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DATA QUALITY OBJECTIVES (DQO) RECORD GUIDE

Signature Sheet:					
DQO	Title	**CHARACTERISATION IN SUPPORT OF HEIGHT REDUCTION OF TRAWSFYNYDD REACTOR BUILDINGS**			
DQO No:	TRAWS/L28302/DOC/0041				
Project Manager:	Adrian Jones	DV No:	28302		
Area:	Trawsfynydd	Building:	Reactor Buildings 1 and 2		
System (s):		WSID(s):	*9G317: Concrete (reactor and non-reactor) LLW*		
Author signature:	Alan Fisher	Name:	Alan Fisher	Date:	14/04/2022
		Title:	Principal Consultant: Radiochemistry		
Verifier signature:	J. Wea...	Name:	Joshua Weatherill	Date:	14/04/2022
		Title:	Specialist Engineer		
Stakeholder 1 signature:	[signature]	Name:	Gareth Van Heerden	Date:	14/04/2022
		Title:	Senior Project Engineer		
Stakeholder 2 signature:	Sion Richards	Name:	Sion Richards	Date:	19/04/2022
		Title:	Head of Radiological Protection		
Stakeholder 3 signature:	[signature]	Name:	Thomas Williams	Date:	26/04/22
		Title:	Waste Manager		
Approver signature:	Adrian Jones	Name:	Adrian Jones	Date:	26/4/22
		Title:	Project Manager		
Acceptor signature:	[signature]	Name:	Nigel Wright	Date:	26/04/22
		Title:	Senior Project Manager		

Revision/Change Register: *It is important that the key stakeholders have agreed to the changes made, even though their signatures are not asked for in this standard revision register. This table may need to be adapted to reflect the buy in from those Stakeholders.*

Version & Date of Revision:	Author, Title and Reason for Revision	Approver: (Signature, Title & Date)		Acceptor: (Signature, Title & Date)	
1	Alan Fisher, Principal Consultant: Radiochemistry, New document	N/A		N/A	

Introduction

The Site Programme for entry into Care and Maintenance 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 2024. The work associated with height reduction is constrained to within the Safestores building footprints and includes the following activities:

- Removal of the existing roofs.
- Removal and dismantling of overhead cranes/rails and any remaining plant above the 75' level.
- Removal of external pre-cast concrete cladding panels and supporting steelwork.
- Removal of Framed window units/glazing/profiled metal cladding & louvers.
- Partial demolition of external cast in situ concrete walls and floors, above the proposed cut off level (*just above Capping Roof level.)*
- Removal of internal walls/ floors & staircases above cut line.
- Removal of steel strengthening structures added to Boiler Boxes, 131' floor, PC Panel restraining brackets etc.
- Development of new structures including the phase 2 capping roofs and installation of interspace cladding, which are not considered for the purpose of this DQO report.

This DQO report describes the characterisation activities to be undertaken ahead of height reduction works commencing. Characterisation is needed to inform the approach to removal of built structures and management of the resulting materials. Whereas most of the building structures are assumed to be Out of Scope (OoS) for the purpose of waste sentencing there is potential for some materials to have been contaminated with radioactivity or activated through exposure to neutron flux. Some materials may have hazardous properties that need careful management owing to the potential for residual chemicals (e.g., oils). The use of asbestos was widespread during the construction of the reactor buildings and will be a relevant consideration for the project when determining the preferred approach to decommissioning and waste management. There is, however, a well-advanced programme of asbestos characterisation already in progress including Refurbishment & Demolition surveys scheduled over the coming 5 to 6 months, and hence the assessment of asbestos is deliberately excluded from the scope of this DQO report. The potential for asbestos is still relevant in terms of its potential for harm to personnel engaged in characterisation work and its influence on the packaging, transport, and routing of materials[i].

In order to minimise handling of materials generated during decommissioning and ensure their efficient onward routing, sufficient characterisation shall be conducted to robustly categorise them in their current configuration and inform any segregation activities that will be required during dismantling. This DQO report is to be developed by the Radiological Assessment and Shielding (RA&S) Team in collaboration with the Height Reduction project, site-based EHSS&Q Team, Site Restoration programme and site-based Waste team.

An initial review of data sources referenced above shall confirm their relevance to the characterisation objectives and provide the basis for planning further characterisation activities. Owing to the scale of the materials to be removed (estimated ~4,000 te metals, ~60,000 te concrete and other materials) it is appropriate that the approach to characterisation involves sub-dividing them between several zones with similar characteristics, and considering each zone as distinct from the others. A separate Characterisation Plan shall be developed to guide the acquisition of data and its processing.

1. State The Problem (DQO Stage 1)

The objective of this step is to clearly define the aims and reasoning behind characterisation requirements so that the focus of the project will be unambiguous. (WD/WAN/0226/17 Section 4.1)

Outputs:

- *A concise description of the problem*
- *A conceptual model of the issue(s) to be investigated with a preliminary determination of the type of data needed and how it will be used;*
- *A list of the planning team members and identification of decision makers or principal data users within the planning team; and,*
- *A summary of available resources and relevant deadlines for the study, including budget, availability of personnel, and schedule.*

1.1 Define the scope

An existing capping roof has been installed at approximately 4 metres above each reactor charge face and extends over the boiler houses and the fuel machine maintenance bay 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 rector building 1). It is the intention of this project to remove all structural features and installed equipment above the level of the capping roofs and to install lower profiled roofs which are required to accord with consented planning commitments agreed with external stakeholders.

Specifically, this involves 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 ageing pre-cast concrete panels and louvres external to the reactor building will also be removed and replaced with a modern aesthetically pleasing weatherproof construction.

This DQO report applies to all materials which are intended to be removed under the scope of the Height Reduction project at Trawsfynydd which are listed in the Introduction. The objectives of characterisation are to:

- Determine the nature, quantities and distribution of any radioactivity and chemically hazardous properties within the specified materials ahead of their removal during decommissioning
- Provide sufficient information on these materials in order that the requirement for additional characterisation to enable transport, disposal and re-use/re-cycling activities is minimal at the point of decommissioning
- Assess which of these materials may be treated as OoS for the purpose of onward sentencing in accordance with the Environmental Permitting Regulations[ii] and industry guidance[iii]
- Support an assessment of decontamination as a tool to minimise the volume of radioactive waste requiring to be managed under the site Permit
- Inform the approach to the segregation of wastes by their radioactive or chemical properties, and taking account of onward routes
- Demonstrate compatibility with identified routes for re-use, re-cycling and disposal for the relevant materials.

Characterisation excludes the boilers, top ducts and sections of the hot gas ducts which were previously removed as enablers to height reduction and remain stored on site.

This DQO report does not consider the need to establish data on asbestos as this is already covered under a well-established parallel programme of characterisation. The presence of asbestos is however a relevant consideration in terms of its potential harm to personnel engaged in characterisation activities, and the onward management of affected materials.

Recognising the synergy between this project and the Rolling Programme of Decommissioning (RPD), where it is convenient and there is clear benefit from doing so characterisation works may extend to other areas of the reactor buildings below the level of the capping roofs.

Access to the cranes and rails for the purpose of characterisation is extremely limited due to safety considerations associated with working at height. Although these have been included as discrete zones (see 4.1) they are outside of the scope of this DQO report. They will be removed, segregated and characterised separately during dismantling works.

Appendix A includes an image illustrating the parts of reactor building 1 to be removed during the Height Reduction project.

1.2 State the problem (s).

Problem Statements

We need to prove the radiological categorisation of items and materials that are currently designated as OoS.

For all other items and materials, we need to determine the extent of decontamination that would be required in order to release them as OoS. This will inform the decommissioning approach, including arrangements for segregation and waste management.

We need to determine a credible radioactive inventory(ies) that may be applied to any radioactively contaminated items and materials to a sufficient standard that would enable their transfer under Environmental Permit for further treatment and/or disposal.

For those materials that will be re-used on site (e.g., for landscaping purposes) we need to show that they comply with relevant conditions concerning their non-radioactive properties.

We need to determine the presence of chemically hazardous characteristics in all items and materials which could have a bearing on their transport and onward routing.

To meet the demands of chemical and radiological characterisation a dual zoning approach shall be adopted for both reactor buildings based on their provenance and pre-existing characterisation information. Zones shall be established based on the potential for chemical hazards, and these shall be overlayed by separate zones that consider radiological hazard. Specifically, we need to address the following:

- Whether or not designated materials or sections of materials exceed the threshold as OoS of classification as radioactive materials for the purpose of transfer or re-use
- Whether or not radioactive or other properties in the remaining materials are compatible with the Waste Acceptance Criteria for the intended routes
- Whether or not OoS materials require to be classified as hazardous in accordance with UK Guidance[iv]
- Whether the material properties of inert non-hazardous OoS materials are consistent with CLAiRE guidance for re-use on the Trawsfynydd site

Information Requirements

The project needs information on levels and types of radioactivity and the chemical properties of the materials to be removed during height reduction of the reactor buildings. Insofar as it is possible, this information shall be acquired ahead of demolition to confirm how the resulting wastes shall be managed and expedite their onward routing.

Overall Objective

Characterisation is a critical enabler to inform the approach to decommissioning and waste management.

1.3 How might the issues have arisen within the scope being discussed?

Radioactive contamination mechanisms

In descending order of likelihood

- Internal contamination of the discharge stack by the shield cooling extract and any other radioactive environments during reactor operations. Contaminants would primarily comprise H-3 and C-14 deposited on the surface of materials. As for other materials noted below, H-3 may have subsequently migrated 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 the areas where cutting was undertaken were subsequently decontaminated, it is possible that some residual contamination remains. If present, this type of contamination is anticipated to be present as surface deposits. The contamination profile is anticipated to comprise chiefly of tritium (H-3), carbon-14 (C-14) and chlorine-36 (Cl-36) generated by neutron activation of the reactor graphite which would have been transported by the coolant gas through the primary circulation system. Radionuclides generated through activation of mild steel may also be present and 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 and crane rails which are above the level of the capping roof and would be expected to mainly comprise H-3 and C-14.
- 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 Ni-63 in any reinforcing steel. These radionuclides would be present within the materials in question, albeit biased toward surfaces closest to the RPV.

