><th>Cl-36</th><th>Fe-55 / Ni-63</th><th>Actinides</th><th>Lead (Pb)</th></tr>
<tr><td>Want to confirm the gamma spec result and confirm that alpha profile is consistent with NORM</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Elevated gross alpha count-rate not correlated with gamma spec data. Need to confirm gross alpha measurement and establish the nature of alpha activity.</td><td>R1 Charge Hall concrete</td><td>TRA/HR/2022/1610/182/C</td><td></td><td></td><td>✓ [3, 4, 5, 6, 7]</td><td></td></tr>
<tr><td rowspan="5">Elevated gross beta count-rates not correlated with gamma spec data. Need to confirm gross beta measurements and establish the nature of beta activity</td><td>R2 Charge Hall</td><td>TRA/HR/2022/2610/163/P</td><td>✓</td><td>✓</td><td></td><td></td></tr>
<tr><td>R2 Charge Hall</td><td rowspan="4">TRA/HR/2022/2610/146/P
TRA/HR/2022/2610/158/P
TRA/HR/2022/2610/161/P
TRA/HR/2022/2670/171/P</td><td rowspan="4">✓</td><td rowspan="4">✓</td><td rowspan="4"></td><td rowspan="4"></td></tr>
<tr><td>R2 Charge Hall</td></tr>
<tr><td>R2 Charge Hall</td></tr>
<tr><td>R2 Maintenance Bay East</td></tr>
</table>

[4] Thorium isotopes (Th-232, Th-230, Th-228)
[5] Plutonium isotopes (Pu-238, Pu-239/240, Pu-241)
[6] Curium isotopes (Cm-242, Cm-243/244)
[7] Americium-241

Rationale	Sample location	Sample ID	Cl-36	Fe-55 / Ni-63	Actinides	Lead (Pb)
		Combine equivalent masses of these samples and conduct phase 2 analysis on the bulk sample				
Additional analyses to understand levels of radionuclides and chemical analytes not analysed during phase 1.						
To gather further evidence to bound levels of potential metal activation.	R1 bolt to gas duct	TRA/HR/2022/1651/134/M		✓		
No evidence of elevated activity. Sample bulks prepared to investigate levels of activation over relevant material types and zones for key activation nuclides.	R1 Roof concrete	TRA/HR/2022/1E91/026/C TRA/HR/2022/1E91/034/C TRA/HR/2022/1E91/037/C Combine equivalent masses of these samples and conduct phase 2 analysis on the bulk sample	✓	✓		
	R2 Charge hall concrete	TRA/HR/2022/2610/181/C TRA/HR/2022/2610/182/C TRA/HR/2022/2610/183/C TRA/HR/2022/2610/184/C	✓	✓		

Rationale	Sample location	Sample ID	Cl-36	Fe-55 / Ni-63	Actinides	Lead (Pb)
		Combine equivalent masses of these samples and conduct phase 2 analysis on the bulk sample				
	R2 Boiler Boxes / Hot Gas Duct Cells concrete	TRA/HR/2022/2601/099/C TRA/HR/2022/2602/100/C TRA/HR/2022/2507/118/C TRA/HR/2022/2508/120/C Combine equivalent masses of these samples and conduct phase 2 analysis on the bulk sample	✓	✓		
To provide lead analysis for all paint types within Charge Hall	R1 Charge Hall	TRA/HR/2022/1610/167/P				✓
	R2 Charge Hall	TRA/HR/2022/2610/154/P				✓
		Totals	**8**	**10**	**2**	**2**

9. Review of Laboratory Analytical Results for Additional Samples plus phase 2 Analytical Results of existing samples

9.1 Analysis of additional samples as per Table 8

9.1.1 Sampling prompted by elevated gamma counts measured by in-situ surveys.

HRGS data for the 8 concrete samples from boiler boxes 1751, 1752 and 2752; top duct areas 1901 and 1951; and NW stairs 2071 revealed evidence of low levels of potassium-40, thorium and uranium decay products consistent with naturally occurring radioactive materials (NORM), as per previous concrete samples. Limits of detection were all suitably low (e.g. Co-60 limit of detection reported at around 0.0025 Bq/g). There was only one positive identification of man-made activity (Eu-155 0.0058+/-0.0017 Bq/g for sample TRA-HR-2022-1901-AS5-C from Top duct 1901 grid square A2) which is a factor of 170 lower than the corresponding EPR limit.

HRGS limits of detection were generally higher for the taki swab samples taken from the same locations as the concrete samples (e.g. Co-60 Limit of detection reported at around 0.23 Bq/sample). There were only two positive radionuclide identifications: 0.293 Bq/sample Co-60 in sample TRA-HR-2022-1951-AS7-T from Top duct 1951 grid square A1; and 0.47 Bq/sample Co-60 in sample TRA-HR-2022-2752-AS8-T from Boiler box 2752 grid square 27. Both of these taki swabs were collected to assess surface activity in the concrete, and assuming a 10% pick-up factor, the higher taki swab result for Co-60 translates as 0.47 Bq/m^2 x 10/10,000 = 0.00047 Bq/cm^2 which is around a factor of 2000 below the 1 Bq/cm^2 surface clearance threshold for Co-60 defined in RP113.

For concrete sample TRA-HR-2022-2071-AS12-C the gross alpha/beta, H-3 and C-14 activities were reported at 0.91, 3.3 (calibrated as Co-60), 0.037 and 0.118 Bq/g respectively. Cl-36, Fe-55 and Ni-63 were all reported as less than appropriately low limits of detection. The gross activity measurements were consistent with the rest of the concrete samples, indicating activity due to NORM only. The analytical results indicate material well below the OoS upper threshold with no explanation for the apparently elevated gamma activity at this location (NW stairs 2071).

For taki rag sample TRA-HR-2022-2071-AS12-T the gross alpha/beta, and C-14 activities were reported at 0.29, 1.82 (calibrated as Co-60) and 1.77 Bq/sample respectively. H-3, Cl-36, Fe-55 and Ni-63 were all reported as less than appropriately low limits of detection. The gross activity measurements were not considered anomalous. As with the concrete sample from the same location (TRA-HR-2022-2071-AS12-C), the taki swab did not indicate activity above the OoS threshold.

In summary, samples were taken from areas where in-situ survey indicated elevated gamma count-rates. Analysis did not identify any activity which challenged the limits for radiological clearance of materials from those areas. It is therefore concluded that the elevated count-rates were likely due to other factors such as shine from another part of the building rather than the materials being characterised.

9.1.2 Sampling prompted by elevated beta counts measured by in-situ surveys

HRGS data for the two concrete samples taken from top duct 1901 and Shield Cooling Fan Room 2771 did not indicate any man-made activity: only thorium and uranium decay products consistent with NORM, as per previous concrete samples.

HRGS limits of detection for the taki rag samples were similar to those above. Only one radionuclide was positively identified: Co-60 at 0.64 Bq/sample for sample TRA-HR-2022-1901-AS6-T from Top duct 1901 grid square 50. As with the swabs above, this result is considerably below the level for surface clearance defined in RP113.

H-3 and C-14 results for the two concrete samples were all low: maximum results of 0.086 and 0.7 Bq/g respectively. Gross alpha and beta measurements were low and consistent with NORM. All other determinands were reported as less than appropriately low limits of detection.

The taki rag sample TRA-HR-2022-1901-AS6-T from Top duct 1901 grid square 50 was reported as having H-3 and C-14 at 4.6 and 5.8 Bq/sample respectively. Gross alpha and beta activities were low and consistent with other taki rags from areas where contamination was not indicated. All other determinands were reported as below suitably low limits of detection.

In summary, there is no evidence of activity above limits for clearance in the area of the Shield Cooling Fan Room with elevated beta count rates. The samples from Top Duct 1961 confirmed Co-60, H-3 and C-14 as the dominant radionuclides present as a surface layer only. Whereas this surface layer of activity is consistent with surface (Bq/cm^2) and bulk (Bq/g) clearance thresholds, the fact that it could be further reduced by simple wiping needs to be considered in the overall scheme for the Height Reduction project.

9.1.3 In-situ surveys indicated an area of potential contamination (Area 2970 HLDC)

HRGS analysis of concrete sample TRA-HR-2022-2970-AS10-C indicated Co-60 and Eu-152 at 0.508 and 0.0177 Bq/g respectively. Co-60 was a factor of 5 times greater than its corresponding EPR limit, consistent with the previous identification of activity in this area. The gross beta measurement (6.6 Bq/g calibrated as Co-60) was slightly higher than typical gross beta measurements for concrete samples consistent with the activities reported by HRGS. Positive results were reported for H-3, C-14, Cl-36 and Fe-55: 3.2, 0.50, 0.97 and 0.13 Bq/g respectively. Ni-63 was reported at less than a suitably low limit of detection.

Co-60 was also positively identified in the taki rag and swab samples (5.93 Bq/sample and 7.43 Bq/sample). Whereas the taki rag sample indicated surface activity well below the surface clearance limits, the swab represented a much smaller area (precise area unknown). The taki and swab results are not comparable since the swab utilised a moistened filter paper.

Considerable positive activities for H-3, C-14, and Cl-36 were reported for the taki rag sample: 234, 39.8, 6.4 Bq/sample respectively; however both Fe-55 and Ni-63 were reported as less than low limits of detection. The enhanced gross beta activity (11.4 Bq/sample as Co-60) was consistent with the Co-60 activity reported by HRGS, and the nature of the reported radionuclides was consistent with provenance.

In summary, samples from this particular location relative to the HLDC in area 2970 confirmed the presence of activity above clearance thresholds. The activity is largely confined to the surface of the concrete, but its significance would need to be considered carefully when planning decommissioning activities in this area. The results for these particular samples should not be read in isolation from other analytical data for area 2970 (see below)

9.1.4 Co-60 positively identified in concrete from 2970 upper plenum

HRGS analysis of concrete sample TRA-HR-2022-2970-AS11-C indicated Co-60 at 0.0264 Bq/g, that is, below the corresponding EPR limit. For reference, the previous sample from this grid square (TRA/HR/2022/2970/050/C) had a reported Co-60 activity of 0.0065 Bq/g.

Co-60 and Eu-152 were positively identified in the taki rag sample TRA-HR-2022-2970-AS10-T at 97.9 and 2.5 Bq/sample. Assuming a 10% pick-up factor for each radionuclide these levels of activity are equivalent to the surface clearance limit for Co-60, but lower than the limit for Eu-152.

The data indicate levels of activity at the surface of the concrete walls in area 2970 which, although below the specific activity levels indicated in EPR, are at the limit for surface clearance. While it could be argued that demolition activities would reduce all of the concrete in this area to rubble, effectively averaging any activity over a larger volume, the sample results suggest it may be beneficial to consider the benefits of surface decontamination when planning decommissioning activities.

9.1.5 Sampling for the purpose of deriving a contamination fingerprint (Area 2970)

Four samples of the debris in the HLDC at area 2970 were removed from each of the four sides. This was taken to represent accumulation of activity that had dripped down the inner walls of the ducts and was therefore representative of the contaminating source term.

HRGS analysis identified Co-60 (Max 9.07, Min 1.47, Average 4.82 Bq/g); Ag-108m (Max 0.0635, Min 0.0164, Average 0.0358 Bq/g); Cs-137 (Max 0.083, Min 0.046, Average 0.067 Bq/g); and Eu-152 (0.233, Min 0.111, Average 0.171 Bq/g). Limits of detection for naturally occurring radionuclides were generally higher than for concrete samples, most notably Pb-210, where a positive measurement of 0.334 Bq/g was noted for sample TRA-HR-2022-2802.west.debris, however this was an order of magnitude higher than the corresponding limits of detection for Pb-214 and Bi-214 and therefore not deemed to be credible.

For each of the samples, positive results were reported for H-3, C-14, Cl-36, Fe-55 and Sr-90, with H-3 and C-14 being the dominant radionuclides (see Table 10). The samples from the east and south walls had significant Cl-36 activity (8.4 and 19 Bq/g respectively) and relatively low positive results for Ni-63: Ni-63 was reported below suitably low limits of detection for the other samples. Gross alpha results were low and broadly consistent with results for concrete samples. Gross beta results calibrated as C-14 were consistent with reported C-14 activities. Gross beta results calibrated as Co-60 clearly had some contribution from Cl-36 and were not directly comparable.

Alpha spectrometry was not undertaken on these samples since previous analyses on samples from around the HLDC had not indicated elevated alpha activity, and elevated alpha activity would have been inconsistent with provenance. This decision was shown to be appropriate considering the outcome of alpha spectrometry carried out on separate samples (see sections 9.2.2 and 9.2.3). For the debris samples, U-235 and Am-241 were not measured by gamma spectrometry above limits of detection that were an order of magnitude below the corresponding clearance limits.

Since the debris was identified as the contaminating material on the inner walls of the area 2970 duct, and there were only 4 samples, it was considered appropriate to derive the fingerprint by directly summing the analytical data for the samples (Bq/g values were used in order to preserve even weighting to the sample data).

In the process of deriving the fingerprint, limits of detection were treated as real values where these corresponded to credible activation products: that is, activation products with half-lives less than one year were rejected on the grounds of no longer being present in significant quantities and/or their corresponding clearance limits were sufficiently high that they would not impact the clearance decision. Data for naturally occurring radionuclides were rejected on the grounds that there was no mechanism for them to be present at elevated activities; in almost all cases they were not measured above limits of detection; and where positive results were obtained these were either very low and consistent with results for similar materials or rejected as not credible (Pb-210). No anthropogenic actinide activities were positively measured and their limits of detection were not used in deriving the fingerprint as this would have been inconsistent with provenance. Fission products were only included in the fingerprint calculation where these had been positively measured.

The resulting fingerprint which is derived in reference xxiii compares well against the Trawsfynydd reactor fingerprint 9G105 which was mentioned in the DQO Report [xxvii] as a point of reference for radionuclides which were considered to be present, but with no assumptions on the relative quantities of these or overall activity levels on the materials to be demolished (refer to Table 10). The large number of decimal places in the reactor fingerprint is preserved for consistency, however this level of precision is unwarranted considering the likely uncertainty on the values.