Non-radioactive contamination mechanisms

- There may be traces of oils in and around the building fabric of the shield cooling filter gallery areas inboard of sidewalls and in any areas where overhead cranes have been used (Main Charge Halls, Fuelling Machine Maintenance Bays, Circulator Halls and 131-foot areas). Other areas may also be affected, but this will be confirmed by a combination of visual inspection and random sampling. A small volume of bulk oils has been estimated by the project but have yet to be confirmed visually once access is enabled.
- Lead-based paints may have been used throughout the buildings
- Bitumen may have been used in the original roofing felt
- Mercury may be present in discrete batteries inboard of sidewalls
- Waste electronic and electrical equipment (WEEE) in the ion chamber rooms inboard of sidewalls and as identified by visual inspection

Provided the activity of radioactive species is lower than the upper threshold defined in reference ii there is no need for decontamination, and the materials may be managed as if they were non-radioactive. For the purpose of assessment against reference ii materials are sub-divided between different physically and chemically distinct layers, for example paint on the surface of metal would be assessed separately from the metal itself.

Should the upper threshold on the classification of material as OoS be exceeded, the project may either treat the whole material as radioactive for sentencing purposes or undertake some further decontamination (e.g., by scabbling). Depending on the choice of techniques available on-site decontamination may need to be undertaken externally, for example removal of a layer of contaminated paint from otherwise radiologically clean metal.

Segregation of materials in terms of their radioactive properties will not necessarily coincide with any requirement for segregation of materials by their non-radioactive properties. Therefore, careful interpretation of the analytical data is needed, taking account of practical arrangements to inform the approach to segregation and onward routing of wastes.

1.4 Summarise Waste Management routes

Waste Routes

Inert materials (i.e., concrete) which are shown to be OoS, and which are compatible with on-site re-use for landscaping purposes in accordance with CLAiRE[v] shall be segregated at the point of decommissioning; removed to a dedicated lay-down area; processed to a suitable engineering grade; and then emplaced within the selected location(s). A Material Management Plan (MMP) shall be prepared which defines a time period for the temporary storage and treatment of materials pending their use in an engineered application. Insofar as it is possible to do so, it is important that characterisation activities are conducted ahead of de-planting: this obviously excludes reassurance monitoring and any characterisation to confirm material is of a suitable engineering grade.

All other OoS materials shall be segregated by the relevant European Waste Codes at the point of removal and transferred for collection in dedicated skips or other bulk haulage containers. Some reassurance monitoring shall be undertaken, most likely on a sampling basis to confirm compliance with the anticipated material properties and confirm that activity does not exceed limits for OoS categorisation. For OoS wastes the selection of waste route shall be informed by the Waste Hierarchy: this will influence the approach to segregation and packaging.

All other wastes shall be managed as Low Level Waste (LLW). This includes any surface scabblings or other radioactive wastes that may be generated as a consequence of decontamination. These shall be segregated, according to the intended waste route. The major volume of solid LLW will likely be disposed as Lower Activity LLW (LALLW) at a suitably permitted landfill; housekeeping wastes and oils, if present will be routed for incineration (separately); and metals will be routed for treatment to remove surface contamination and prepare them for recycling. It is unlikely that any of the LLW will need to be disposed in the national repository, however that option is available if required.

All the waste management arrangements shall be agreed in advance with the site Waste Team who will also oversee their implementation. Site Waste Engineers shall work closely with Site Movement Liaison Officers (SMLOs) to make arrangements for the packaging and dispatch of all materials and wastes to their appropriate destinations. The Site Restoration Programme shall make all necessary arrangements for the re-use of relevant materials on site.

The PWMP shall elaborate on waste routing from the point of generation onwards.

1.5 Who needs the information?

Stakeholder	Interest
Height Reduction Project Manager	Confirm the relevant properties of the materials to be removed in order to prepare an informed plan (cost and schedule) and make all relevant arrangements, including resourcing, to deliver the project efficiently and safely. Characterisation provides information that informs the selection of Best Available Techniques (BAT).
Head of Waste / Waste Team	All materials to be generated (wastes and non-wastes) are characterised sufficiently to make informed decisions about their management well in advance of their removal from the reactor buildings. The approach to characterisation minimises the need for further handling following their removal from the reactor buildings, allowing their swift transition to identified routes.
Site Restoration Programme	Confirm that materials are suitable for emplacement on site as part of future landscaping arrangements
Head of Radiological Protection / ASQEP(M)	The demand for additional surveying effort is proportional to the risk and can be resourced without compromising on the quality of the surveys. All characterisation activities present no unnecessary risks to workers. The designation of materials as OoS is technically defensible and defined with sufficient clarity to be correctly applied in practice.
Landfill / Recycling Centre Operator LLWR and its treatment / disposal suppliers	Characterisation has been completed according to recognised best practice arrangements, providing accurate information on attributes which apply to their receipt and processing of wastes.
Site Movement Liaison Officer (SMLO)	Characterisation has been completed according to recognised best practice arrangements, yielding information that informs the selection of packaging and transport options.

For any materials that are categorised as LLW, the Waste Team shall prepare a Waste Characterisation Form for LLWR's approval to establish the relevant route(s). All characterisation information including this DQO report shall be made available to the operators of landfill or recycling centres upon request.

1.6 Summarise the available resources and relevant deadlines pertinent to acquiring the data.

Actual Height Reduction work is scheduled to commence in December 2024. This defines the timescale for completion of characterisation work and all decisions on the onward management of materials.

All initial planning to support a make/buy decision on on-site characterisation works was completed by quarter 3 2021/22. Bearing in mind the need for engineered access arrangements which may include the erection of scaffolding, all on-site characterisation activities should ideally be complete by quarter 2 2022/23, coinciding with the identification of a preferred supplier for external services (transport and analysis of samples, and provision of packaging). All characterisation tasks should be completed and reported in full to the satisfaction of the Magnox Intelligent Customer by quarter 4 2022/23.

2. Identify the goals of the campaign (DQO Stage 2)

Define the decision that best captures the needs to be resolved to fulfil the project requirements. A decision statement can be answered from the interpretation of data available or resolved by new data acquisition. (WD/WAN/0226/17 Section 4.2)

Outputs:

- *Well-defined principal study question(s).*
- *A listing of alternative outcomes or actions as a result of addressing the principal questions.*
- *For decision problems, a list of decision statements that address the study question.*
- *For estimation problems, a list of estimation statements that address the study question.*

2.1 What are the contaminants or analytes of interest?

Radioactive

H-3, C-14 and measurable gamma emitting species (all materials)

Cl-36, Co-60, Fe-55, Ni-63 (areas where boilers were size-reduced and any potentially activated metalwork)

Ca-41, Eu-152, Eu-154, Eu-155 (concrete with potential to be activated through exposure to neutron flux)

Ni-63, Fe-55, Co-60 (reinforcing steel within concrete located around sections of the hot gas ducts)

Non-radioactive

Total petroleum hydrocarbons (TPH) C6 to C40

EPA PAH 16 suite

Benzo-a-pyrene (BaP)

A broad range of metallic elements including mercury and lead

Acid-soluble sulfates (concrete aggregate only)

2.2 What is the description of the investigation?

Through a process of radiological surveys and the analysis of physical samples (concrete, metal, paint, oils etc) evaluate the radiological and non-radiological condition of the materials to be removed by the Height Reduction project and enable their categorisation for transport and routing.

2.3 What decisions need to be made regarding the investigation?

Determine whether radiological contaminants exceed limits for the classification of materials as OoS.

Decide whether the properties of the materials to be removed are compatible with the acceptance criteria corresponding to the identified routes, taking account of complementary information on asbestos hazards.

Decide whether the materials can be transported using currently available packaging and conveyances.

3. Identify the Information Inputs (DQO Stage 3)

Identify information that will be required to address the principal question(s) that define the project requirement. This section will contain details of currently available knowledge and a summary of information that will be required to underpin the decisions on characterisation. (WD/WAN/0226/17 Section 4.3)

Outputs:

- *Lists of characteristics that will resolve the decision or estimate and potential sources for the desired information inputs*
- *Information on the number of variables that will need to be collected.*
- *The type of information needed to meet performance or acceptance criteria.*
- *Information on the performance of appropriate sampling and analysis method*

3.1 What historical data exists?

This DQO report is principally informed by an early draft of the Project Waste Management Plan (PWMP) which describes the various materials to be removed as waste. Further information sources include the site asbestos register; fixed contamination register; register of permanent controlled areas; extensive Health Physics surveys conducted since 2012; radiochemical analysis to determine levels of tritium in historical core samples; and high-resolution gamma spectrometry assay of various samples acquired within the last 18 months during enabling activities for the Height Reduction project.

The site Fixed Contamination Register identifies measurable radioactivity in the following areas, noting that only room 2423 and the Charge Hall Walls above the level of the capping roof are within the scope of this DQO report:

- Room 1501, associated with primary circuit components (up to a maximum of 110μSv/hr on contact, 4.9μSv/hr at 0.5m)
- Room 1552, associated with primary circuit section and valve (up to a maximum of 2.8mSv/hr on contact, 40μSv/hr at 0.5m)
- Room 1560 Charge Face Floor and walls (walls not specified)
- Room 2423, Fourth GV7-General vent system duct (precise location not specified)
- Room 2501, associated with stored primary circuit components
- Room 2551, associated with stored primary circuit components
- Room 2560 Charge Face Floor and walls (walls not specified)

The following areas are identified on the site Permanent Controlled Areas Register:

- All areas internal to the reactor 1 and reactor 2 fence-line (No contamination controls, R2)
- Reactor building 2 charge face over-head crane – area 2610 (C2, R2). However, there is also conflicting evidence that this crane was de-planted in 2016 and the area was subsequently re-designated C0, R2
- Reactor building 2 South Shield Cooling Stack – area 2960 (C2, R2). However, there is also conflicting evidence that this has since been re-designated C0, R2
- There are further areas which are currently radiologically designated, but which should be removed by enabling works prior to the Height Reduction project commencing

Historic sampling has been performed to determine levels of tritium activity in building materials throughout reactor buildings 1 and 2, some of which are included in the scope of the Height Reduction project (locations 03 and 04 of area 2610 on the 6th floor of reactor building 2, above the level of the capping roof)[vi]. For every sample tritium was recorded at less than 0.4 Bq/g which is much lower than the 100 Bq/g threshold under the Environmental Permitting Regulations[ii].

A sampling campaign was carried out during 1997 in reactor buildings 1 and 2 to determine tritium ingress into concrete in the vicinity of the hot gas ducts and boilers[vii]. The campaign included 11 samples of concrete in the near vicinity of the top duct spanning the distance between the vertical section of the hot gas duct and the boiler for reactor 1 gas circuit 2, and 5 samples in a similar location for reactor 2 gas circuit 11. A further 8 concrete samples were acquired between the 117.3' level and the 1st floor of reactor 1 gas circuit 2 near the boiler and hot gas duct. In all cases, the concentration of tritium measured by the laboratory was higher in the first 1 to 2 cm, reducing with depth. The maximum concentration of tritium over all the samples was 1.3 Bq/g in the first 0 to 1cm of concrete from a sample taken in the wall of the 131' Area of reactor 1 3m above the boiler for gas circuit 2. This sample location also gave the maximum concentration of tritium over all of the samples over a 0 to 3cm depth (0.485 Bq/g).

Surveying and sampling of materials has been carried out in different locations between the basement and 5th floor of both reactor buildings in connection with developing new openings as part of Height Reduction enablers[vi]. Surveys covered a range of wall openings over 67 locations in each reactor building: these locations were deemed radiologically clean (technically OoS) and 'dirty' by the Acc HP based on provenance and legacy survey reports. A total of 65 samples were recovered from reactor building 1 and 71 from reactor building 2. Sampling work targeted outer surfaces of the building fabric (paint, bagwash) and only included the substrate (concrete, block and brickwork) in the event of positive identification of activity above background levels in the outer surfaces. Although this work is still ongoing, to date activity marginally above OoS thresholds has only been identified in 4 cases for each reactor building: results were below the thresholds for all other samples. The approach to analysis is, however, only semi-quantitative comprising measurement of Co-60 using on-site high resolution gamma spectrometry and the inference of all other radionuclides using the 9G105 fingerprint which represents general day to day wastes within the reactor buildings. In each case the samples represent the outer surfaces of concrete blocks removed as part of Height Reduction enablers.

Where available, historic survey reports have been reviewed during the preparation of this DQO report, however those particular surveys were conducted for the purpose of demonstrating that bulk levels of contamination had been either removed or sealed-in in readiness for the site's entry to a Care and Maintenance regime. Their emphasis is on radiation dose-rates and there is very little information on surface contamination monitoring.

3.2 What process knowledge exists?

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. Existing analysis data from these areas indicate tritium activity in the concrete is very low.

The interspace between the reactor pressure vessel 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 3No inlet systems (operable independently or in unison) and 1No 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. The building fabric within the areas that the shield cooling extract passed through have lower potential for radioactive contamination than the areas which house the primary circuit and boilers. The stack should be regarded as internally contaminated and needs to be the subject of targeted sampling.

Chemicals used in connection with reactor operations and maintenance were stored and used throughout each reactor building (refer to section 1.3).

The original roofing material is noted as layers of asphalt/felt overtop insulation board laid on metal decking, which was overlayed with a liquid plastic formulation on the main and intermediate roofs in campaigns between 2007 and 2015. It is possible that the asphalt may contain a coal-tar based binder in which case it would require to be classified as a Hazardous waste upon removal.

Given the age of the buildings it is credible that lead-based paints may have been used on the internal surfaces. The use of x-ray fluorescence devices may help provide an initial indication of where this is the case, enabling a more targeted approach to sampling to determine the lead content of paint.

Pre-cast concrete panels which line the outside of the reactor buildings down to ground floor on the east and west faces are due to be removed as part of the Height Reduction project. They are known to contain asbestos which is being characterised separately but otherwise 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.

3.3 What additional data must be collected?

A series of risk-informed surveys shall be completed for the purpose of supporting the clearance of building materials. Surveys shall focus on the walls and floors of areas that are more likely to have been exposed to contamination.

The main contaminant is tritium, which is not measurable by hand-held probe, but has a relatively high release limit under EPR[ii]. The contamination profile is likely to include C-14 and Cl-36 which have low to medium maximum beta energies but are still measurable using conventional hand-held probes. Most of the activity is considered to be present as surface contamination which may be detected by probe, however there may be some activation of the concrete and reinforcing steel which are less easy to monitor because of self-absorption by the matrix and the low energy of any emissions. An assumption is made that Cl-36 and C-14 are co-located given they both arise from irradiation of graphite, which would have been distributed in either gaseous form or as sooty particles around the primary circuit and boilers. Surveying should be undertaken using a probe that is optimised for Cl-36 detection (its beta E_{max} is 709 keV compared to 156 keV for C-14 which makes it easier to detect) and has a reasonably large aperture which enables monitoring of large areas in fairly short periods of time.

Co-60 is not expected to be present at appreciable concentrations due to its short half-life (around 6 half-lives have elapsed since the reactors ceased production) and decontamination operations within the safestores. Nevertheless, some gamma monitoring should be conducted as a coarse screen in areas that formerly housed the hot gas ducts and upper sections of the boilers, since it is a useful marker for other metallic activation products (specifically Fe-55 and Ni-63) which cannot be readily detected *in-situ*. Ideally, surveys should be undertaken in these areas using a gamma sensitive probe supported by gamma spectrometry capability: changes in the spectral profile may indicate a deviation from normal levels of naturally occurring radioactive material (NORM) in building materials.

The laying of a liquid plastic coating over the roof will help to shield any low energy beta emitters which have been deposited via the stack. Comprehensive monitoring of the whole of the roof surfaces is therefore not considered to be an optimal use of resources. At least in the first instance, monitoring should be carried out over an area of approximately 20m^2 around each of the stacks using beta and gamma-sensitive devices. Should evidence of contamination be found, this DQO shall be reviewed, and the monitoring area may be extended further.

The detailed approach to surveying is set out in the separate survey plan (TRAWS/L28302/DOC/0060).

The taking of physical samples is necessary to gain information on the distribution and quantity of radionuclides which may be difficult to detect (e.g., tritium) as well as informing the sentencing decisions. Physical samples shall be collected and analysed to determine levels of radioactivity and chemical contaminants in the materials to be removed during height reduction works. The facilities shall be zoned for this purpose according to the potential for radioactive and chemical contamination. The approach to sampling for radioactivity shall be informed by provenance and Health Physics survey results. A random sampling approach to establish characterisation information for bulk material quantities will be complemented by biased sampling in areas where contamination or attributes of interest are known to be present. Biased samples inform the need for remediation / segregation ahead of demolition and help to confirm the nature of any activity present. Samples shall be taken in such a manner that enables depth profiling, and sufficient samples shall be taken from each zone to enable statistically meaningful conclusions about the relevance of any residual contamination to the objectives of characterisation.

In general, a phased approach to analysis shall be employed whereby samples are initially subjected to a series of basic tests, and the results of those tests shall inform the need for further analyses. For biased samples a fuller or more specific range of analyses corresponding to the possible contaminants may be adopted.

For every sample acquired to assess radiological properties a sub-sample shall be analysed to determine tritium (H-3) and C-14 through a process of controlled combustion and absorbing the off-gases for analysis by liquid scintillation counting. Residual solid samples shall be digested in nitric acid or similar (additional chemical processing such as the addition of hydrofluoric acid to concrete may be required) to achieve full dissolution of radionuclides and each sample shall be prepared in a standard geometry for high resolution gamma spectrometry. The use of bubblers filled with a solution of sodium hydroxide will be a necessary addition during the acid digestion of solid materials to prevent the loss of Cl-36 (see later). Each sample shall also be analysed for gross alpha and gross beta activity. Depending on the comparison of gamma spectrometry and gross alpha counting, full chemical separation of actinides followed by alpha spectrometry may also be required. Similarly, depending on the comparison of gamma spectrometry and gross beta counting (e.g. evidence of fission products and/or gross beta activity that's uncorrelated with other analytical data) full chemical separation followed by analysis for Sr-90, Tc-99 and Cl-36 may be required. For certain samples Ca-41, Fe-55 and Ni-63 analyses shall also be specified. In all cases, limits of detection shall not exceed 0.5 times the upper limit for exclusion of the relevant radionuclide under the Environmental Permitting Regulations.

Samples of roofing materials and any suspect bituminous materials shall be initially submitted for EPA PAH 16 suite, benzopyrene (CAS 50-32-8), Coronene, Phenol, and Cresol). A selection of paint samples representing different areas within each zone shall be submitted for full elemental analysis. Materials known or suspected of containing oil shall be analysed for TPH(C6-C40) Petroleum Group and benzopyrene. A selection of concrete samples shall be tested for acid-soluble sulfate content in accordance with BS EN 13242:2002+A1:2007

4. Define the boundaries of the study/campaign (DQO Stage 4)

Define the spatial and temporal aspects of the population that is being studied in the project to ensure that the data collected are representative of the population(s). Practical constraints that could interfere with sampling are also identified here. Locations and sampling sub-areas will be defined here as will materials to be sampled. (WD/WAN/0226/17 Section 4.4)

Outputs:

- *Definition of the target population with detailed descriptions of geographic limits (spatial boundaries),*
- *Detailed descriptions of what constitutes a sampling unit*
- *Time frame appropriate for collecting data and making the decision or estimate, together with those practical constraints that may interfere with data collection, and*
- *The appropriate scale for decision making or estimation.*

4.1 Define the spatial and temporal boundaries of the potential contamination?

The scope of materials to be removed during height reduction works is described in the Introduction section. As stated throughout this document, these materials shall be sub-divided among several discrete zones set out below corresponding to materials where the provenance indicates they should have similar characteristics. The number and definition of zones shall be reviewed following review of the analytical results for samples from these areas.