Table 10: Fingerprint derived from Area 2970 HLDC debris compared to reactor fingerprint 9G105

Radionuclide	**9G105 (%) Decay-correct to July 2021**	**Area 2970 debris (%) Decay-correct to May 2023**
H-3	56.7628	56.82
C-14	28.1935	20.40
Cl-36	0.3663	11.24
Mn-54	0.0000	0.00
Fe-55	1.5078	2.06
Co-60	4.1105	7.35
Ni-63	8.7313	1.60
Zn-65	0.0000	0.00
Nb-94	0.0081	0.02
Ag-108m	0.0355	0.05
Sb-125	0.0002	0.00
Ba-133	0.0271	0.00
Cs-137	0.0701	0.10
Eu-152	0.0219	0.26
Eu-154	0.0504	0.03
Eu-155	0.0019	0.02
Sr-90	0.0676	0.02
Ru-106	0.0000	0.00

Radionuclide	9G105 (%) Decay-correct to July 2021	Area 2970 debris (%) Decay-correct to May 2023
I-129	0.0000	0.00
Cs-134	0.0000	0.00
Ce-144	0.0000	0.00
Pm-147	0.0001	0.00
U-234	0.0000	0.00
U-235	0.0000	0.00
Pu-238	0.0013	0.00
U-238	0.0000	0.00
Pu-239	0.0018	0.00
Pu-240	0.0023	0.00
Am-241	0.0083	0.00
Pu-241	0.0307	0.00
Cm-243	0.0000	0.00
Cm-244	0.0003	0.00
Total	100	100

In the case of both fingerprints, for the purpose of assessment against the clearance criteria set out in EPR [xxv] Co-60 is the most sensitive radionuclide despite only comprising a small percentage of the overall activity, as illustrated in Figure 35 and Figure 36. The chart entries represent each radionuclide's percentage abundance in the fingerprint divided by the corresponding clearance limit. Rounding to 2 decimal places, the clearance threshold corresponds to 0.08 Bq/g of Co-60 in both cases (refer to Appendix H: Assessment of fingerprints against EPR and RP113 clearance limits).

Figure 35: Relative significance of radionuclides to clearance assessment (9G105)

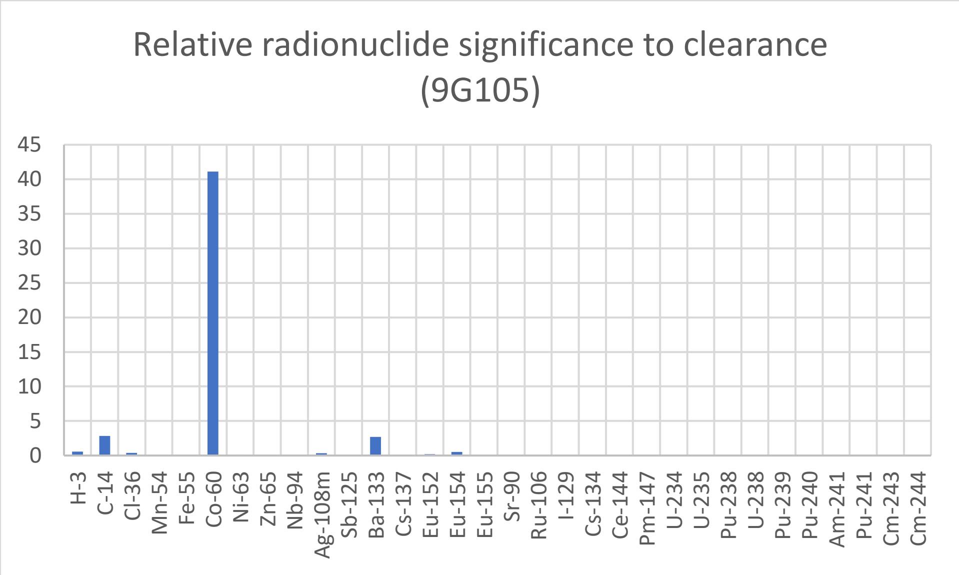
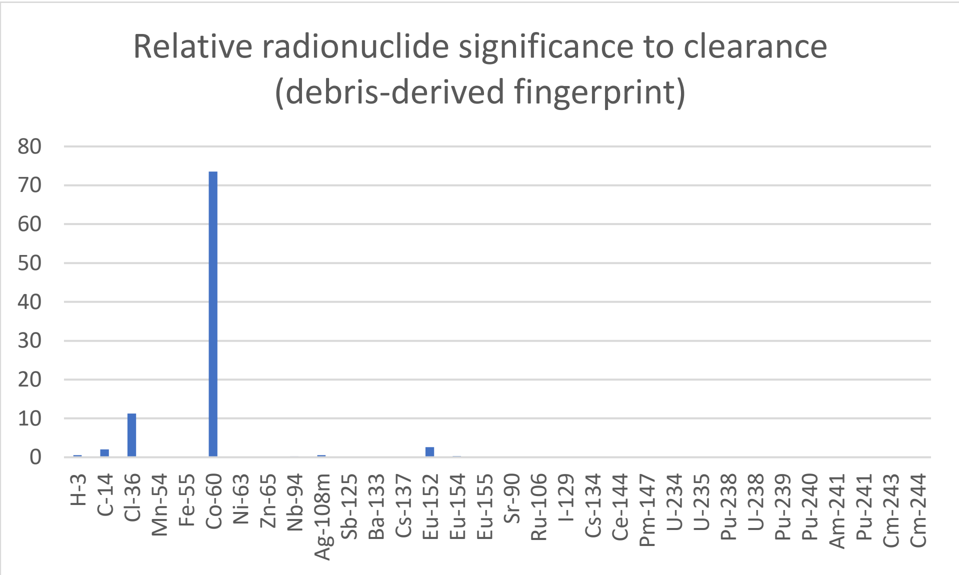


Figure 36: Relative significance of radionuclides to clearance assessment (debris-derived fingerprint)



9.2 Phase 2 analysis of previously analysed samples as per Table 9

9.2.1 Areas where Co-60 was positively detected by HRGS

A bulk sample of concrete from the R1 South Shield Stack was analysed for Cl-36, Fe-55 and Ni-63. While there was a positive result for Cl-36 (0.303 Bq/g) Fe-55 and Ni-63 were not measured above low limits of detection. The Cl-36 result was around an order of magnitude lower than the Cl-36 result for the debris removed from the R1 HLDC.

The oil sample from the R1 Shield Cooling Fan room was analysed for Cl-36, Fe-55 and Ni-63. Cl-36 was reported at 13.91 Bq/g but Fe-55 and Ni-63 were not measured above low limits of detection. The origin of the oil needs to be determined: it could have been associated with the oil filter in which case the Cl-36 may be explained by exposure to the Shield Cooling Extract during operations. Positive measurements for H-3 and C-14 in this sample were around an order of magnitude lower than the Cl-36 result.

There was no evidence of Fe-55 or Ni-63 above limits of detection in the metal sample from the R2 Hot Duct Cell, indicating that levels of activation in the steel were negligible. This sample location was deliberately chosen to bound levels of activation in metals throughout the structures above the level of the capping roof. Co-60 was previously measured at 0.0067 Bq/g in this sample which is a factor of 15 below the Co-60 clearance threshold.

9.2.2 High Bi-214 in R1 North Upper Plenum samples

Further analysis of sample TRA/HR/2022/1960/057/C revealed 0.849 Bq/g of Cl-36; no Fe-55 or Ni-63 above suitably low limits of detection; and uranium isotopes that were consistent with natural isotopic composition at levels around two orders of magnitude below the corresponding clearance limit (U-238 was reported at 0.03 Bq/g). By comparison, the reported HRGS results for Bi-214 and Pb-214 (approx. 0.07 Bq/g) appear slightly enhanced. Although Bi-214 and Pb-214 are associated with Ra-226 via the Rn-222 daughter product there is no credible mechanism whereby Ra-226 would be enhanced by reactor operations, and hence their results are dis-regarded.

9.2.3 Elevated gross alpha count-rate

The elevated gross alpha count-rate for sample TRA/HR/2022/1610/182/C prompted comprehensive alpha spectrometry analysis which is also used to indicate whether actinide contamination is a feature of the broader scope of material to be removed by the Height Reduction project. Uranium activities were low and broadly consistent with natural isotopic composition (U-238 reported at 0.02 Bq/g) indicating it was present at naturally occurring levels in the concrete. Th-228 was reported at 0.001 Bq/g which was around a factor of 3 to 4 lower than predicted from review of the gamma spectrometry results for this sample, and certainly not indicative of enhanced activity. Plutonium, americium and curium isotopes were not measured above suitably low limits of detection.

Taking into account the activities of uranium and thorium indicated by gamma and alpha spectrometry and applying these across the full decay chains, the gross alpha activity appears overestimated for this sample by around a factor of 3. There is no evidence of enhanced actinide activity in this sample. Considering also the results for sample TRA/HR/2022/1960/057/C which was analysed for uranium, prompted by an apparently high Bi-214 result by HRGS analysis which was later disproven by alpha spectrometry, there is no requirement to account for actinides for the purpose of the clearance assessment.

9.2.4 Elevated gross beta count-rates

There was no evidence of Cl-36 or Ni-63 in sample TRA/HR/2022/2610/163/P or the composite paint sample from the R2 Charge Hall. Fe-55 was reported at 0.252 and 0.116 Bq/g respectively which are both well below the corresponding clearance thresholds.

There is no evidence of enhanced beta activity in the paint which could reasonably have been associated with routine operations. The elevated gross beta count-rates are considered to be unreliable.

9.2.5 Potentially activated metal

For sample TRA/HR/2022/2652/132/M there was no evidence of Fe-55 or Ni-63 above low limits of detection. The reported activity of Co-60 was very low (0.0067 Bq/g). Hence, there is no evidence of activation of metal at this position which was considered to bound activation of metalwork in the structures above the level of the capping roof.

9.2.6 Further consideration of all material types and zones

Cl-36, Fe-55 and Ni-63 were not measured above low limits of detection for any of the remaining composite samples from the R1 roof, R2 Charge Hall and R2 Boiler Boxes / Hot Gas Duct Cells.

9.2.7 Further analysis of lead in paint

Lead was reported at very small concentrations, 0.018% and 0.006% for samples TRA/HR/2022/1610/167/P and TRA/HR/2022/2610/154/P respectively. Hence, the paint contains no hazardous properties associated with lead since the concentration is < 0.1%.

10. Assessment of activities against Clearance criteria

The provenance of the structures to be removed by the Height Reduction project is summarised in Appendix B and presented more fully in the DQO Report [xxvii]. The project has undertaken extensive characterisation activities over the relevant structures of both safestores, generating information on types and levels of radioactivity which are relevant for assessment against clearance thresholds. In accordance with the NICoP [xxiv], both the limits on activity per unit mass (Bq/g) set out in table 2 of EPR [xxv] and the limits on activity per unit area (Bq/cm^2) set out in European Commission document RP113 [xix] are relevant.

Although any contamination is likely to be mostly distributed on the surfaces, radionuclides such as tritium may have penetrated to a few millimetres' depth into porous materials such as concrete. For assessment against EPR limits (Bq/g) the reported activities representing the depth of sampling are used. Concrete samples are typically a few centimetres deep; for roofing felt the samples would typically be of the order of 1 cm deep; paint is likely to be only a few microns deep. In the case of concrete where only the surface of a much greater volume of material has been assessed, this represents a conservative approach. In accordance with RP113, all measured activity in the concrete, roofing felt and paint shall be assumed to be distributed on the surface. Nominal sample areas for the paint, concrete and felt samples are 300 cm^2, 30 cm^2 and 20 cm^2 respectively.

For assessment purposes, NORM has been ignored in accordance with the definition of radioactive material provided in reference [xxvi] on the grounds that by provenance it was not used for its fissile, fertile or radioactive properties (see also the conclusions from section 9.2.3). Specifically, NORM in this context includes naturally occurring uranium and thorium and their decay chain members plus potassium-40 (K-40).

Gross alpha and beta results were used for the purpose of informing the selection of analyses, and establishing confidence in the reported radionuclide activities only; hence they are not relevant to the quantitative assessment against clearance thresholds.

The following assessment against clearance criteria takes account of all sample results. To aid interpretation the assessment has been sub-divided between:

- samples where phase 1 analysis did not indicate elevated activity; and
- samples that were collected and/or analysed in response to elevated phase 1 analytical results or apparently elevated survey results.

10.1 Assessment of samples where phase 1 analysis did not indicate elevated activity

Section 9.1.5 derived a fingerprint based on debris in the area 2970 HLDC and showed that this was very similar to the reactor fingerprint 9G105. Furthermore, the clearance assessment for this fingerprint was most sensitive to Co-60, for which a maximum activity concentration of 0.08 Bq/g corresponded to the clearance threshold. For the purpose of assessment against clearance thresholds, the debris-based fingerprint has been applied by default to those samples where preliminary analysis did not indicate a requirement to undertake quantitative analysis other than for gamma spectrometry, H-3 and C-14 analyses.

314 samples collected from zones 1, 2, 4, 5 and 6[8] [9] were initially submitted for phase 1 analysis. These comprised concrete, paint, oil, metal and felt. Co-60 was only reported above 0.04 Bq/g in two instances relating to the R2 north side HLDC and these were the subject of further sampling and analysis so their results are considered separately in section 10.2.

For the remaining 312 samples, H-3, C-14, Cs-137 and Eu-155 were positively identified in some samples with maximum activities of 5.13, 0.67, 0.03 and 0.01 Bq/g. These values have been used to form a bounding assessment, with all other radionuclides in the fingerprint inferred from their relationship to Co-60. The Sum of Fractions (SoF) calculation is set out below.