Zoning for radioactive properties (to be mirrored as separate zones in reactor building 1 and 2)

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 which was generated in the interspace between the RPV and bioshield
3	Cranes and rails[1]	Possible exposure to airborne contamination which would likely be concentrated in a surface paint layer
4	131' 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 on the fuelling machines
6	Stairwells, Shield Fan Rooms, Boiler Interspaces and roof trusses	Relatively low potential for contamination

Zoning for non-radioactive properties (to be mirrored as separate zones in reactor building 1 and 2)

Zone #	Geographical Area	Anticipated properties
7	Internal walls and floors	Concrete material properties relevant to future on-site re-use scenario
8	Cranes and rails[1]	Paint which may be of interest for the purpose of metal processing
9	Charge Hall and Fuelling Machine Maintenance Bay walls	Potential for spills of oils during routine operations
10	Batteries	Mercury
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	Oils used during maintenance activities
12	Damp proofing and roofing materials	Bitumen, lead flashing around roof lights

4.2 What considerations affect the sampling/survey location choices?

[1] Access limitations mean that the cranes and rails shall not be assessed under this DQO. These features will be removed during dismantling work, segregated and assessed to identify the most appropriate sentencing route under a separate characterisation plan.

There is known or suspected asbestos throughout the buildings which will impact on the manner in which surveys are undertaken and samples are acquired; the types of samples that are acquired; the requirements for packaging and transport of samples; and the selection of laboratories for undertaking analysis. There are too many instances of the use of asbestos as a building material to list definitively here and it is sufficient to note that it was used extensively, for example as a composite material or textured coating within the walls, floors and ceilings and pre-cast panels; as insulation within the boiler boxes and interspaces; and as cement to the pre-cast panels. This DQO report cannot meaningfully present a definitive list of the presence of asbestos therefore the site asbestos register shall be consulted during the planning of sampling locations.

Where surfaces have been painted the paint would have tended to act as a barrier to contamination ingress. Furthermore, in accordance with NICoP guidance[iii] it is necessary to consider levels of activity in the paint as separate from the underlying substrate. Where surfaces have been painted sampling shall focus on acquiring paint scrapings: a smaller number of samples may be taken from the substrate to confirm the effectiveness of the paint as a barrier. Manual scraping is preferable to the use of electronic vibrational devices in order to limit the loss of paint during the removal process.

Imposed load restrictions need to be considered throughout the building prior to undertaking activities which require person-access.

Some areas of the buildings have restricted access / egress arrangements, for example to maintain social distancing.

Work on the roof will need to be planned to avoid coinciding with bad weather.

Characterisation of the shield cooling stack internal surfaces may need to be deferred to coincide with demolition due to access limitations. Should this be the case, the stack should be removed carefully in sections, and segregated from the remaining demolition waste.

Working at Height

The structures requiring to be surveyed include areas such as the Top Duct Rooms and Hot Gas Duct Cells which are high (up to 22 metres) and therefore cannot be accessed safely without suitable engineered arrangements. In all cases these areas were surveyed as part of environmental clean work between 2001 and 2021 when full scaffolding was in place. All scaffolding has since been removed.

The project management team, supported by the site Head of Radiation Protection has declared that all surfaces at the time of the environmental clean were surveyed using a combination of surface beta contamination probes (EP15) and radiation probes, and that any positively identified radioactivity would have been removed as part of operations to prepare the safestores for the height reduction work. Unfortunately, survey results from that time are no longer available.

It is necessary to undertake characterisation work now to underpin final categorisation of those structures and possibly segregation and sentencing schemes for the resulting wastes and materials. Characterisation must be suitably representative of the structures to be removed by the height reduction project. A balance needs to be struck between the effort required to attain that characterisation information including risks to workers, and the benefits of the information to be acquired. Considering the recent extensive surveys and the assertion from the project management / site Head of Radiological Protection that positive finds of contamination would have been removed at the time, it is not proportionate to require full scaffolding be erected to enable surveying or sampling over the full height of the structures. Hence access limitations are an important factor to be considered when planning characterisation activities.

A review of currently available technology concluded that it was not feasible to conduct surface contamination surveys of high structures without the use of scaffolding. A balance of effort to enable access has been struck in the form of 'zip-up' scaffolding which makes it relatively straightforward to survey up to 4 metres above floor height. In defined areas 'zip-up' scaffolding enables access to a maximum of 10 to 12 metres.

Surveying activities will be carried out within the limitations of access afforded by 'zip-up' scaffolding, described above. Further detail on the intended surveying work is provided in the separate survey plan (TRAWS/L28302/DOC/0060). The absence of positive finds of activity by this approach shall be taken as confirmation that no activity measurable by survey instrumentation remained in-situ following the environmental clean. However, should activity be identified above background levels it shall be necessary to review the decision to only implement 'zip-up' scaffolding and not survey the higher structures.

4.3 Are there sampling/survey issues?

Co-ordination with other trades. Both buildings have been handed over to external Principal Contractor delivering Height Reduction Enabling works.

Good sampling management arrangements undertaken by SQEP personnel are needed to maintain a traceable link between analysis results, the material being sampled in each case and this DQO report; and to prevent cross-contamination.

Characterisation activities at height will require construction of scaffolding or other means of safely accessing the required surfaces. Semi-remote sampling equipment based on a laser-ablation technique could be deployed to limit working at height, however this tends to deliver a relatively small volume of sample material which may be inconsistent with the aim of demonstrating bulk materials are OoS.

There is potential for loss of tritium as a volatile radionuclide, and since tritium is likely to be a major contributor to total activity in many of the samples the way the samples are acquired and managed needs to be carefully controlled. Conventional sampling methods such as chiselling or coring are likely to be preferable and the use of water to cool coring heads should be avoided. All samples required for tritium analysis shall be double wrapped in plastic close to the point of acquisition and maintained in cool conditions (4 degrees Centigrade) up until the point of sample preparation and analysis by the laboratory.

For painted metals it will be relevant to establish the activity per surface area (Bq/cm^2) hence the surface area corresponding to any samples of paint shall be recorded to the nearest 0.1 cm^2.

5. Develop the analytic approach (DQO Stage 5)

The key elements from Steps 1 through 4 are used to develop a decision based on a Null Hypothesis. The "Null Hypothesis", H0, refers to the assumptions about facility based on the Conceptual Site Model. The more rigorous statistical test is to assume that the site is "contaminated" i.e. exceeds a specified action level, and then prove that it is does not i.e. the site is "clean". The original null hypothesis will be maintained unless there is convincing evidence to the contrary. (WD/WAN/0226/17 Section 4.5)

Outputs:

- *Identification of the population parameters most relevant for making inferences and conclusions on the target population;*
- *For decision problems, the "if..., then...else..." theoretical decision rule based upon a chosen Action Level; and*
- *For estimation problems, the specification of the estimator to be used.*

5.1 What is the population parameter of interest and what is the action level?

Radiological Action Limits

For planning purposes, it is expected that zones 1, 4, 5 and 6 may be disposed as OoS, however their radiological status remains unproven. As per the Clearance and Radiological Sentencing Code of Practice[iii] a null hypothesis, H_o is proposed whereby materials from these zones would contain radioactivity at levels requiring them to be treated as radioactive for sentencing purposes. The alternative hypothesis H_1 is that concentrations of radioactivity are sufficiently low to enable classification as OoS: that is, excluded from the radiological substances regulation regime. The test on which the alternative hypothesis H_1 depends is that over all of the radioactive species present the sum of fractions (the activity per unit mass of each radionuclide divided by the corresponding exclusion limit set out in reference[ii]) does not exceed 1. There is a complementary requirement to apply a similar test based on activity per surface area, sub-dividing these data by the values provided in reference viii.

For planning purposes zone 2 is nominally LALLW due to internal contamination of the discharge stack. In this case, the null hypothesis H_o is that the material exceeds the limit for receipt at permitted landfill and therefore requires to be sent to the national repository for disposal. In order to satisfy the alternative hypothesis H_1 the total concentration of activity averaged over each transport consignment (approx. 20 m^3) needs to be below 200 Bq/g.

Although outside of the scope of this DQO report for planning purposes zone 3 is nominally regarded as OoS. In this case, the null hypothesis Ho is that the waste must be further treated to remove a surface layer of contamination and reveal a recyclable product. There are a range of suppliers for metal treatment and there is no consensus on what constitutes acceptable limits or even how these are defined, and even then, there appears to be flexibility in the way that published acceptance limits are implemented. In the absence of simple action limits for the acceptance of metallic wastes for treatment, sample results representing zones 2 and 3 shall be used to inform negotiation with LLWR concerning the routing of these wastes.

Non-Radiological Action Limits

Regardless of the nature of the non-radiological chemical hazards, the null hypothesis is that the material in question contains components at or above limits requiring it to be classified as hazardous according to UK Government guidance[iv] or exceeds limits defined in BS EN 13242 for the use of aggregates in civil engineering work. Bearing in mind that investigation of asbestos is excluded from this study the alternative hypothesis H_1 does not necessarily imply that the material may be managed as non-hazardous: further investigation shall be required beyond the scope of this work. Nevertheless, for the purpose of this study the alternative hypothesis H_1 requires that levels of chemicals corresponding to Hazardous European Waste Codes would need to be below defined thresholds.

Should any of the samples indicate agreement with the null hypotheses described above there is a requirement to further define the extent of the radiological or non-radiological contamination. This may involve re-appraisal of this DQO report and possibly acquiring further samples.

5.2 Develop a Decision Rule

The following rules are to be applied to each material type subject to re-evaluation of zones and re-appraisal of the spread of radioactivity or hazardous chemicals in each case. For each of the two sets of limits start with the first rule and move sequentially through the rules until an appropriate decision is identified for each material or item.

Radiological Action Limits

Rule Rad 1 (zones 1, 4, 5 and 6): If the radioactivity per unit mass results in a mean ‘sum of fractions’ value less than 1 the null hypothesis Ho will be rejected, and the material will be considered to be OoS. Depending on the material properties it will either be re-used on site as part of landscaping activities, or it will be transferred to a suitably permitted third party for processing and/or disposal subject to its chemically hazardous status. Wastes shall be managed as per non-radioactive wastes in line with the Waste Framework Directive.