Table 11: Bounding Sum of Fractions calculation for the 314 samples that were analysed for H-3, C-14 and HRGS only (excludes paint bulks, swab samples and 2 x samples with Co-60 in excess of EPR limit)

Radionuclide	Bq/g	EPR limits (Bq/g)	Bounding activity / EPR limit[10]
H-3	5.13	100	0.0513
C-14	0.67	10	0.067
Cl-36	0.061125	1	0.061125065
Fe-55	0.011209	1000	1.12091E-05
Co-60	0.04	0.1	0.4
Ni-63	0.008729	100	8.72859E-05
Nb-94	0.000119	0.1	0.001193565
Ag-108m	0.000288	0.1	0.002879087
Cs-137	0.03	1	0.03
Eu-152	0.001416	0.1	0.01415672
Eu-154	0.000187	0.1	0.001868189
Eu-155	0.01	1	0.01
Sr-90	0.000131	1	0.000130773
		Total	**0.639751894**

10.1.1 Sensitivity analysis

In deriving the bounding assessment, maximum measured activities were only available for H-3, C-14, Cs-137 and Eu-155; all other radionuclides were inferred from reference to the Area 2970 debris fingerprint and these have been highlighted in the above table. It's therefore important to provide some measure of the sensitivity of the above assessment.

<u>Fe-55/Ni-63</u>

Of the inferred radionuclides, Fe-55 and Ni-63 have relatively high clearance thresholds and it is unlikely that their true activity concentrations would be sufficiently high to impact the overall SoF

[8] Zone 3 being inaccessible for sampling
[9] Refer to Table 17: Initial zoning of each reactor building
[10] The 'total' value is the SoF. A SoF value of 1 or less is consistent with the definition in EPR of materials that are suitable for clearance as OoS. Values in excess of 1 indicate that materials exceed the limit for categorisation as OoS and should be managed as radioactive for the purpose of disposal. The large number of significant figures is unwarranted but included to aid traceability of calculations

value. Referring to the sample bulks[11] which were prepared to investigate levels of activation products following phase 1 analysis of the concrete, it can be seen that there was only one positive measurement for Fe-55, 0.116 Bq/g and no positive measurements for Ni-63. The impact of Fe-55 and Ni-63 on the SoF calculation is negligible due to their relatively high clearance thresholds (1000Bq/g and 100 Bq/g respectively) hence Fe-55 and Ni-63 are ignored for the purpose of the sensitivity analysis.

Radionuclides with readily-measurable gamma emissions

Nb-94, Ag-108m, Eu-152 and Eu-154 all have equivalent clearance thresholds but over the entire population of samples they were all reported as below limit of detection with the exception of Eu-152 which was reported for the area 2970 HLDC debris and sample TRA-HR-2022-2970-AS10-C which was recovered from slightly above the area 2970 HLDC: clearly the samples of debris and materials from around the HLDC are not representative of the broader scope of materials and it would be inappropriate to apply the measured activity concentrations for those samples to this assessment. Of the above radionuclides, Eu-152 activity concentration (Bq/g) is the highest and influences the SoF calculation the most. The inferred activity concentrations for the above radionuclides would all have to increase by a factor of 18 each in order for the SoF to equal 1, which is considered unlikely.

Sr-90

Sr-90 was only measured in the debris samples, and even then at very low activities compared to activation products (i.e. H-3, Cl-36, Fe-55) which may be considered consistent with the nature of activity identified throughout the broader scope of material. Inferring Sr-90 relative to the bounding value for Cs-137 activity would result in an activity concentration of 0.007 Bq/g which in itself would only increase the SoF value to 0.647. The inferred activity concentration for Sr-90 would need to increase by a factor of nearly 3,000 in order for the SoF to equal 1, which is also considered unlikely given the provenance of the materials to be removed by the project.

Cl-36

Because of the sensitivity of Cl-36 to the clearance assessment (its clearance threshold is 1 Bq/g) it is beneficial to refer to the analysis results for the four sample bulks representing paint and concrete which were prepared to investigate levels of activation products following phase 1 analysis of the concrete (see Table 9). Cl-36 was not positively identified in any of the bulks. The maximum limit of detection for Cl-36 in the bulks was 0.045 Bq/g which is lower than the value assumed for the SoF calculation.

In the SoF assessment presented here, Cl-36 would have to increase by around a factor of 6 in order for the SoF to equal 1. This is considered unlikely considering the results of the supplementary analysis.

Phase 1 analysis of the oil/grease sample and metal samples did not indicate elevated activities however it was appropriate to submit them for phase 2 analysis. Assessment of these materials against clearance thresholds is considered in section 10.2.

The bounding assessment demonstrates that samples from zones 1, 4, 5 and 6 comply with the clearance threshold with the exception of the oil/grease. Assessment against surface clearance limits is unnecessary because for the radionuclides concerned and the surface areas assumed EPR

[11] See Table 9 for description of the bulks

limits are more restrictive. Surface clearance is considered in section 10.2 for samples of similar materials with greater activity concentration.

Because phase 1 analysis of samples from zone 2 exceeded the clearance threshold all analyses of zone 2 samples have been considered separately in the next section.

10.2 Assessment of Samples That Were Collected and/or Analysed in Response to Either Elevated Phase 1 Analytical Results or Apparently Elevated Survey Results

For all other samples, activity assessments were derived using the same approach as in section 10.1, but undertaken on a per-sample basis rather than on a theoretical bounding sample. For the purpose of inferring activities, LoDs for Co-60 were used in the absence of a positive measurement. The resulting activities are presented in Table 12.

10.2.1 Assessment against EPR limits

SoF calculations relating to activity per unit mass (Bq/g) are presented in Table 13. As expected, the majority of activity is associated with the debris recovered from area 2970 HLDC and this has since been removed to be managed as radioactive waste. Concrete sample TRA-HR-2022-2970-AS10-C which was taken from above the area 2970 HLDC is indicated as exceeding the clearance threshold. The Co-60 activity reported for 2022-2970-AS10-C is comparable to that in samples 2022-2970-061-C and 2022-2970-062-C which were taken from the same location. In descending order, the SoF value for the debris samples and 2022-2970-AS10-C is primarily influenced by Co-60, then Cl-36 and C-14/Eu-152, all of which were directly measured by the laboratory.

The calculations for both metal samples are consistent with the previous observations (section 9.2.5) and demonstrate that the metal samples are OoS.

The oil sample clearly exceeds the threshold for categorisation as OoS, predominantly because of the high Cl-36 activity which was measured directly, and not inferred. This sample was taken from the FM Auxilliary Crane hook on the Capping Roof, and it is unclear why this should be contaminated to this degree with Cl-36 with relatively little contribution from any other radionuclides except H-3.

The SoF for concrete sample TRA/HR/2022/1960/057/C from sector 63 of the R1 North upper plenum is very close to the maximum value for categorisation as OoS due mainly to the contribution of measured Cl-36 activity. The ratio of Cl-36 to Co-60 in this sample is around 20:1 whereas the same ratio for the debris samples and the sample from near the Area 2970 HLDC was 1.5:1 and 0.2:1 respectively. This sample is the only one of a total of 60 collected from the upper plenums that was individually analysed for Cl-36. None of concrete from the plenums was composited for analysis and hence only this one sample is available to represent Cl-36 levels in the plenums as part of zone 2.

The remaining paint and concrete samples were taken from the R2 Charge Hall, R2 NW Stairs, R1 Top Duct 1901 and R2 Shield Cooling fan Room 2771, i.e. zones 5, 6 and 4, and were all indicated as OoS.

10.2.2 Assessment against Surface Clearance Limits

Since the mechanism whereby concrete may have become radioactive is the aerial deposition of contamination, any radioactivity which is present will be highly localised toward the surface of the concrete. It was impractical to sample only a thin layer of the concrete and all samples were collected by hammer and chisel to a depth of around a few centimetres. As stated previously, for the purpose of determining compliance with surface clearance limits it is assumed that the activity reported by the laboratory is confined to the surface of the concrete and this is a reasonable approximation of the true distribution.

Excluding the debris recovered from the HLDC (which is known to exceed clearance thresholds and cannot reasonably be averaged over a larger mass) it can be seen that concrete sample 2022-2970-AS10-C exceeds the surface clearance limits set out in RP-113 by a factor of 3.46 (Table 14). Sample data indicate that the R2 north stack from where this sample was taken is the most contaminated of all four stacks, and it is therefore inappropriate to assume that this is representative of all stacks. No anthropogenic activity was positively reported for samples from the R2 south and R1 north stacks. Positive activities for Co-60 were reported for samples from the R1 south stack, with a maximum of 0.0425 Bq/g which is an order of magnitude less than the activity reported for 2022-2970-AS10-C. A composite sample formed from all of the samples from the R1 south stack indicated Cl-36 activity at 0.303 Bq/g which is less than half the Cl-36 activity concentration for 2022-2970-AS10-C. Assuming that the sampled concrete from the R1 south stack contains similar levels of activity for all other radionuclides to the R2 north stack the SoF assessment against RP-113 gives a value of 0.329 indicating compliance (Table 15). Hence, of the 4 ducts within zone 2, radiochemical analysis of samples indicates that there is contamination exceeding surface clearance limits within the R2 north stack only.

Sample TRA/HR/2022/1960/057/C is bounding for the remaining features within zone 2 that were accessible for characterisation. Table 16 indicates that this sample is complaint with reference surface clearance limits.

10.2.3 Averaging of activity over the volume of material present

Each of the concrete samples represents concrete to a depth of a few centimetres, where the nature of any activity present will be highly localised toward the surface of the concrete. Excluding the R2 north stack which has been shown to be non-compliant with surface clearance limits, sample TRA/HR/2022/1960/057/C from the R1 north plenum is considered to bound levels of activity throughout the remainder of zone 2. The SoF calculated against EPR for this sample was 0.911 which is lower than the defined limit of 1, however once averaging over a greater depth is taken into account it is clear that this level of activity can be considered OoS.

Table 12: Inferred activities for the remaining samples that were subject to further analysis (excludes paint bulks, swab samples and composite samples). All activities in Bq/g

Laboratory ID	NRS ID	Material	Sample location	H-3	C-14	Cl-36	Fe-55	Ni-63	Sr-90	Co-60	Ag-108m	Cs-137	Eu-152	Eu-154	Eu-155	Nb-94
				Bq/g	**Bq/g**	**Bq/g**	**Bq/g**	**Bq/g**	**Bq/g**	**Bq/g**	**Bq/g**	**Bq/g**	**Bq/g**	**Bq/g**	**Bq/g**	**Bq/g**
NB6544	TRA/HR/2022/1651/134/M	Metal	R1 bolt to gas duct	1.20E-02	1.44E-02	7.95E-03	1.46E-03	1.13E-03	1.70E-05	5.20E-03	3.74E-05	7.26E-05	1.84E-04	2.43E-05	1.44E-05	1.55E-05
NB6565	TRA/HR/2022/1605/232/O	Oil / Grease	R1 Shield Cooling Fan Room - South (upper)	1.52E+00	8.10E-02	1.39E+01	1.01E-02	7.86E-03	1.18E-04	3.60E-02	2.59E-04	5.02E-04	1.27E-03	1.68E-04	9.94E-05	1.07E-04
NB6592	TRA/HR/2022/1960/057/C	Concrete	R1 North Upper Plenum	1.29E-01	1.97E-01	8.49E-01	1.09E-03	8.51E-04	1.28E-05	3.90E-03	2.81E-05	5.44E-05	1.38E-04	1.82E-05	1.08E-05	1.16E-05
NB7059	TRA/HR/2022/2610/163/P	Paint (flakes)	R2 Charge Hall	2.24E-01	8.05E-02	4.43E-02	2.52E-01	6.33E-03	9.48E-05	2.90E-02	2.09E-04	4.05E-04	1.03E-03	1.35E-04	8.01E-05	8.65E-05
NB7069	TRA/HR/2022/2652/132/M	Metal	R2 Hot Duct Cell - South Cct 8 (lower)	8.00E-03	3.00E-03	1.02E-02	1.88E-03	1.46E-03	2.19E-05	6.70E-03	4.82E-05	9.35E-05	2.37E-04	3.13E-05	1.85E-05	2.00E-05
NC4106	TRA-HR-2022-2071-AS12-C	Concrete	NW stairs 2071	3.70E-02	1.18E-01	5.65E-03	1.04E-03	8.07E-04	1.21E-05	3.70E-03	2.66E-05	5.16E-05	1.31E-04	1.73E-05	1.02E-05	1.10E-05
NC4115	TRA-HR-2022-1901-AS6-C	Concrete	Top duct 1901 grid square 50	8.60E-02	7.00E-02	4.43E-03	8.13E-04	6.33E-04	9.48E-06	2.90E-03	2.09E-05	4.05E-05	1.03E-04	1.35E-05	8.00E-03	8.65E-06
NC4116	TRA-HR-2022-2771-AS9-C	Concrete	Shield cooling fan room 2771 grid square 27	2.90E-02	9.00E-03	3.51E-03	6.45E-04	5.02E-04	7.52E-06	2.30E-03	1.66E-05	3.21E-05	8.14E-05	1.07E-05	6.35E-06	6.86E-06
NC4119	TRA-HR-2022-2970-AS10-C	Concrete	Location 6 to 8 " above high level drainage channel 2970 east side	3.22E+00	4.95E-01	9.74E-01	1.25E-01	1.11E-01	1.50E-02	5.08E-01	3.66E-03	7.09E-03	1.77E-02	2.37E-03	1.40E-03	1.52E-03
NC4125	TRA-HR-2022-2802.north.debris	Debris	High level drainage channel 2970	3.85E+01	1.55E+01	9.95E-01	7.66E-01	1.20E+00	2.40E-02	5.50E+00	3.05E-02	7.10E-02	1.79E-01	2.57E-02	1.52E-02	1.64E-02
NC4126	TRA-HR-2022-2802.east.debris	Debris		4.89E+01	1.91E+01	8.37E+00	2.65E+00	4.63E-01	1.80E-02	9.07E+00	6.35E-02	8.30E-02	2.33E-01	4.24E-02	2.50E-02	2.71E-02
NC4127	TRA-HR-2022-2802.south.debris	Debris		4.39E+01	1.38E+01	1.90E+01	1.43E+00	3.61E+00	6.00E-03	3.23E+00	2.83E-02	6.89E-02	1.59E-01	1.51E-02	8.92E-03	9.64E-03
NC4128	TRA-HR-2022-2802.west.debris	Debris		1.76E+01	5.06E+00	1.08E+00	5.54E-01	3.21E-01	4.81E-03	1.47E+00	1.64E-02	4.60E-02	1.11E-01	6.87E-03	4.06E-03	4.39E-03