Rule Rad 2 (zones 1, 4, 5 and 6): Should the mean ‘sum of fractions’ value exceed 1, the null hypothesis is true, and the material shall be sentenced as radioactive waste. Refer to decision rules 3, 4 and 5 below.

Rule Rad 3 (zones 1, 2, 4, 5 and 6): If the total radioactivity in the material is less than 200 Bg/g, it shall be sentenced as LALLW. It shall be transferred under the terms of the site permit to a suitably permitted waste receiver for disposal.

Rule Rad 4 (zones 1, 2, 4, 5 and 6): If the total radioactivity in the material exceeds 200 Bg/g, then depending on the material properties it shall be assessed for compliance with upper limits on the relevant route (combustion, metal treatment or LLW disposal). It is not considered credible that the materials would exceed these limits. The materials shall be packaged appropriately and transferred as radioactive waste to a suitably permitted receiver.

Non-Radiological Action Limits

Rule Non-Rad 1: For OoS materials, should there be no indication from provenance or sampling results that the material requires to be classified with a Hazardous European Waste Code (taking account of parallel work on asbestos characterisation) it shall be managed as non-hazardous material.

Rule Non-Rad 2: For radioactive wastes, analytical data for hazardous components shall inform requests for processing and/or disposal. If hazardous properties exceed limits for the intended route, it may be necessary to raise a Variation Request for approval by LLWR. Additional sampling or analysis work may be necessary. A Dangerous Goods Safety Adviser (DGSA) or Dangerous Goods Transport Officer (DGTO) shall be consulted regarding classification and packaging for transport.

Rule Non-Rad 3: For OoS materials, if they require to be managed as Hazardous they shall be routed to an appropriately permitted Hazardous Waste Landfill. This applies equally to suitable materials intended for re-use on site. A DGSA or DGTO shall be consulted regarding classification and packaging for transport.

Rule Non-Rad 4: For OoS materials, should they exceed threshold values for the re-use of aggregates in civil construction (allowing for processing on or off site) an appropriate off-site disposal solution shall be employed.

5.3 Consequences of decision errors

Radioactive Properties

Zones 1, 4, 5 and 6

Error	Consequence
Alpha or Type I – False rejection of Ho which will correspond to concluding that sufficient evidence has been collected to support the management decision that material is OoS	Material will be incorrectly assumed to be OoS and falsely sentenced to civil waste streams or re-used on site, resulting in unintended dose consequences to workers and the public, accompanied by possible regulatory enforcement action and reputational / commercial impacts.
Beta or Type II – False acceptance of Ho	Waste is incorrectly assumed to be LLW (including LALLW) when it is actually OoS incurring higher disposal costs (treatment / disposal and packaging). Opportunities to re-use materials as part of landscaping work would not be realised and the management routes for waste would be more costly and take longer to implement.

Zone 2

Error	Consequence
Alpha or Type I – False rejection of Ho which will correspond to concluding that sufficient evidence has been collected to support the management decision that the material is LALLW	Material is incorrectly assumed to be LALLW, and falsely sentenced to a permitted landfill resulting in unintended dose consequences to workers and the public, accompanied by possible regulatory enforcement action and reputational / commercial impacts.
Beta or Type II – False acceptance of Ho	Material will be incorrectly assumed to be LLW when it is actually LALLW and falsely sentenced to the national repository, taking up capacity unnecessarily within a precious national resource and attracting higher cost, estimated using current cost norms to be in the order of £4,000/m^3 compared to £700/m^3.

Non-Radioactive Properties

Error	Consequence
Alpha or Type I – False rejection of Ho which will correspond to concluding that sufficient evidence has been collected to support the management decision that material is not hazardous	Material will be incorrectly assumed to be non-hazardous or not exceeding limits for chemical properties specified by LLWR framework suppliers. Insufficient controls would then be applied to the onward management of the material with consequences for the health and safety of workers, and the environment. Regulatory action and commercial issues associated with loss of reputation are credible.
Beta or Type II – False acceptance of Ho	Material is incorrectly assumed to be Hazardous Waste or to exceed limits specified by LLWR framework providers. Opportunities to re-use materials as part of landscaping work would not be realised and the management routes for waste would be more costly and take longer to implement.

6. Specify the Performance/ Acceptance Criteria (DQO Stage 6)

Specify the tolerable limits on decision errors, which are used to establish performance goals for the data collection design. (WD/WAN/0226/17 Section 4.6)

Outputs:

The primary output from Step 6 of the DQO Process is a set of performance or acceptance criteria (i.e., data quality objectives) that your collected data should achieve in order to minimize the possibility of either making

a decision error or failing to keep uncertainty in estimates to within acceptable levels. *You establish these criteria according to whether your problem is a decision-making problem requiring statistical hypothesis testing (Step 6A) or primarily an estimation problem (Step 6B).* *In a statistical hypothesis setting, the outputs from performing Step 6A of the DQO Process that lead to performance or acceptance criteria on your collected data would include:* • *Specification of the range of possible true values of the parameter of interest that correspond to the baseline condition.* • *Specification of the gray region containing possible true values of the parameter of interest that fall within the alternative condition and for which you can tolerate high probabilities of making false acceptance decision errors.* • *The set of tolerable decision error limits at selected true values of the parameter of interest (i.e., at the boundaries of the gray region).* • *You generate these outputs by considering the consequences of making decision errors along the range of possible true values of the parameter of interest: false rejection decision errors within the range representing the baseline condition, and false acceptance decision errors within the range representing the alternative condition.* • *Presenting these outputs with a Decision Performance Goal Diagram is an effective, graphical means of communicating, to the planning team and to stakeholders, draft versions of these outputs while they are being formulated, and as the final set of outputs.* *When you will be calculating confidence intervals in an estimation setting, the outputs from performing Step 6B of the DQO Process are:* • *The confidence level that specifies the likelihood that the interval will contain the true value of the parameter* • *An acceptable width associated with the interval, expressed in either absolute or relative terms.* • *If you simply plan to calculate standard errors associated with your estimates, your outputs from Step 6B may correspond to bounds placed on the size of the standard error relative to the parameter estimate, either in absolute and relative terms, along with specifications placed on the various components of total study error in your data.*
6.1 What steps are to be taken after the measurement results are obtained?
Analysis report to be reviewed by Intelligent Customer to ensure that the analysis techniques and calibration standards/controls used are appropriate and ideally fully traceable to ISO standards. Required analytical limits of detection will be 50% of the associated EPR OoS level or better. Measurement uncertainty will be 20% or better, calculated as a minimum as Type A for a coverage factor, k, of 2 (namely at the 95% confidence level). Specifications shall be defined in the analytical scope of work such that the data can be confidently reviewed against the task decision rules. Any gross beta/alpha measurements must be reviewed / reconciled against key companion data to test data consistency.
6.2 What are the tolerable limits on decision errors?
<u>Radioactive properties for zones 1, 4, 5 and 6</u> For each of the above zones, tolerable type-1 and type-2 decision errors of 5% and 10% respectively are to be applied. For each zone, 25 samples shall be obtained and analysed as described in section 3.3. For each sample, a ‘sum of fractions’ calculation shall be performed based on its bulk activity (Bq/g). The resulting 25 ‘sum of fractions’ values shall then be assessed for outliers and if necessary, this DQO Study shall be reviewed. Depending on the spread of values and their proximity to the legal sentencing limit a judgement shall be made as to whether or not further samples are required. The Sign test described in section 8.3 of reference ix shall be applied to the ‘sum of fractions’ values for the sample data to help decide whether or not to reject the null hypothesis (i.e., sentence as OoS) In addition to the above statistical test, the measured activity of each radionuclide (Bq) within each of the samples shall be divided by the surface area over which the sample was acquired to derive activity per unit area (Bq/cm^2). A pessimistic assumption is made that all of the measured activity is contained at the surface of the material. A ‘sum of fractions’ calculation shall be calculated for each sample referencing the recommended surface clearance values noted in reference viii. Provided all of the ‘sum of fractions’ values are less than 1, there is no need to undertake further decontamination to achieve compliance with reference surface clearance values.

For the assessment of bulk activity (Bq/g) an additional test shall be carried out to confirm the adequacy of the sample size, provided the mean ‘sum of fractions’ value is less than 1 and the output of the Sign test indicates that the waste is OoS.

For the sake of this assessment we assume that any radioactive material detected by the laboratory is entirely anthropogenic, therefore the sample size calculation for the one-sample Sign test as set out in MARSSIM[ix] section 5.5.2.3 is appropriate. The calculation is reproduced below:

$$N = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4(Sign\ p - 0.5)^2}$$

Where:

N = the number of samples required to achieve the desired statistical confidence in the sentencing decision

$Z_{1-\alpha}$ = the one-sided z-score for 1-α, where α represents a 5% probability of making a Type-1 error in the sentencing decision (i.e. deciding that the material is OoS when in fact it is contaminated above the threshold set out in EPR[ii]). In this case, $Z_{1-\alpha} = 1.645$.

$Z_{1-\beta}$ = the one-sided z-score for 1-β, where β represents a 10% probability of making a Type-2 error in the sentencing decision (i.e. deciding that the material is contaminated above the threshold set out in EPR[ii] when in fact it is OoS). In this case, $Z_{1-\beta}$ =1.282.

Sign p = the value given in table 5.4 of reference ix corresponding to the value of Δ/σ (see below).

Δ = the width of the grey region, i.e., the extent to which we are prepared to accept a Type-2 error, noting the consequences set out in section 5.3 of this DQO report. In this case a ‘sum of fractions’ score of 0.8 has been set since it is considered that there should be very little activity in the materials and hence little chance of approaching the legal limit of 1. That is, Δ = 0.2.

σ = the standard deviation of the ‘sum of fractions’ values for the population of 25 samples

Additionally, MARSSIM recommends increasing the calculated number of samples by 20% to allow for lost or unusable data.

Using the above equation to determine the required number of samples the only variable is Sign p, which is a function of Δ and σ. Since Δ has been determined already, this means that the standard deviation of the ‘sum of fractions’ values is the key variable affecting the number of samples required. For illustration, should σ = 0.1 or 0.2, Sign p will be 0.977250 or 0.841345 respectively and therefore the number of samples required, applying the additional 20% factor, is 11 or 22 respectively. Should σ = 0.3, the number of samples required would rise to 38.

<u>Radioactive properties for zone 2</u>

A total of two biased samples shall be taken from each of the discharge ducts, one from the top and one from the bottom making 8 samples in total. Each sample shall be subject to the full range of analyses indicated in section 3.3. Provided the average results for the pair of samples corresponding to each duct do not breach the upper activity limit for LALLW they will be used to assess the radioactive inventory of their duct. It is not assumed that the liner from the duct will be removed during dismantling and hence this approach which does not average the activity over the greater mass of the duct is necessarily conservative. Should the results breach the upper limits for LALLW this DQO report shall be revised and possibly additional samples will be analysed to reduce the conservatism.

<u>Non-radioactive properties (all zones)</u>

Where targeted sampling has been undertaken to establish the properties of a known material with uniform characteristics (e.g., concrete, roof felt, paint) it is not relevant to follow a statistical approach as outlined above for radioactive properties.

Samples from each area within zones 9 and 11 shall be used to establish the extent of oil contamination. Ahead of sampling, a visual inspection of the areas shall be undertaken to establish the potential for oil contamination. For areas with low potential, a minimum of three samples shall be analysed and provided they do not indicate a Hazardous classification (see below) no further sampling is required. For areas with higher potential a minimum of 10 samples per area shall be used for the purpose of assessment. For example, within each reactor building the FMMB shall be treated as one area with enhanced potential for oil contamination and so 10 samples shall be used to assess Hazardous status due to oil within each FMMB.

A series of numerical limits are set out in reference iv to determine whether materials require to be categorised as Hazardous due to contamination with unknown oils based on the concentration of TPH, and the concentration of BaP relative to TPH. For areas with low potential, the results for each sample shall be used individually for this assessment and should any of these exceed the limits in reference iv this DQO report shall be revised and additional samples shall be used for assessment. For areas with higher potential, the 95th percentile value of TPH shall be used, calculated as:

95th percentile = μ+(SE x 1.833)

Where

μ = the mean value of TPH for the population

SE = the standard error on the measurement, defined as SE = $s/(\sqrt{n})$ where s = the standard deviation of the TPH results for the population and n = the number of samples analysed

And 1.833 = the critical value of the 1-sided t-distribution corresponding to 95% confidence with 9 (i.e., n-1) degrees of freedom

In all cases, the BaP concentrations relative to TPH shall be assessed for each individual sample.

The approach to determining the concentration of acid-soluble sulfates in concrete samples relative to the maximum limits set out in table 13 of BS EN 13242 shall be similar to that employed for TPH, that is the 95th percentile will only be used where either any of the analytical results exceed the limits or the mean result is deemed sufficiently close to the limit by the Intelligent Customer.

7. Develop the Plan for Obtaining Data (DQO Stage 7)

Identify the most resource-effective data collection design for generating data that are expected to satisfy the DQOs specified in the preceding steps and develop the requirements for the Characterisation Plan. (WD/WAN/0226/17 Section 4.7)

Outputs:

The outputs from Step 7 of the DQO Process are discussed/recorded here, but are to be documented in full detail within the subsequent arising Characterisation Plan (WD/WAN/0225/17 Appendix D2). These outputs include:

- *Full documentation of the final sampling and analysis design, along with a discussion of the key assumptions underlying this design;*
- *Details on how the design should be implemented together with contingency plans for unexpected events;*
- *The Quality Assurance and Quality Control procedures that would be performed to detect and correct problems and so ensure defensible results.*

7.1 Review the outputs of steps 1 to 6.

The outputs of steps 1 to 6 were shared with internal stakeholders and no comments were received. Therefore, the outputs are considered to still be relevant.

7.2 State the type of data to be obtained.

Radiological survey data shall be used to indicate the location and distribution of any measurable activity above background. These shall help to inform the approach to sampling and assist with the interpretation of sample results as input to sentencing decisions. Where available, relevant pre-existing survey reports for the areas mentioned in Appendix B shall be used. Subject to limitations on access (refer to section 4.2) fresh surveys shall be conducted in any of these areas where there is either no survey reports available; the survey pre-dates the possible re-introduction of contamination; or survey outputs have been poorly recorded. A separate survey plan (TRAWS/L28302/DOC/0060) has been prepared and agreed with the ASQEP(M) and Project Manager.

Analytical data for representative samples shall inform the categorisation of materials to be removed as waste, and the approach to their final characterisation / assurance checking. Sampling plan TRAWS/L28302/DOC/0061 documents the assumed locations and material type of samples. The sampling plan shall be updated based on the evidence of radiological surveys ahead of being implemented. Additional observations at the time of surveying and/or sampling shall be recorded on the sample plan.

The analytical report(s) for radiological or non-radiological analysis of the samples shall be key to satisfying the objectives of this DQO report.

7.3 State the approach to sample selection and optimisation

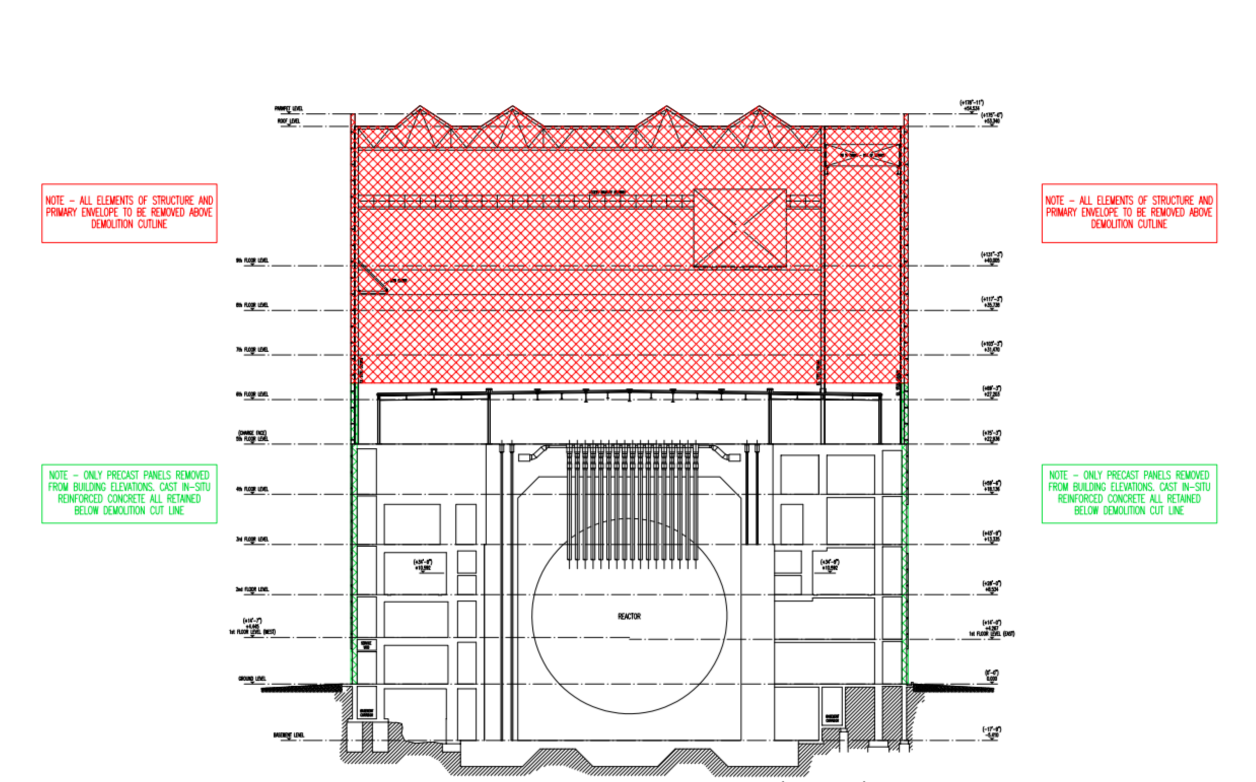
A relatively small number of samples shall be acquired from any areas of known or suspected hazards (informed by survey data, provenance and observations). Analytical data for these samples shall inform the preparation of radionuclide fingerprints, where relevant and the approach to segregation / decontamination.

Statistically relevant numbers of randomly distributed samples shall be acquired throughout the remaining areas of the building fabric to underpin assessment of hazard levels and thereby challenge the null hypotheses set out in section 5.