Table 13: Sum of Fractions calculations for the remaining samples that were subject to further analysis (excludes paint bulks, swab samples and composite samples)

			H-3	**C-14**	**Cl-36**	**Fe-55**	**Ni-63**	**Sr-90**	**Co-60**	**Ag-108m**	**Cs-137**	**Eu-152**	**Eu-154**	**Eu-155**	**Nb-94**	**Total**
Laboratory ID	**NRS ID**	**EPR limits (Bq/g)**	**100**	**10**	**1**	**1000**	**100**	**1**	**0.1**	**0.1**	**1**	**0.1**	**0.1**	**1**	**0.1**	
NB6544	TRA/HR/2022/1651/134/M	Metal	1.20E-04	1.44E-03	7.95E-03	1.46E-06	1.13E-05	1.70E-05	5.20E-02	3.74E-04	7.26E-05	1.84E-03	2.43E-04	1.44E-05	1.55E-04	6.42E-02
NB6565	TRA/HR/2022/1605/232/O	Oil / Grease	1.52E-02	8.10E-03	1.39E+01	1.01E-05	7.86E-05	1.18E-04	3.60E-01	2.59E-03	5.02E-04	1.27E-02	1.68E-03	9.94E-05	1.07E-03	1.43E+01
NB6592	TRA/HR/2022/1960/057/C	Concrete	1.29E-03	1.97E-02	8.49E-01	1.09E-06	8.51E-06	1.28E-05	3.90E-02	2.81E-04	5.44E-05	1.38E-03	1.82E-04	1.08E-05	1.16E-04	9.11E-01
NB7059	TRA/HR/2022/2610/163/P	Paint (flakes)	2.24E-03	8.05E-03	4.43E-02	2.52E-04	6.33E-05	9.48E-05	2.90E-01	2.09E-03	4.05E-04	1.03E-02	1.35E-03	8.01E-05	8.65E-04	3.60E-01
NB7069	TRA/HR/2022/2652/132/M	Metal	8.00E-05	3.00E-04	1.02E-02	1.88E-06	1.46E-05	2.19E-05	6.70E-02	4.82E-04	9.35E-05	2.37E-03	3.13E-04	1.85E-05	2.00E-04	8.11E-02
NC4106	TRA-HR-2022-2071-AS12-C	Concrete	3.70E-04	1.18E-02	5.65E-03	1.04E-06	8.07E-06	1.21E-05	3.70E-02	2.66E-04	5.16E-05	1.31E-03	1.73E-04	1.02E-05	1.10E-04	5.68E-02
NC4115	TRA-HR-2022-1901-AS6-C	Concrete	8.60E-04	7.00E-03	4.43E-03	8.13E-07	6.33E-06	9.48E-06	2.90E-02	2.09E-04	4.05E-05	1.03E-03	1.35E-04	8.00E-03	8.65E-05	5.08E-02
NC4116	TRA-HR-2022-2771-AS9-C	Concrete	2.90E-04	9.00E-04	3.51E-03	6.45E-07	5.02E-06	7.52E-06	2.30E-02	1.66E-04	3.21E-05	8.14E-04	1.07E-04	6.35E-06	6.86E-05	2.89E-02
NC4119	TRA-HR-2022-2970-AS10-C	Concrete	3.22E-02	4.95E-02	9.74E-01	1.25E-04	1.11E-03	1.50E-02	5.08E+00	3.66E-02	7.09E-03	1.77E-01	2.37E-02	1.40E-03	1.52E-02	6.41E+00
NC4125	TRA-HR-2022-2802.north.debris	Debris	3.85E-01	1.55E+00	9.95E-01	7.66E-04	1.20E-02	2.40E-02	5.50E+01	3.05E-01	7.10E-02	1.79E+00	2.57E-01	1.52E-02	1.64E-01	6.06E+01
NC4126	TRA-HR-2022-2802.east.debris	Debris	4.89E-01	1.91E+00	8.37E+00	2.65E-03	4.63E-03	1.80E-02	9.07E+01	6.35E-01	8.30E-02	2.33E+00	4.24E-01	2.50E-02	2.71E-01	1.05E+02
NC4127	TRA-HR-2022-2802.south.debris	Debris	4.39E-01	1.38E+00	1.90E+01	1.43E-03	3.61E-02	6.00E-03	3.23E+01	2.83E-01	6.89E-02	1.59E+00	1.51E-01	8.92E-03	9.64E-02	5.54E+01
NC4128	TRA-HR-2022-2802.west.debris	Debris	1.76E-01	5.06E-01	1.08E+00	5.54E-04	3.21E-03	4.81E-03	1.47E+01	1.64E-01	4.60E-02	1.11E+00	6.87E-02	4.06E-03	4.39E-02	1.79E+01

Table 14: Assessment against Reference Surface Clearance Limits (RP-113) for TRA-HR-2022-2970-AS10-C

Assumed surface area of sample (cm^2)	Mass of sample received by the laboratory (g)		**H-3**	**C-14**	**Cl-36**	**Fe-55**	**Ni-63**	**Sr-90**	**Co-60**	**Ag-108m**	**Cs-137**	**Eu-152**	**Eu-154**	**Eu-155**	**Nb-94**	
30	199	Activity concentration (Bq/g)	3.22E+00	4.95E-01	9.74E-01	1.25E-01	1.11E-01	1.50E-02	5.08E-01	3.66E-03	7.09E-03	1.77E-02	2.37E-03	1.40E-03	1.52E-03	
		Calculated total activity (Bq)	6.41E+02	9.85E+01	1.94E+02	2.49E+01	2.21E+01	2.99E+00	1.01E+02	7.28E-01	1.41E+00	3.52E+00	4.72E-01	2.79E-01	3.02E-01	
		Calculated activity per square centimetre (Bq/cm^2)	2.14E+01	3.28E+00	6.46E+00	8.29E-01	7.35E-01	9.95E-02	3.37E+00	2.43E-02	4.70E-02	1.17E-01	1.57E-02	9.30E-03	1.01E-02	
		RP113 surface clearance limits for demolition (Bq/cm^2)	10000	10000	100	10000	100000	100	1	10	10	10	10	100	10	**Total SoF**
		Activities / Surface clearance limits	2.14E-03	3.28E-04	6.46E-02	8.29E-05	7.35E-06	9.95E-04	3.37E+00	2.43E-03	4.70E-03	1.17E-02	1.57E-03	9.30E-05	1.01E-03	3.46E+00

Table 15: Assessment against Reference Surface Clearance Limits (RP-113) for R1 south stack samples

Assumed surface area of sample (cm2)	Mass of sample received by the laboratory (g)		**H-3**	**C-14**	**Cl-36**	**Fe-55**	**Ni-63**	**Sr-90**	**Co-60**	**Ag-108m**	**Cs-137**	**Eu-152**	**Eu-154**	**Eu-155**	**Nb-94**	
30	200	**Activity concentration (Bq/g)**	3.22E+00	4.95E-01	3.03E-01	1.25E-01	1.11E-01	1.50E-02	4.25E-02	3.66E-03	7.09E-03	1.77E-02	2.37E-03	1.40E-03	1.52E-03	
		Calculated total activity (Bq)	6.44E+02	9.90E+01	6.06E+01	2.50E+01	2.22E+01	3.00E+00	8.50E+00	7.31E-01	1.42E+00	3.54E+00	4.75E-01	2.80E-01	3.03E-01	
		Calculated activity per square centimetre (Bq/cm^2)	2.15E+01	3.30E+00	2.02E+00	8.33E-01	7.39E-01	1.00E-01	2.83E-01	2.44E-02	4.73E-02	1.18E-01	1.58E-02	9.35E-03	1.01E-02	
		RP113 surface clearance limits for demolition (Bq/cm^2)	10000	10000	100	10000	100000	100	1	10	10	10	10	100	10	**Total SoF**
		Activities / Surface clearance limits	2.15E-03	3.30E-04	2.02E-02	8.33E-05	7.39E-06	1.00E-03	2.83E-01	2.44E-03	4.73E-03	1.18E-02	1.58E-03	9.35E-05	1.01E-03	3.29E-01

Table 16: Assessment against Reference Surface Clearance Limits (RP-113) for sample TRA/HR/2022/1960/057/C

Assumed surface area of sample (cm2)	Mass of sample received by the laboratory (g)		**H-3**	**C-14**	**Cl-36**	**Fe-55**	**Ni-63**	**Sr-90**	**Co-60**	**Ag-108m**	**Cs-137**	**Eu-152**	**Eu-154**	**Eu-155**	**Nb-94**	
30	222	**Activity concentration (Bq/g)**	1.29E-01	1.97E-01	8.49E-01	1.09E-03	8.51E-04	1.28E-05	3.90E-03	2.81E-05	5.44E-05	1.38E-04	1.82E-05	1.08E-05	1.16E-05	
		Calculated total activity (Bq)	2.86E+01	4.37E+01	1.88E+02	2.43E-01	1.89E-01	2.83E-03	8.66E-01	6.23E-03	1.21E-02	3.06E-02	4.04E-03	2.39E-03	2.58E-03	
		Calculated activity per square centimetre (Bq/cm^2)	9.55E-01	1.46E+00	6.28E+00	8.09E-03	6.30E-03	9.44E-05	2.89E-02	2.08E-04	4.03E-04	1.02E-03	1.35E-04	7.97E-05	8.61E-05	
		RP113 surface= clearance limits for demolition (Bq/cm^2)	10000	10000	100	10000	100000	100	1	10	10	10	10	100	10	
		Activities / Surface clearance limits	9.55E-05	1.46E-04	6.28E-02	8.09E-07	6.30E-08	9.44E-07	2.89E-02	2.08E-05	4.03E-05	1.02E-04	1.35E-05	7.97E-07	8.61E-06	9.21E-02

11. Conclusions

Structures that will be removed from the R1 and R2 safestores at Trawsfynydd have been characterised to determine levels and types of radioactivity plus levels of relevant chemical species ahead of mobilisation of the demolition contractor, for the purpose of informing the approach to demolition and waste management. Characterisation work to date represents a significant targeted effort and has generated useful data that are traceable to the structures to be removed.

Characterisation informs the approach to decommissioning; and segregation, categorisation and onward management of the materials that will be produced by the Height Reduction project.

Characterisation does not supersede the requirement for reassurance monitoring of those materials, however the degree of effort associated with reassurance monitoring can be optimised to reflect the level of risk (see Recommendations). It is appropriate to undertake reassurance monitoring which confirms the outcome of characterisation. Where structures were inaccessible during characterisation these should be the assessed directly once access is available.

Regardless of whether the structures to be removed are intended for disposal or re-use either on or off of the Trawsfynydd site, assessments have been made based on whether those structures satisfy the criteria set out in the Environmental Permitting Regulations [xxv] and Basic Safety Standards Directive RP113 following the principles of the Nuclear Industry Code of Practice on Clearance and Radiological Sentencing [xxiv] and associated references.

Radiological surveys have tended not to indicate discrete areas of elevated count-rates in the floors, walls etc. A small number of localised increases in count-rates were investigated but did not appear to result from elevated activity in the structures being investigated.

Analysis of samples of the materials within the scope of the Height Reduction project has indicated very low levels of activity throughout the majority of the structures and confirmed zone 2 (Shield Cooling Discharge ducting and stack) as having the greatest potential for activity in limited areas. In particular:

- Where present, activity will tend to be localised toward the surface of the structures but in general, the samples indicate compliance with surface clearance criteria: the exception is the R2 north stack.
- Acknowledging that the concrete samples represent only a few centimetres of the total depth of concrete, instances where concrete samples approach or exceed the clearance threshold will comply with the clearance threshold defined in EPR once reasonable averaging over a few more centimetres (i.e. 10 to 20 cm) is allowed for. Averaging over depth is not a feature of surface clearance assessment and hence in this assessment surface clearance limits are the constraining factor for clearance of concrete.
- All samples from zones 1, 4, 5 and 6 are indicated as OoS with the exception of one oil/grease sample (see below).
- Samples from zone 2 are mostly indicated as OoS, with the clear exception of debris samples from the R2 north duct HLDC. Samples removed from near the R2 north duct HLDC are indicated as exceeding surface clearance limits for concrete.
- Only 4 samples of oil/grease were collected, and only one of these was assessed for Cl-36 which indicated it was well above clearance criteria. For all other

radionuclides the sample was comparable to the other oil/grease samples therefore these should be considered radioactive (oils are treated as a 'relevant liquid' for assessment against EPR [xxvi]).

- Analysis of roofing felt for coal tar components indicated it did not require to be managed as Hazardous Waste.
- Analysis of concrete with dark staining for oil indicated it did not require to be managed as Hazardous Waste.
- Analysis of paint for lead content indicated it did not need to be managed as Hazardous Waste

12. Recommendations

The evidence gathered from a provenance review, surveying and analysis of samples indicates that the building materials throughout the zones should be considered as OoS (see comment on zone 2 below). It should be noted however that that not all features within these zones were accessible for surveying or sampling during the course of characterisation works, and hence some reassurance monitoring is considered appropriate during the course of demolition works when better access can be arranged. More recent surveys have been undertaken at height within the 6th and 9th floors of each safestore, which have not identified activity above background levels.

NICoP guidance [xxiv] recommends that decontamination be considered where radioactivity is heterogeneously distributed, such as in this scenario where any radioactivity present would be preferentially located toward the surface of the structures to be removed. Decontamination is unnecessary in zones 1, 4, 5, 6 and the majority of zone 2 where characterisation indicates compliance with EPR and surface clearance levels.

Within zone 2, analysis of samples taken from the area around the HLDC in the R2 north stack suggested that the concrete in question was non-compliant with surface clearance limits. Acknowledging that only a small area around the HLDC of the R2 North Stack was sampled, it is appropriate to undertake further characterisation assessment of the stack internal surfaces and identify the extent of any features where decontamination maybe relevant.