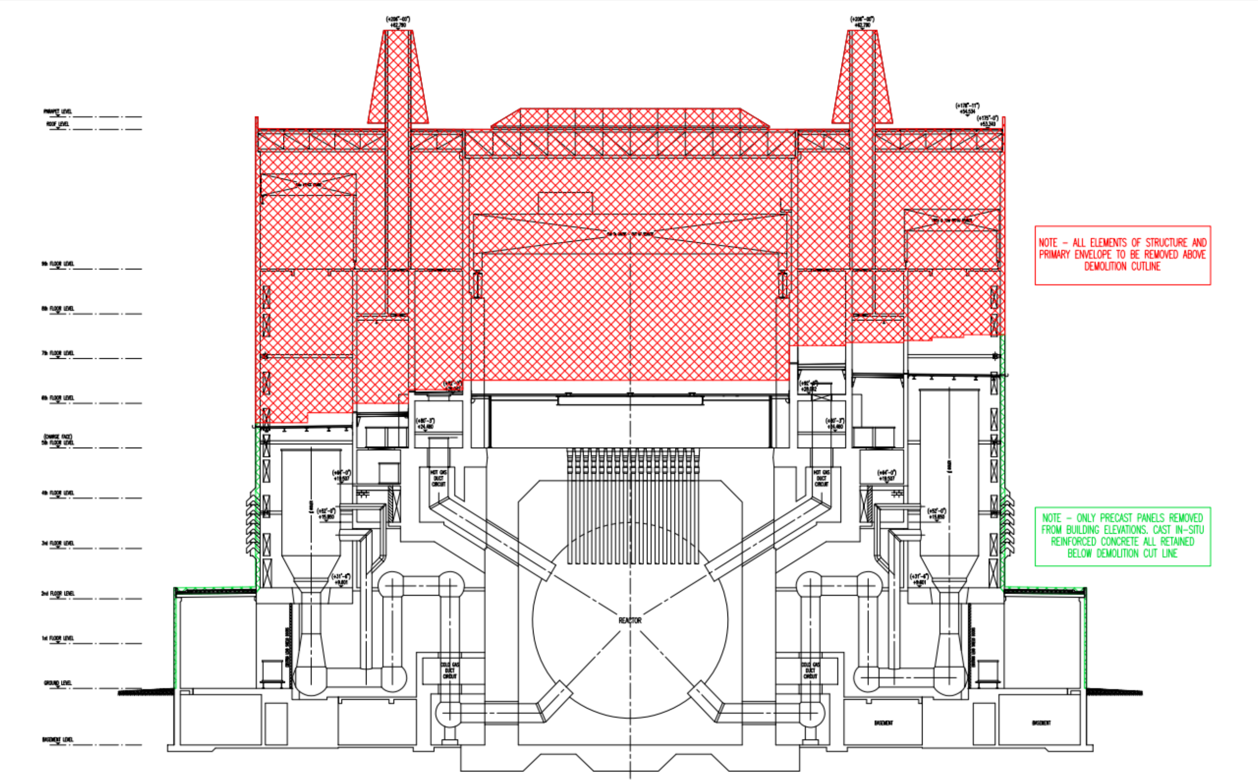
7.4 Summary of characterisation implementation, with contingency arrangements.
Ahead of a review of the available survey data and completion of any further surveys, and making assumptions about the distribution of sample results, the numbers of samples required to make sentencing decisions with a defined level of confidence (refer to section 4.1) is as presented in section 6. It is recommended that duplicate samples are taken from the targeted positions, and at least 50% more randomised samples are acquired. This approach allows for a more nuanced selection of samples for analysis, mitigates the risk that samples are mislaid or destroyed, and enables further investigation should the analytical results indicate this is necessary. The effort to collect these additional samples over and above the numbers specified in section 6 should be negligible. The location of randomised samples shall span the full surface area of the relevant sub-zones. There shall be no expectation that there will be a set number of samples from each individual room within the particular sub-zones. Randomised samples shall generally be taken from the walls and floors, but in areas of the facility which contained primary or secondary circuits some samples shall be taken from the ceilings as well. A technique such as Visual Sampling Plan (Visual Sample Plan | PNNL) may be used to plot the locations of the random samples. All samples shall be assessed on site to assess their activity levels to inform the selection of samples to be sent for radiological analysis, and to inform transport activity assessments. Samples shall be acquired using cold-cutting techniques which avoid the production of dusts or gases. All samples shall be individually labelled and fully traceable to a central register that is periodically updated. Samples shall be individually wrapped in plastic bags and maintained at low temperature (preferably -18^{o}C) in a refrigerator whilst on site to avoid loss of volatile components. Samples shall be transported in a cool box which maintains low temperature conditions.
7.5 Summary of Quality Assurance and Quality Control procedures.
The Sampling Plan shall be written in such a way that makes it easy to read and understand for staff carrying out the sampling work. They shall contribute to sections on access arrangements and sample acquisition techniques, and peer review the document. Their feedback on layout or content shall inform a further review to make sure that the requirements are unambiguous. Staff undertaking sampling work shall receive training in good sampling practice, emphasising the need for traceability and avoiding cross-contamination. Sampling work shall be overseen by local project management and is subject to acceptance by a Subject Matter Expert (nominally the Principal Consultant for Radiochemistry) based on good records that are explicitly required by the sampling plan (e.g., photographs, accurate written descriptions of locations including diagrams, Health Physics survey results, general descriptions, serial numbers etc). The selection of samples for analysis shall be a joint decision between project management and the Subject Matter Expert, informed by gamma spectrometry data and/or other information. Chain of Custody Forms shall be used to confirm the samples to be analysed and the range of analyses required. Analytical quality assurance / control measures shall be as set out in the Analytical Scope of Work accompanying this DQO Study.

Appendix A

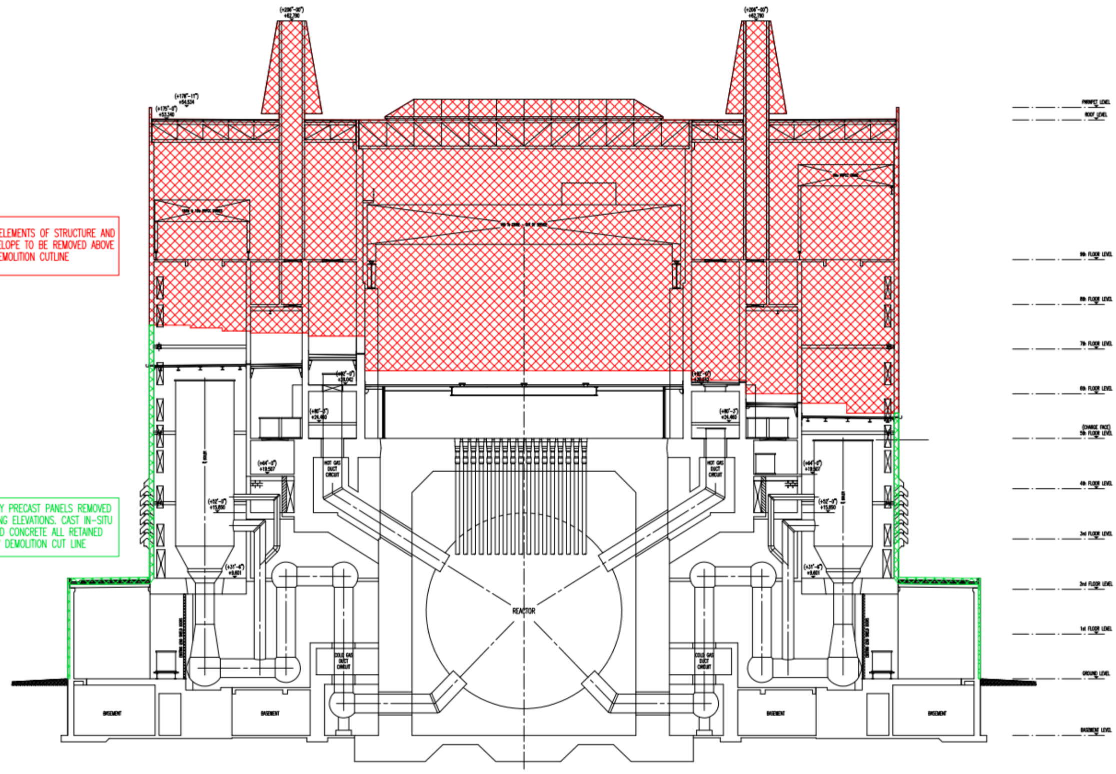
Figures showing side elevations of the reactor buildings. Red shading designates the areas to be removed.



REACTOR BUILDING CROSS SECTION (TYPICAL)



REACTOR BUILDING 1 LONGITUDINAL SECTION – CENTRE CIRCUITS



REACTOR BUILDING 2 LONGITUDINAL SECTION – CENTRE CIRCUITS

Appendix B

List of areas within the reactor buildings that will be directly impacted by height reduction works

Green =	Areas where partial decommissioning only will be undertaken (e.g., removal of precast panels)
Red =	Areas that will be removed in their entirety

Reactor Building 1

Space	Space Name		Space	Space Name
1001	Gas Circulator Hall - South		1143	Gas Circ Basement Vent Plant Room - NE
1010	Lobby to Stairs & Goods Lift (SE)		1210	Lobby to SE Stairs & Goods Lift (2nd)
1014	Corridor (Southeast end)		1212	Lobby – Southeast
1015	Corridor (East)		1220	Lobby to SW Stairs (2nd)
1020	Lobby to SW Stairs (Ground)		1228	SW Lobby (2nd)
1024	West Corridor (South end)		1230	Lobby to NW Stairs & Goods Lift (2nd)
1025	West Corridor (Grnd)		1238	Lobby to Goods Lift NW (2nd)
1030	Lobby to NW Stairs (Ground)		1240	Lobby to NE Stairs & Pass Lift (2nd)
1034	West Corridor (North end)		1310	Lobby to SE Stairs & Goods Lift (3rd)
1040	Lobby to Stairs & Pass Lift - NE		1311	Steam Pipe Riser - Southeast
1044	East Corridor (North end)		1312	Steam Pipe Race (East)
1051	Gas Circulator Hall - North		1316	Lobby to SE Stairs (3rd)
1060	Boiler Interspace 1/2 Southeast (lower)		1320	Lobby to SW Stairs (3rd)
1070	Boiler Interspace 2/3 Southwest (lower)		1322	Corridor - West
1080	Boiler Interspace 4/5 Northwest (lower)		1330	Corridor NW (3rd)
1090	Boiler Interspace 5/6 Northeast (lower)		1336	Lobby to NW Stairs & Goods Lift (3rd)
1099	External Ground Level		1346	Lobby to NE Stairs & Pass Lift (3rd)
1112	Gas Circ Basement Vent Plant Room - SE		1409	Lobby to SE Stairs
1114	East Corridor (1st)		1410	Lobby to Goods Lift SE (4th)

1122	Gas Circ Basement Vent Plant Room - SW
1130	Lobby to NW Stairs & Goods Lift (1st)
1132	West Corridor North
1133	Gas Circ Basement Vent Plant Room - NW
1507	Boiler Box - Southeast Cct 1 (upper)
1508	Boiler Box - South Cct 2 (upper)
1509	Boiler Box - Southwest Cct 3 (upper)
1510	Lobby to SE Goods Lift (5th)
1512	Boiler Interspace 2/3 Southwest (upper)
1514	Boiler Interspace 1/2 Southeast (upper)
1525	SW Stairs Lobby (5th)
1530	Lobby to NW Stairs & Goods Lift (5th)
1535	NW Stairs Lobby (5th)
1545	Lobby to NE Stairs & Pass Lift (5th)
1585	SE Stairs Lobby (5th)
1610	Charge Hall
1620	Vent/Vac Plant Filter Room (SW)
1630	Lobby to NW Stairs (Sixth)
1633	Charge m/c Control Room Northwest (Upper)
1634	Charge m/c Control Room (Upper)
1640	NE Stairs Lobby (Lower)
1641	NE Plant Room (Upper)
1670	Maintenance Bay - East