The project should agree with the ASQEP(M) the degree of reassurance monitoring to be applied in the case of the Top Duct Areas, Charge Halls, FMMBs, Hot Gas Ducts and Boiler Boxes, and work with the contractor to enable access and undertake the required works. Areas of likely deposition, such as ledges, may need particular consideration. The ASQEP(M) should then determine based on the evidence of reassurance monitoring whether the structures in question are suitable for clearance. For reference, surveying and sampling work undertaken as part of pre-demolition characterisation within these structures was generally restricted to 2 metres height. Discrete sections of the walls, approximately 10 metres high by one metre wide were surveyed within the Charge Halls and Top Ducts Areas.

There is limited evidence that oils/greases may be contaminated above clearance thresholds. It is recommended that the project consider the likely mechanisms for contamination of the FM auxiliary crane hook, and the implications for related components. Further sampling and analysis may be beneficial, coupled with a targeted segregation scheme for oils/greases.

Items such as cranes, gantries and struts within the scope of zone 3 were not available for surveying or sampling during the course of characterisation works, and will need to be the subject of appropriate clearance monitoring protocols to assess their categorisation during the demolition project. Where surfaces have been painted, the paint should be assessed separately from the underlying materials as per NICoP guidance.

Other features such as the CO_2 ventilation ducts in the Top Duct Areas and down-pipes which were also outside of the scope of the pre-decommissioning characterisation work should be investigated further by the contractor to inform the approach to sorting/segregation/sentencing.

Measures should be put in place by the project to prevent mixing of materials that have been demonstrated as OoS with:

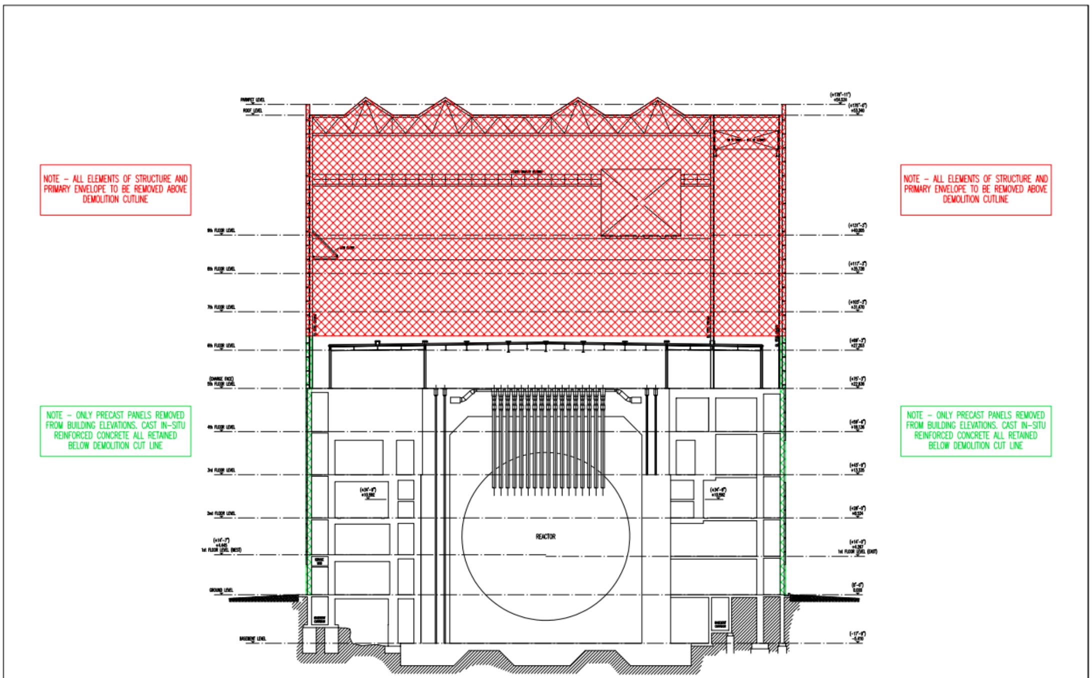
a) Materials whose radiological status has yet to be confirmed
b) Materials that have been determined as radioactive in accordance with reference xxv

The project should discuss the outcomes of pre-demolition characterisation with the Site Waste Team and End State Team and agree the onward routing of the materials to be removed.

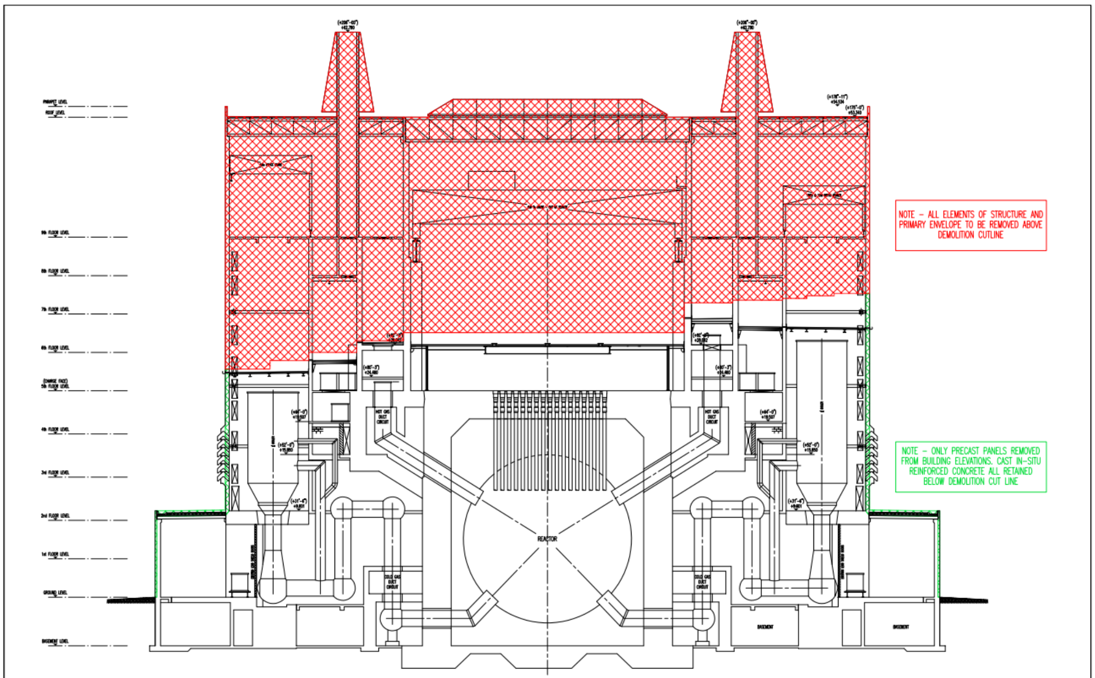
The project should establish segregation schemes to prevent mixing of Hazardous and Non-Hazardous materials.

Appendix A: Figures illustrating Scope of Height Reduction Works[12]

Side elevations of the reactor buildings. The red shaded areas indicate the structures to be demolished. The green shaded areas indicate locations of precast concrete panels to be removed.

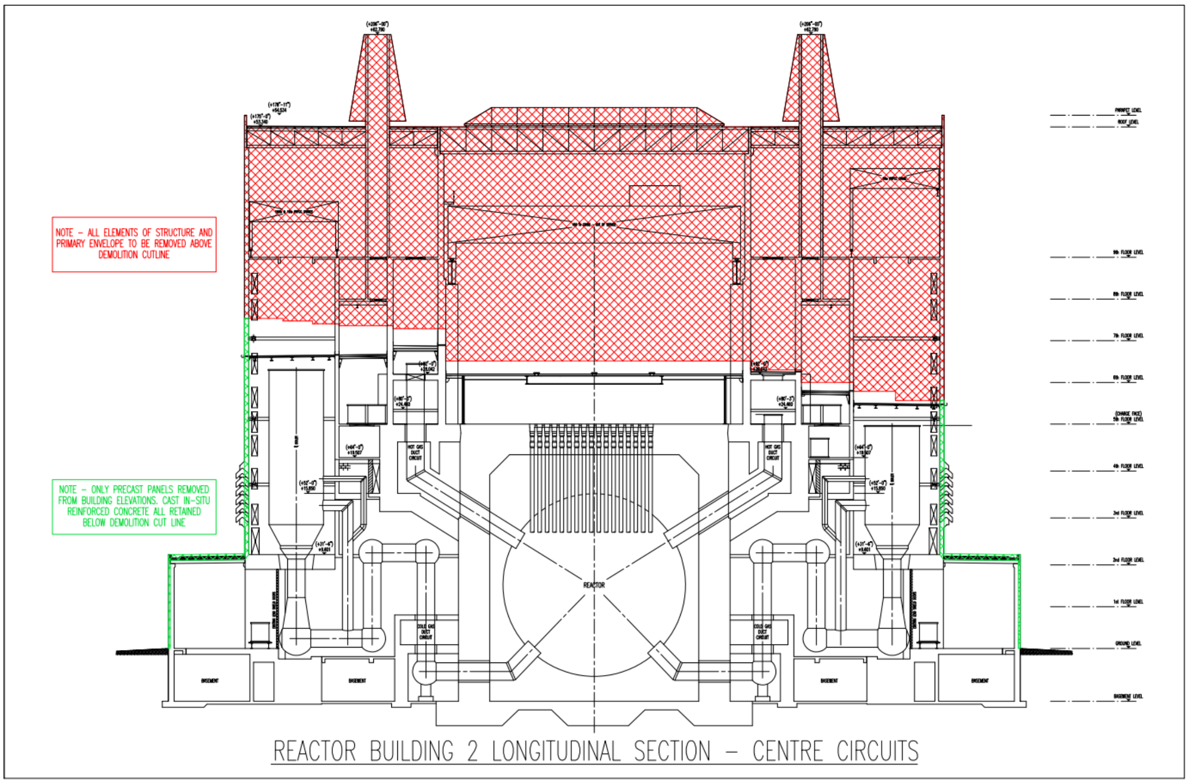


REACTOR BUILDING CROSS SECTION (TYPICAL)

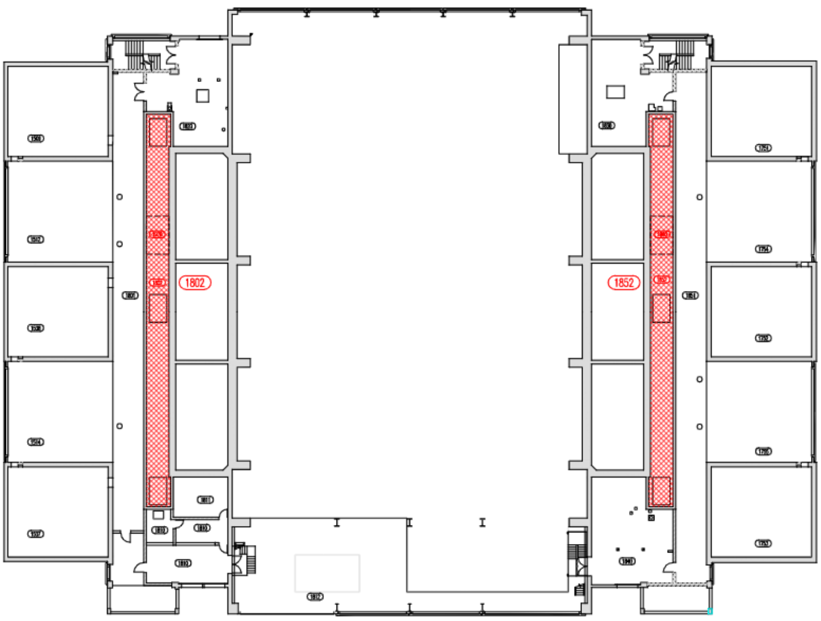


REACTOR BUILDING 1 LONGITUDINAL SECTION – CENTRE CIRCUITS

[12] Red shading designates the areas to be removed.



Plan elevation illustrating the Upper Plenums on R1.



REACTOR BUILDING 1
8TH FLOOR

Appendix B: History and Provenance

Reactor Operations

Construction of the two reactors at Trawsfynydd commenced in 1959, and electricity was first supplied to the grid in 1965. The site ceased electricity generation in 1991 (during a routine outage). Permanent shutdown was subsequently announced in 1993 after 26 years of operation.

Broadly, the structures to be removed from the reactor buildings during the Height Reduction programme were used in connection with:

- Re-fuelling / removal of spent fuel and reactor core furniture (Charge Halls and FMMBs);
- Distribution of coolant gas and steam generation (Boiler Boxes, Top Duct Areas, Hot Gas Duct Cells); and
- Cooling and ventilation of the space between the reactor pressure vessel (RPV) and the bioshield (Shield Fan Rooms, Ducts and Stacks).

These are illustrated in Appendix D: Photographs of structures to be removed by the Height Reduction programme.

Access to the reactor for operations such as fuelling/de-fuelling was via the standpipes in the Charge Hall. Fuelling machines used in such operations were maintained in the FMMB.

Each reactor was connected to 6 boilers by hot and cold gas ducts which circulated the coolant gas (carbon dioxide) thereby providing a source of heat to the boilers as the basis of electricity generation and maintaining a safe reactor core temperature during operations. The boilers were large, mild steel heat exchangers or steam raising units, of which there are six per reactor. The boilers are housed in individual 'boiler boxes', with three at each of the North/South ends of each building. The hot and cold gas ducts are mild steel ducts that were routed through the building, radiating out from the RPV, and connecting to the boiler units. The hot gas ducts exit the bioshield into the hot gas outlet duct chamber areas located on 3rd/4th floor whilst the cold gas ducts enter from the cold gas duct inlet areas within the basement. There are six hot and six cold gas ducts per Reactor Building, each pair forming one of the primary circuits. There are two central circuits per Reactor and four wing circuits, at which there are greater lengths of ductwork between the reactor pressure vessel and the bioshield.

Post Operational Phase

Following de-fuelling of the reactors in 1995, and in accordance with the site planning agreement, work commenced to re-profile the reactor buildings. The upper sections of the boilers and the majority of the hot gas ducts were removed, size-reduced and placed within the boiler interspaces awaiting removal as part of final site clearance. A capping roof was installed at approximately 4 metres above each reactor charge face which extends over the boiler houses and the FMMB to provide complete weather protection for each building. The capping roof is raised and lowered in the direction of site north/south as illustrated for reactor building 1 in the diagram at Appendix A (for reactor building 2, the profiling of the capping roof is a mirror image of reactor building 1).

Following the removal of the boilers and hot duct sections each reactor building was the subject of a thorough environmental clean between 2001 and 2021 that primarily focussed on removing asbestos. Surfaces at the time of the environmental clean were surveyed using a combination of surface beta contamination probes (EP15) and radiation probes. The records from those surveys were not well preserved and only information on radiation dose-rates was available at the time of planning characterisation work during 2021/22. Some historic sampling had been undertaken throughout the reactor buildings indicating that levels of radioactivity in the building fabric were likely to be consistent with Out-of-Scope categorisation [xxvii]. Unfortunately, the number of samples from the relevant areas was relatively low and analysis was generally limited to on-site high resolution gamma spectrometry and/or tritium analysis and hence was insufficient for the purpose of categorising the materials from those areas for the purpose of disposal and/or further processing.

Although scaffolding had been erected for the purpose of the environmental clean, it had been removed by the time of planning and executing further characterisation activities in 2021/22. Alternative measures were implemented to gain access to the features of interest, noting that these did not enable access to the cranes and gantries and some of the upper sections of walls plus ceilings in the Charge Halls, FMMBs, Top Duct Areas, Hot Gas Duct Cells and Boiler Interspaces.

Appendix C: Mechanisms for Potential Radioactivity and Level of Radiological Risk

In descending order of likelihood, mechanisms whereby materials may have become radioactive are:

- Internal contamination of the discharge stack by the shield cooling extract and any other radioactive environments during reactor operations. Radiological activity in the extract gas would primarily comprise H-3, C-14 and other activation products which may have been deposited on the surface of materials. As in the case of other materials noted below, H-3 may have subsequently diffused into the substrate up to a few millimetres.
- Deposition of airborne radioactive contamination generated during the previous size-reduction and capping of sections of the hot gas ducts and boilers. Whereas local containment was in place during cutting and the areas where cutting was undertaken were subsequently decontaminated, it is possible that some residual contamination remained. If present, this type of contamination would be present as surface deposits. The contamination profile would comprise chiefly of tritium (H-3), carbon-14 (C-14) and chlorine-36 (Cl-36) generated by neutron activation of the reactor graphite and in-core furniture which would have been transported by the coolant gas through the primary circulation system and deposited to varying degrees on the internal surfaces of the Hot Gas Ducts and Boilers. Fission products and actinides are not considered likely due to limited fuel failure history at Trawsfynydd. Deposits of radionuclides generated through activation of mild steel are credible: although cobalt-60 (Co-60) and iron-55 (Fe-55) will have likely decayed to very low levels there may be nickel-63 (Ni-63) present.
- Airborne radioactive contamination may have been generated within the Charge Hall during re-fuelling or de-fuelling operations, or the extraction of in-core components such as control rods. If present, this would be deposited on the surface of features such as the walls, roof trusses and crane rails which are above the level of the capping roof and would be expected to mainly comprise H-3 and C-14 plus radionuclides produced by activation of reactor steelwork.
- Materials closer to the reactor pressure vessel (RPV) may have been activated over time, yielding radionuclides such as C-14, H-3, calcium-41 (Ca-41) and europium isotopes in the concrete, and Co-60, Fe-55 and Ni-63 in any reinforcing steel. These radionuclides would be present within the materials in question, albeit their locations are limited toward materials closest to the reactor pressure vessel (RPV).

Cranes in the Charge Hall and Fuelling Machine Maintenance Bay (FMMB) were used to manoeuvre the fuelling machines. The fuelling machines would have been internally contaminated but were designed to provide a seal against contamination as well as shielding to protect workers. Nevertheless, small airborne releases during the process of re-fuelling and de-fuelling cannot be discounted. A similar role in respect of worker protection was provided by the bioshield and standpipe closure assemblies engineered within the charge face, although these are outside of the scope of the Height Reduction project.

During operational stand-downs, fuelling machines may have been transferred to the Fuelling Machine Maintenance Bay adjacent to the Charge Hall for maintenance. Engineered enclosures would have been used to prevent the spread of contamination during maintenance activities but it is possible that small quantities of contamination may have been released on occasion which may not have been completely removed afterwards.

It is possible that surfaces of the building fabric in the vicinity of the hot gas ducts and boilers (i.e., the 131' areas, boiler boxes, Hot Gas Duct Cells) may have been exposed to gas leaks from the primary circuit during operation, however it is more likely that any contamination in these areas is associated with subsequent size-reduction of the boilers and primary circuit. The environmental clean is expected to have removed contamination within the structures to be demolished and pre-existing analysis data from these areas indicate tritium activity in the concrete is very low and well below the 100 Bq/g out-of-scope threshold under the Environmental Permitting Regulations.

The interspace between the RPV and the bioshield was extracted through a system contained in rooms between the hot gas duct and the boilers. In addition to universally controlling temperature through induced air flow, the shield cooling air system was designed to prevent undesirable build-up of air activity within the vault by introducing frequent air change. The design featured three inlet systems (operable independently or in unison) and one common extraction system. From the head ring main internal to the biological shield, air was bled off via wing circuit 'take-off' points and ducted to the north/south sides of the building. The exhaust fans, sited at either end of the 75' level, drew the air through the filter inlet rooms at 52' level and through oil precipitate filter banks into the filter outlet rooms. The filtered air then passed up to the lower plenum at 64' level before entering a vertical duct system and eventually discharging into a communal north/south upper plenum at 117' level and out to atmosphere through the stack. The vertical metal ducts have already been removed.

Pre-cast concrete panels which line the outside of the reactor buildings down to ground floor on the east and west faces should not be affected by radioactive or non-radioactive contamination. Similarly, the louvres and precast panels to north/south that are due to be removed are not anticipated to be contaminated.

For ease of assessment, reactor safestore structures within the scope of the Height Reduction project were sub-divided between six zones with distinct contaminating mechanisms summarised below. A complimentary zoning scheme was established for non-radiological properties, however the primary focus of characterisation was the radiological properties :

Table 17: Initial zoning of each reactor building

Zone	Geographical Area	Anticipated Properties
1	Roof (excluding discharge stack); pre-cast concrete panels; and louvres	External features that should have little or no exposure to radioactive contamination
2	Shield Cooling Discharge Stack	Potential for activity in the internal surfaces, generated in the interspace between the RPV and bioshield

3	Cranes and rails	Possible exposure to airborne contamination which would likely be concentrated in a surface paint layer
4	Top Duct Area; the 6 Boiler Boxes above the level of the capping roof; and the 6 Hot Gas Duct Cells	Possible contamination of the walls and floor resulting from historical size-reduction of the top ducts and boilers, and gas leaks during reactor operations
5	Charge Hall and Fuelling Machine Maintenance Bay Walls	Possible contamination of the walls and floor stemming from operation and maintenance activities in the fuelling machines
6	Stairwells, Shield Fan Rooms, Boiler Interspaces and roof trusses	Relatively low potential for contamination

Appendix D: Photographs of structures to be removed by the Height Reduction programme

Charge Hall including crane and gantry

Charge Hall with 1 x 9 metre strip for surveying

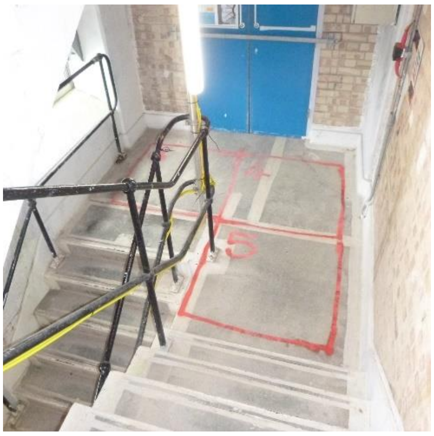
Boiler Box viewed from above

Boiler Box with grids

FMMB with 1 x 10 metre strip for surveying

Interspace with grids


Hot Gas Duct Cell


Stairs with grids


Shield Cooling Fan Room


Shield Cooling Fan Room with grids


Top Duct Area


Top Duct Area with grids

Reactor roof indicating Shield Cooling Stack

Appendix E: Survey Schedule

Zone	Description	Space	Probe type	Coverage	Additional information
1	Roof	R1 Main roof (1E91) R2 Main roof (2E91)	Beta probe Gamma survey[13]	A circle with area approximately 20 m^2 around each discharge stack	The monitoring area to be extended in 20m^2 increments up to the full surface area of the roof in the event that contamination is identified.
2	Shield Cooling Discharge Stack	2 stacks per RB R1 south (1970) & R1 north (1960) R2 south (2960) & R2 north (2970)	Beta probe Gamma survey[13]	100% of internal surfaces within the upper plenum and accessible areas where it is safe to do so	Due to access limitations monitoring will likely have to be carried out following removal from the Safestore as part of demolition.
4	131' Area; the 6 Boiler boxes above the level of the capping roof; and the 6 Hot Gas Duct Cells	1901 Top Duct Area - South 1951 Top Duct Area – North (R2 = 2901 north & 2951 south)	Beta probe	25% of all floors and walls to a maximum height of 4m. At 4 locations along the shear wall monitor a strip 1m wide between the floor and the maximum safe working height (nominally 10 to 12 metres)	Subdivide the walls and floors into 1m^2 sections. Uniquely identify each section then monitor a selection of these to provide even coverage of the defined feature (noting the defined % coverage).
			Gamma survey[13]	As above	
		1751 Boiler Box -	Beta probe	100% of opposing faces per boiler box (2 faces in total) up to a safe working height,	In the event that contamination is identified, monitor the

[13] Reference to Gamma survey in this schedule require a large area survey using an uncollimated low resolution gamma detector (Ludlum 44-10) targeting the location of highest recorded gamma activity.

Zone	Description	Space	Probe type	Coverage	Additional information
		Northwest Cct 4 (upper) 1752 Boiler Box - North Cct 5 (upper) 1753 Boiler Box - Northeast Cct 6 (upper) R2 (2751, 2752 & 2753)		nominally 4m. To include all faces of the strengthening steel.	remaining faces at the corresponding height.
			Gamma survey[13]	As per beta surveys of the boiler boxes	Only undertake further LRGS survey of the remaining boiler boxes if there is evidence of enhanced radioactivity distinguishable from NORM
		1509 Boiler Box - Southwest Cct 3 (upper) 1508 Boiler Box - South Cct 2 (upper) 1507 Boiler Box - Southeast Cct 1 (upper) R2 = 2509, 2508, 2507	Beta probe	100% of opposing faces per boiler box (2 faces in total) up to a safe working height, nominally 4m. To include all faces of the strengthening steel.	In the event that contamination is identified, monitor the remaining faces at the corresponding height.
			Gamma survey[13]	As per beta surveys of the boiler boxes	Only to be undertaken subject to review of LRGS data for the north circuit boiler boxes.
		1761 Hot Gas Duct Cell - Northwest Cct 4 (upper) 1762 Hot Gas Duct Cell - North Cct 5 (upper)	Beta probe	100% of opposing faces per Hot Gas Duct Cell (2 faces in total) up to a safe working height, nominally 4m	
			Gamma survey[13]	100% of each face of 3 of the hot duct cells up to a maximum of 4m.	Only undertake further LRGS survey of the remaining hot

Zone	Description	Space	Probe type	Coverage	Additional information
		1763 Hot Gas Duct Cell - Northeast Cct 6 (upper) R2 = 2761, 2762, 2763			duct cells if there is evidence of enhanced radioactivity distinguishable from NORM
		1603 Hot Duct Cell - Southwest Cct 3 (upper) 1602 Hot Duct Cell - South Cct 2 (upper) 1601 Hot Duct Cell - Southeast Cct 1 (upper) R2 = 2603, 2602, 2601	Beta probe	100% of opposing faces per Hot Gas Duct Cell (2 faces in total) up to a safe working height, nominally 4m	
			Gamma survey[13]	100% of each face of 3 of the hot duct cells up to a maximum of 4m.	Only to be undertaken subject to review of LRGS data for the north circuit hot duct cells.
5	Charge Hall and Fuelling Machine Maintenance Bay walls	1610 Charge Hall walls (above capping roof) R2 = 2610	Beta probe	A 1m-wide strip from the floor up to a maximum safe working height, nominally 12m on the north wall. Two x 1m-wide strip from the floor up to a maximum safe working height, nominally 12m on the south wall. Strips to be separated by at least 5m from each other	
			Gamma survey[13]		
			Beta probe		

Zone	Description	Space	Probe type	Coverage	Additional information
		1670 & 1812 Fuelling Machine Maintenance Bay R2 = 2670 & 1812	Gamma survey[13]	A 1m-wide strip from the floor up to a maximum safe working height, nominally 12m on the north wall. Two x 1m-wide strips from the floor up to a maximum safe working height, nominally 12m on the south wall. Strips to be separated by at least 5m from each other	
6	Stairwells, Shield Fan Rooms, Boiler Interspaces and roof trusses	N/A	Beta probe	50% of stair landings and handrails around the landings 50% of roof trusses 50% of all walls in the Shield Fan Room to a maximum height of 4m.100% of 1 face per each of the boiler interspaces to a safe working height, nominally 4m, alternating between north, south, west and east faces	

Appendix F: Sample Schedule

Zone	Description	Sample type	Sample number	Sample locations[14]	Analytes[15]
1 & 12	Roof (excluding discharge stack); cast in-situ reinforced concrete; pre-cast concrete panels; and louvres / Damp proofing and roofing materials	Roofing felt / plastic (~ 50 mm diameter coupons); Cast in-situ reinforced concrete (~200 g from top 20 – 30 mm), avoiding steel reinforcing bar	40 total comprising 20 roofing felt / plastic and 20 concrete (15 of these due to be held in reserve on site)[16]	Any areas of suspected contamination and/or elevated activity identified in the initial survey to be specifically targeted. Otherwise, random locations but ~ 80% of samples should be taken downwind of the discharge stacks (dominant wind direction is south westerly). At least 10 of the roofing samples should be taken < 5 metres away from the discharge stacks. Pre-cast concrete panels will not be sampled so not to compromise their functional purpose. Most (if not all) louvres have been removed and do not require sampling.	25 x H-3 and C-14 (pre-digestion) 25 x HRGS; gross alpha; gross beta (post-digestion) Up to 5 x Sr-90, Cl-36 and Tc-99 (to be specified by NRS IC following reporting of analytes above) 2 x EPA PAH 16 suite, benzopyrene (CAS 50-32-8), Coronene, Phenol, and Cresol)
2	Shield Cooling Discharge ducting and stack, including the upper plenum	Concrete (~ 200 g from top 20 – 30 mm)	48 (15 of these to be held in reserve at site)	24 samples to be taken from each of the two discharge ducts. These should comprise 4 samples from the area of the internal perimeter drainage channel (one from each face of the stack) and 20 samples from the upper plenum around	33 x H-3 and C-14 (pre-digestion) 33 x HRGS; gross alpha; gross beta (post-digestion) Up to 5 x Sr-90, Cl-36 and Tc-99 (to be specified by NRS IC following reporting of analytes above)

[14] The precise sampling locations for each zone will be agreed between the SME and site management following review of the radiological survey data, i.e. during Hold Point 1.
[15] Analysis requirements here are indicative. The full set of required analysis will be set out in a separate Analytical Scope of Work (ASOW).
[16] Sampled areas of the roof will require patch repair. Appropriate methods for repair of both concrete and liquid plastic areas have been identified by site and will be self-performed by site.

Zone	Description		Sample type	Sample number	Sample locations[14]	Analytes[15]
					the vicinity of the discharge stack. Upper plenum samples should be targeted at areas of suspected contamination and/or elevated activity, otherwise random locations. At least two of the samples should be taken from areas stained with black oil residues. Sample locations should be away from Asbestos Contaminated Material (ACM).	2 x TPH(C6-C40) Petroleum Group and benzo(a)pyrene
4 & 7	131' Area; the six Boiler Boxes above the level of the capping roof; and the six Hot Gas Duct Cells.	Internal walls & floors	Concrete (~ 200 g from top 20 – 30 mm)	40	5 samples from each of the 131' areas (10 total), 3 samples from each of the six hot gas duct cells (18 total) and 2 samples from each of the six boiler boxes (12 total). At least 2 of the samples taken from each gas hot duct cell should be from the floor, i.e., the concrete surface closest to the reactor neutron flux. Any areas of suspected contamination and/or elevated activity identified in the initial survey to be specifically targeted. Otherwise, random locations spanning the accessible areas. Sample locations should be away from Asbestos Contaminated Material (ACM).	40 x H-3 and C-14 (pre-digestion) 40 x HRGS; gross alpha; gross beta (post-digestion) Up to 12 x Sr-90, Cl-36, Ca-41 and Tc-99 (to be specified by NRS IC following reporting of analytes above) 5 x Acid-soluble sulphate content

Zone	Description		Sample type	Sample number	Sample locations[14]	Analytes[15]
		Potentially activated metals directly below the hot gas duct cells	Mild steel annulus plate (~ 200 g)	6 (4 of which to be held in reserve on site)	Sixth floor annulus plates at the high end of the reactor buildings. Take 2 samples from each of the 3 annulus plates adjacent to the 3 hot gas duct cells at the high end of the reactor building, giving a total of 6 samples. Samples should preferentially be taken from the side of the plate closest to the reactor. If sampling of the annulus plate is not possible, scissor plates that originally capped the annulus should instead be sampled. These are now located at the fifth floor. Identification of significant activation in these samples, or in concrete from the hot gas duct cells, may prompt the additional requirement for sampling from the steel reinforcing bar within concrete in the hot gas duct cells	2 x H-3 and C-14 (pre-digestion) 2 x HRGS; gross alpha; and gross beta 2 x Fe-55 and Ni-63
5 & 9	Charge Hall and Fuelling Machine Maintenance Bay walls		Paint (scrapings covering an area of ~ 300 cm^2); Concrete (~ 200 g from top 20 – 30 mm)	50 total comprising 45 paint samples and 5 concrete samples (~ 25 samples	All paint samples must be from original paint layers and not from any areas that were painted at a later date. At least 2 paint samples to be taken from the mezzanine stairwell. Concrete samples should preferentially be taken from any joints / cracks, i.e., areas where contamination may have accumulated. Any areas of elevated activity identified in	25 x H-3 and C-14 (pre-digestion) 25 x HRGS; gross alpha; gross beta(post-digestion) Up to 5 x Sr-90, Cl-36, and Tc-99 (to be specified by NRS IC following reporting of analytes above) 5 x paint samples for lead (Pb)

Zone	Description	Sample type	Sample number	Sample locations[14]	Analytes[15]
			will be held in reserve on site)	the initial survey to also be specifically targeted. Otherwise, random locations spanning the accessible areas. Sample locations should be away from Asbestos Contaminated Material (ACM).	
		Concrete with evidence of oil contamination (~ 200 g from top 20 – 30 mm)	5	Where present.	5 x H-3 and C-14 (pre-digestion) 5 x HRGS; gross alpha; gross beta(post-digestion) 5 x TPH(C6-C40) Petroleum Group and benzo(a)pyrene
6	Stairwells, Shield Fan Rooms, Boiler Interspaces, and roof trusses	Concrete (~ 200 g from top 20 – 30 mm)	40 (15 samples will be held in reserve on site)	All samples should be taken from the Shield Fan Rooms and the Boiler Interspaces, unless surveys indicate the presence of contamination in the stairwells. Any other areas of suspected contamination and/or elevated activity identified in the initial survey to be specifically targeted. Otherwise, random locations spanning the accessible areas. Sample locations should be away from Asbestos Contaminated Material (ACM).	25 x H-3 and C-14 (pre-digestion) 25 x HRGS; gross alpha; gross beta(post-digestion) Up to 5 x Sr-90, Cl-36, and Tc-99 (to be specified by NRS IC following reporting of analytes above)
10	Batteries	Whole batteries	2 (if present; may have already been	Where present.	Mercury It may be possible to confirm from a written description in each case whether the batteries in question contain mercury or other materials with hazardous

Zone	Description	Sample type	Sample number	Sample locations[14]	Analytes[15]
			removed and disposed)		properties, and it may be possible to obtain information from a relevant Safety Data Sheet in which case analysis is not required.
11	131' Area and the following areas above the level of the capping roof: the 6 Boiler boxes; the 6 Hot Gas Duct Cells; Stairwells; Shield Fan Rooms; and Boiler Interspaces	Bulk oils	No bulk oils are expected. However, if present, ~ 5 samples.	Where present.	TPH(C6-C40) Petroleum Group and benzopyrene

Appendix G: Photographs of roofing felt

Roofing felt samples illustrating the mixture of the original felt (black) and insulation materials (brown)

Appendix H: Assessment of fingerprints against EPR and RP113 clearance limits

9G105 Fingerprint decay correct to 2021		**RP113 surface clearance limits for demolition (Bq/cm2)**	**% / RP113 limit**	**Normalised activities (Bq/cm2) corresponding to RP113 clearance threshold**		**EPR limits (Bq/g)**	**%/EPR limit**	**Normalised activities (Bq/g) corresponding to EPR clearance threshold**
Radionuclide	**%**							
H-3	56.7628	10000	0.005676	13.64832008		100	0.567628	1.156110643
C-14	28.1935	10000	0.002819	6.778980464		10	2.81935	0.574228287
Cl-36	0.3663	100	0.003663	0.08807493		1	0.3663	0.007460579
Mn-54	0	10	0	0		0.1	0	0
Fe-55	1.5078	10000	0.000151	0.362542669		1000	0.001508	0.030709965
Co-60	4.1105	1	4.1105	0.98834835		0.1	41.105	0.083720197
Ni-63	8.7313	100000	8.73E-05	2.099395681		100	0.087313	0.177833878
Zn-65	0	10	0	0		0.1	0	0
Nb-94	0.0081	10	0.00081	0.001947603		0.1	0.081	0.000164976
Ag-108m	0.0355	10	0.00355	0.00853579		0.1	0.355	0.000723043
Sb-125	0.0002	10	0.00002	4.8089E-05		0.1	0.002	4.07348E-06
Ba-133	0.0271	10	0.00271	0.006516054		0.01	2.71	0.000551957
Cs-137	0.0701	10	0.00701	0.01685518		1	0.0701	0.001427755
Eu-152	0.0219	10	0.00219	0.005265741		0.1	0.219	0.000446046
Eu-154	0.0504	10	0.00504	0.012118418		0.1	0.504	0.001026517
Eu-155	0.0019	100	0.000019	0.000456845		1	0.0019	3.86981E-05
Sr-90	0.0676	100	0.000676	0.016254068		1	0.0676	0.001376836
Ru-106	0	100	0	0		0.1	0	0
I-129	0	10	0	0		0.01	0	0
Cs-134	0	10	0	0		0.1	0	0
Ce-144	0	100	0	0		10	0	0
Pm-147	0.0001	10000	1E-08	2.40445E-05		1000	1E-07	2.03674E-06
U-234	0	10	0	0		1	0	0
U-235	0	10	0	0		1	0	0
Pu-238	0.0013	1	0.0013	0.000312578		0.1	0.013	2.64776E-05
U-238	0	10	0	0		1	0	0
Pu-239	0.0018	1	0.0018	0.000432801		0.1	0.018	3.66613E-05
Pu-240	0.0023	1	0.0023	0.000553023		0.1	0.023	4.6845E-05
Am-241	0.0083	1	0.0083	0.001995692		0.1	0.083	0.000169049
Pu-241	0.0307	100	0.000307	0.007381655		10	0.00307	0.000625279
Cm-243	0	10	0	0		1	0	0
Cm-244	0.0003	10	0.00003	7.21334E-05		1	0.0003	6.11022E-06
		Total	**4.158959**	**24.04443189**		Total	**49.09807**	**2.024766539**

Area 2970 HLDC debris-derived fingerprint		**RP113 surface clearance limits for demolition (Bq/cm2)**	**% / RP113 limit**	**Normalised activities (Bq/cm2) corresponding to RP113 clearance threshold**		**EPR limits (Bq/g)**	**%/EPR limit**	**Normalised activities (Bq/g) corresponding to EPR clearance threshold**
Radionuclide	**%**							
H-3	56.824405	10000	0.005682	7.554479498		100	0.568244	0.622760973
C-14	20.4018314	10000	0.00204	2.712306743		10	2.0401831	0.223591683
Cl-36	11.2377989	100	0.112378	1.49400106		1	11.237799	0.123159452
Mn-54		10	0	0		0.1	0	0
Fe-55	2.06079105	10000	0.000206	0.273970378		1000	0.0020608	0.022585018
Co-60	7.35397101	1	7.353971	0.977668368		0.1	73.53971	0.080595057
Ni-63	1.60474562	100000	1.6E-05	0.213341748		100	0.0160475	0.017587038
Zn-65		10	0	0		0.1	0	0
Nb-94	0.02194361	10	0.002194	0.002917277		0.1	0.2194361	0.000240489
Ag-108m	0.0529318	10	0.005293	0.00703698		0.1	0.529318	0.0005801
Sb-125		10	0	0		0.1	0	0
Ba-133		10	0	0		0.01	0	0
Cs-137	0.10261976	10	0.010262	0.01364271		1	0.1026198	0.00112465
Eu-152	0.26027028	10	0.026027	0.034601444		0.1	2.6027028	0.002852404
Eu-154	0.03434652	10	0.003435	0.004566173		0.1	0.3434652	0.000376417
Eu-155	0.02030261	100	0.000203	0.002699116		1	0.0203026	0.000222504
Sr-90	0.02404256	100	0.00024	0.003196321		1	0.0240426	0.000263492
Ru-106		100	0	0		0.1	0	0
I-129		10	0	0		0.01	0	0
Cs-134		10	0	0		0.1	0	0
Ce-144		100	0	0		10	0	0
Pm-147		10000	0	0		1000	0	0
U-234		10	0	0		1	0	0
U-235		10	0	0		1	0	0
Pu-238		1	0	0		0.1	0	0
U-238		10	0	0		1	0	0
Pu-239		1	0	0		0.1	0	0
Pu-240		1	0	0		0.1	0	0
Am-241		1	0	0		0.1	0	0
Pu-241		100	0	0		10	0	0
Cm-243		10	0	0		1	0	0
Cm-244		10	0	0		1	0	0
		Total	**7.521948**	**24.07504053**		Total	**91.245931**	**1.095939276**

Appendix I: Summary of Radiological Survey Results

Zone	Reactor building	Area Description	Area Code	Sub-description	Survey Report Ref	BP19 background (cps b/g)	BP19 maximum integrated count-rate over a 1m2 square (cps b/g)	BP19 maximum count-rate within a 1m2 square (cps b/g)	Ludlum 44-10 background (cps b/g)	Ludlum 44-10 max result (cps b/g)
1	R1	reactor roof around south stack	1E91	N/A	TRA-HR-2021-Area-1E91-Survey-Report	6.8	7.6	10.5	30	40
		reactor roof around north stack		N/A		6.8	7.6	10.5	30	40
	R2	reactor roof around south stack	2E91	N/A	TRA-HR-2021-Area-2E91-Survey-Report	8	9.8	13.5	45	48
		reactor roof around north stack		N/A		8	10.4	14.2	45	53
2	R1	south stack	1970	Internal surfaces	Not undertaken due to access constraints	N/A	N/A	N/A	N/A	N/A
		north stack	1960	Internal surfaces	Not undertaken due to access constraints	N/A	N/A	N/A	N/A	N/A
	R2	south stack	2960	Internal surfaces	Not undertaken due to access constraints	N/A	N/A	N/A	N/A	N/A
		north stack	2970	Internal surfaces	Not undertaken due to access constraints	N/A	N/A	N/A	N/A	N/A
	R1	Shield Cooling Discharge (Upper) Plenum - North	1852	N/A	TRA-HR-2021-Area-1852-Survey-Report	12.5	16.9	20.4	68	74
		Shield Cooling Discharge (Upper) Plenum - South	1802	N/A	TRA-HR-2021-Area-1802-Survey-Report	12.2	16	24	65	78

Zone	Reactor building	Area Description	Area Code	Sub-description	Survey Report Ref	BP19 background (cps b/g)	BP19 maximum integrated count-rate over a 1m2 square (cps b/g)	BP19 maximum count-rate within a 1m2 square (cps b/g)	Ludlum 44-10 background (cps b/g)	Ludlum 44-10 max result (cps b/g)
		Shield Cooling Discharge (Upper) Plenum - South	2852	N/A	TRA-HR-2021-Area-2852-Survey-Report	14.5	17.1	25.1	74	89
	R2	Shield Cooling Discharge (Upper) Plenum - North	2802	N/A	TRA-HR-2021-Area-2802-Survey-Report	12	14.7	18.8	79	89
3	No surveys of cranes and rails undertaken due to access issues									
4	R1	Top Duct Area - South	1901	1m wide x 8m high strips in 4 locations evenly spaced over the wall adjacent to the charge hall	TRA-HR-2021-Area-1901-Survey-Report	11	12.3	16.1	70	84
				Floor central. 2 x 4m2 grids toward the centre of the floor	TRA-HR-2021-Area-1901-Survey-Report	9	14.1	17.5	60	65
				South additional walls. Walls monitored to 2m height around south, east and west sides of the room.	TRA-HR-2021-Area-1901-Survey-Report	11.4	14.5	21.4	54	76
				South east floor. 70m2 area.	TRA-HR-2021-Area-1901-Survey-Report	10.5	15.5	22.2	59	69
				South west floor. 70m2 area.	TRA-HR-2021-Area-1901-Survey-Report	11	14.4	20.9	59	71
	R1	Top duct area - north	1951	1m wide x 8m high strips in 4 locations evenly spaced over the wall adjacent to the charge hall	TRA-HR-2021-Area-1951-Survey-Report	14	12.4	16.3	74	83

Zone	Reactor building	Area Description	Area Code	Sub-description	Survey Report Ref	BP19 background (cps b/g)	BP19 maximum integrated count-rate over a 1m2 square (cps b/g)	BP19 maximum count-rate within a 1m2 square (cps b/g)	Ludlum 44-10 background (cps b/g)	Ludlum 44-10 max result (cps b/g)
				Floor central	TRA-HR-2021-Area-1951-Survey-Report	13	13.8	19.4	62	64
				North additional walls. Walls monitored to 2m height around north, east and west sides of the room.	TRA-HR-2021-Area-1951-Survey-Report	11.1	13.1	20.6	53	71
				North east floor	TRA-HR-2021-Area-1951-Survey-Report	9	14.2	20.4	65	68
				North east wall. Wall monitored to 2m high	TRA-HR-2021-Area-1951-Survey-Report	10	11.9	19	60	66
				North west floor	TRA-HR-2021-Area-1951-Survey-Report	10	14.2	19.7	58	70
				North west wall. Wall monitored to 2m high	TRA-HR-2021-Area-1951-Survey-Report	8.5	12	16	52	75
	R2	Top duct area – north	2901	1m wide x 8m high strips in 4 locations evenly spaced over the wall adjacent to the charge hall	TRA-HR-2021-Area-2901-survey report columns	10.5	12.5	15.6	68	85
				Walls	TRA-HR-2021-Area-2901-survey report floors	10.8	14.7	19.2	60	67
				Floors	TRA-HR-2021-Area-2901-survey report walls	11.2	15.1	20.9	64	69
		Top duct area – south	2951	columns. 1m wide x 8m high strips in 4 locations evenly spaced over the wall adjacent to the charge hall	TRA-HR-2021-Area-2951-survey report columns	10.5	12.5	19.5	68	88

Zone	Reactor building	Area Description	Area Code	Sub-description	Survey Report Ref	BP19 background (cps b/g)	BP19 maximum integrated count-rate over a 1m2 square (cps b/g)	BP19 maximum count-rate within a 1m2 square (cps b/g)	Ludlum 44-10 background (cps b/g)	Ludlum 44-10 max result (cps b/g)
				walls	TRA-HR-2021-Area-2951-survey report walls	10.9	14.8	22.3	55	70
				floors	TRA-HR-2021-Area-2951-survey report floors	8.7	16.1	21.1	60	73
	R1	Boiler box	1751	Boiler box 4 NW upper. All 4 faces to a max height of 2m	TRA-HR-2021-Area-1751-Survey-Report	12.8	13	17	62	87
		Boiler box	1752	Boiler box 5 north. All 4 faces to a max height of 2m	TRA-HR-2021-Area-1752-Survey-Report	12.2	13.3	19	55	96
		Boiler box	1753	Boiler box 6 NE. All 4 faces to a max height of 2m	TRA-HR-2021-Area-1753-Survey-Report	12.2	10.8	15.9	58	70
		Boiler box	1509	Boiler box 3 SW upper. All 4 faces to a max height of 2m	TRA-HR-2021-Area-1509-Survey-Report	13	14.9	18.6	62	70
		Boiler box	1508	Boiler box 2 S upper. All 4 faces to a max height of 2m	TRA-HR-2021-Area-1508-Survey-Report	10.5	12.3	16.5	63	67
		Boiler box	1507	Boiler Box - Southeast Cct 1 (upper). All 4 faces to a max height of 2m	TRA-HR-2021-Area-1507-Survey-Report	11.5	12.2	15.8	65	68
	R2	Boiler box	2751	Boiler Box - Southwest Cct 9 (upper)	TRA-HR-2021-Area-2751-Survey Report	9	12.6	14	60	77.5
		Boiler box	2752	Boiler Box - South Cct 8 (upper)	TRA-HR-2021-Area-2752-Survey Report	9.5	14.9	19.4	66	93
		Boiler box	2753	Boiler Box - Southeast Cct 7 (upper)	TRA-HR-2021-Area-2753-Survey Report	10.7	13.2	18.2	56	69
		Boiler box	2509	Boiler Box Northwest Cct 10 (upper)	TRA-HR-2021-Area-2509-Survey-Report	10	13.9	17.7	52	71.1

Zone	Reactor building	Area Description	Area Code	Sub-description	Survey Report Ref	BP19 background (cps b/g)	BP19 maximum integrated count-rate over a 1m2 square (cps b/g)	BP19 maximum count-rate within a 1m2 square (cps b/g)	Ludlum 44-10 background (cps b/g)	Ludlum 44-10 max result (cps b/g)
		Boiler box	2508	Boiler Box North Cct 11 (upper)	TRA-HR-2021-Area-2508-Survey-Report	12.3	13.5	15.4	60.5	72.1
		Boiler box	2507	Boiler Box Northeast Cct 12 (upper)	TRA-HR-2021-Area-2507-Survey-Report	9.6	12.4	14.6	61	68.2
	R1	Hot Gas Duct monitored to 2m height	1761	Hot duct cell Northwest Cct 4 (upper)	TRA-HR-2021-Area-1761-Survey-Report	14	15.2	18.4	63	69
	R1	Hot Gas Duct monitored to 2m height	1762	Hot duct cell North Cct 5 (upper)	TRA-HR-2021-Area-1762-Survey-Report	12	14.4	17.2	60	68
	R1	Hot Gas Duct monitored to 2m height	1763	Hot duct cell Northeast Cct 6 (upper)	TRA-HR-2021-Area-1763-Survey-Report	11	14.6	19.5	60	69
	R1	Hot Gas Duct monitored to 2m height	1601	Hot Gas Duct West	TRA-HR-2021-Area-1601-Survey-Report	12.3	13	20	66	70
	R1	Hot Gas Duct monitored to 2m height	1602	Hot Gas Duct Centre	TRA-HR-2021-Area-1602-Survey-Report	10	11.5	18	61	74
	R1	Hot Gas Duct monitored to 2m height	1603	Hot Gas Duct East	TRA-HR-2021-Area-1603-Survey-Report	10	12	17.6	61	69
	R2	Hot Gas Duct monitored to 2m height	2761	Hot Duct Cell - Southwest Cct 9 (Upper)	TRA-HR-2021-Area-2761-Survey-Report	10	14.1	17.9	56	68
	R2	Hot Gas Duct monitored to 2m height	2762	Hot Duct Cell - South Cct 8 (Upper)	TRA-HR-2021-Area-2762-Survey-Report	10.2	13.6	26.3	59	71
	R2	Hot Gas Duct monitored to 2m height	2763	Hot Duct Cell - Southeast Cct 7 (Upper)	TRA-HR-2021-Area-2763-Survey-Report	10.8	13.3	20.9	59	70
	R2	Hot Gas Duct monitored to 2m height	2603	Hot duct cell-Northwest Cct 10	TRA-HR-2021-Area-2603-Survey-Report	10.7	13.2	18.2	58	70

Zone	Reactor building	Area Description	Area Code	Sub-description	Survey Report Ref	BP19 background (cps b/g)	BP19 maximum integrated count-rate over a 1m2 square (cps b/g)	BP19 maximum count-rate within a 1m2 square (cps b/g)	Ludlum 44-10 background (cps b/g)	Ludlum 44-10 max result (cps b/g)
		Hot Gas Duct monitored to 2m height	2602	Hot duct cell - North Cct 11	TRA-HR-2021-Area-2602-Survey-Report	10.2	13.4	19.1	60	70
		Hot Gas Duct monitored to 2m height	2601	Hot duct cell - North east Cct 2	TRA-HR-2021-Area-2601-Survey-Report	10	13.8	18.9	62	68
5	R1	Capping Roof - Charge Hall	1610	Capping Roof Main Area. 3 evenly spaced 1m wide x 9m high strips on the walls adjoining the boiler boxes	TRA-HR-2021-Area-1610-Survey-Report	10.5	11.3	15.3	65	76
	R2	Capping Roof - Charge Hall	2610	Capping Roof Main Area. 3 evenly spaced 1m wide x 9m high strips on the walls adjoining the hot gas duct cells	TRA-HR-2021-Area-2610-Survey-Report	8.6	10.1	16	66	78
	R1	Capping Roof - Maintenance Bay	1670	Capping Roof - Maintenance Bay. 3 1m wide x 10m high strips on the walls adjoining the boiler boxes	TRA-HR-2021-Area-1670-Survey-Report	9.6	11.2	15.8	63	74
		Maintenance Bay Higher Slab (SE)	1812	N/A	Not available					
	R2	Capping Roof - Maintenance Bay	2670	Capping Roof - Maintenance Bay. 3 1m wide x 10m high strips on the walls	TRA-HR-2021-Area-2670-Survey-Report	8.8	11.6	18.6	64	74
		Maintenance Bay Higher Slab (NE)	2812	N/A	Not available					
6	R1	Boiler Interspace	1754	interspace 4/5 NW Upper. Monitored on all sides to a height of 2m	TRA-HR-2021-Area-1754-Survey-Report	12.8	11.4	15	58	64

Zone	Reactor building	Area Description	Area Code	Sub-description	Survey Report Ref	BP19 background (cps b/g)	BP19 maximum integrated count-rate over a 1m2 square (cps b/g)	BP19 maximum count-rate within a 1m2 square (cps b/g)	Ludlum 44-10 background (cps b/g)	Ludlum 44-10 max result (cps b/g)
		Boiler Interspace	1755	Interspace NE. Monitored on all sides to a height of 2m	TRA-HR-2021-Area-1755-Survey-Report	12.6	11	15.7	60	62
		Boiler Interspace	1512	Boiler interspace 2/3 southwest (upper). Monitored on all sides to a height of 2m	TRA-HR-2021-Area-1512-Survey-Report	10.8	15.9	25.2	55	70
		Boiler Interspace	1514	Boiler interspace 1/2 southeast (upper). Monitored on all sides to a height of 2m	TRA-HR-2021-Area-1514-Survey-Report	12	12.8	18.5	64	64
	R2	interspace 10/11	2512	Monitored east/west sides up to 2m	TRA-HR-2021-Area-2512-Survey Report	11.8	13.8	16.8	64	79.2
		interspace 11/12	2514	Monitored east/west sides up to 2m	TRA-HR-2021-Area-2514-Survey Report	10.5	12.1	15.2	55	83.5
	R1	Shield Cooling Fan Room	1771	Shield Cooling Fan Room surveyed to max 1m height	TRA-HR-2021-Area-1771-Survey-Report	14.1	14.9	20.9	65	90
		Shield Cooling Fan Room	1605	Shield Cooling Fan Room 5 (upper)	TRA-HR-2021-Area-1605-Survey-Report	10	16.2	19.2	61	72
	R2	Shield Cooling Fan Room	2605	Shield cooling fan room - North (upper)	TRA-HR-2021-Area-2605-Survey-Report	10.2	15	22.3	62	78
		Shield Cooling Fan Room	2771	Shield cooling fan room	TRA-HR-2021-Area-2771-Survey-Report	10	13.6	23.2	55	68
	R1	Staircase	1131	NW staircase	TRA-HR-2021-Area-1131-Survey-Report	10.9	14.6	12.4	76	99
		Staircase	1111	SE staircase	TRA-HR-2021-Area-1111-Survey-Report	11	13.8	16.4	81	98

Zone	Reactor building	Area Description	Area Code	Sub-description	Survey Report Ref	BP19 background (cps b/g)	BP19 maximum integrated count-rate over a 1m2 square (cps b/g)	BP19 maximum count-rate within a 1m2 square (cps b/g)	Ludlum 44-10 background (cps b/g)	Ludlum 44-10 max result (cps b/g)
		Staircase	1121	SW staircase	TRA-HR-2021-Area-1121-Survey-Report	14.2	13.4	16.9	96	96
		Staircase	1141	NE staircase	TRA-HR-2021-Area-1141-Survey-Report	10	12.4	14.4	80	94
	R2	Staircase	2111	NE staircase	TRA-HR-2021-Area-2111-Survey-Report	9	17.1	20.8	70	77
		Staircase	2121	NW staircase	TRA-HR-2021-Area-2121-Survey-Report	11.2	15.6	19.2	64	96
		Staircase	2131	SW staircase	TRA-HR-2021-Area-2131-Survey-Report	13.4	15.1	20.7	67	72
		Staircase	2141	SE staircase	TRA-HR-2021-Area-2141-Survey-Report	11	16.4	20.3	62	77

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