1420	Lobby to SW Stairs (4th)
1423	Access Corridor (West - North)
1430	Lobby to NW Stairs & Goods Lift (4th)
1440	Corridor NE (4th)
1732	Vent Plant Room (for Control Room) NW
1733	Viewing Gallery (NW)
1740	Lift Motor Room - Northeast
1751	Boiler Box - Northwest Cct 4 (upper)
1752	Boiler Box - North Cct 5 (upper)
1753	Boiler Box - Northeast Cct 6 (upper)
1754	Boiler Interspace 4/5 Northwest (upper)
1755	Boiler Interspace 5/6 Northeast (upper)
1761	Hot Duct Cell - Northwest Cct 4 (upper)
1762	Hot Duct Cell - North Cct 5 (upper)
1763	Hot Duct Cell - Northeast Cct 6 (upper)
1771	Shield Cooling Fan Room - North (upper)
1801	Steam Pipe Race - South
1802	Shield Cooling Discharge (Upper) Plenum - South
1803	Lobby to South Steam Pipe Race - East
1810	Maintenance Bay Vent Plant Room (SE)
1811	FMMB Vent Room (Southeast)
1812	Maintenance Bay Higher Slab (SE)
1820	Vent Plant Room - Southwest

1710	Goods Lift Motor Room - Southeast
1720	Vent Plant Room (SW)
1730	Lobby to NW Stairs & Goods Lift (7th)
1731	NW Plant Room (above Shield Fan Room)
1901	Top Duct Area - South
1951	Top Duct Area - North
1960	North Stack
1970	South Stack

1830	Goods Lift Motor Room - Northwest
1840	Tank Room - Northeast
1851	Steam Pipe Race - North
1852	Shield Cooling Discharge (Upper) Plenum - North

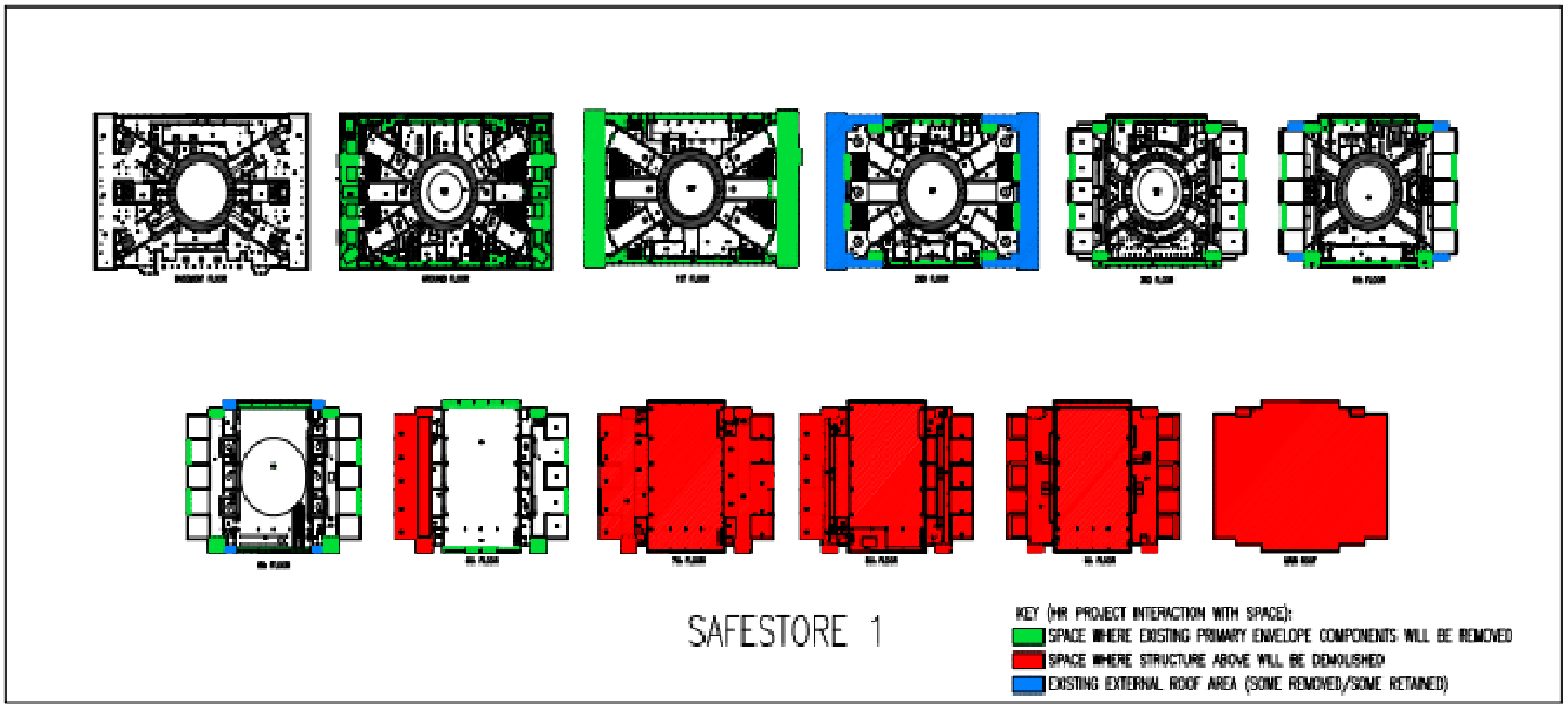
Contd. Overleaf

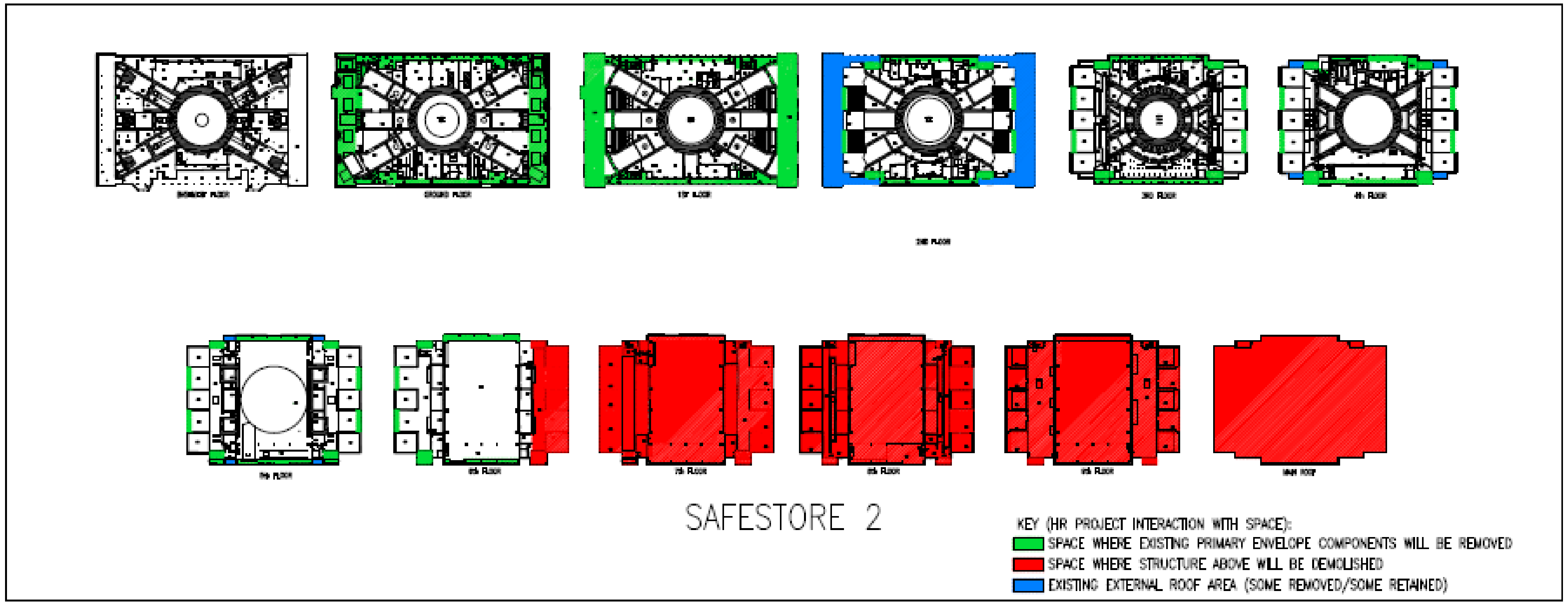
Reactor Building 2				
Space	Space Name		Space	Space Name
2001	Gas Circulator Hall - North		2212	Lobby - Northeast
2010	Lobby to Stairs & Goods Lift (NE)		2220	Lobby to NW Stairs (2nd)
2014	Corridor (Northeast end)		2228	NW Lobby (2nd)
2015	Corridor (East)		2230	Lobby to SW Stairs & Goods Lift (2nd)
2020	Lobby to NW Stairs (Ground)		2238	Lobby to Goods Lift SW (2nd)
2024	West Corridor (North end)		2240	Lobby to SE Stairs & Pass Lift (2nd)
2025	West Corridor (Grnd)		2310	Lobby to NE Stairs & Goods Lift (3rd)
2030	Lobby to SW Stairs (Ground)		2311	Steam Pipe Riser - Northeast
2034	West Corridor (South end)		2312	Steam Pipe Race (East)
2040	Lobby to Stairs & Pass Lift - SE		2316	Lobby to NE Stairs (3rd)
2044	East Corridor (South end)		2320	Lobby to NW Stairs (3rd)
2051	Gas Circulator Hall - South		2322	Corridor - West
2060	Boiler Interspace 11/12 Northeast (lower)		2330	Corridor SW (3rd)
2070	Boiler Interspace 10/11 Northwest (lower)		2336	Lobby to SW Stairs & Goods Lift (3rd)
2080	Boiler Interspace 8/9 Southwest (lower)		2346	Lobby to SE Stairs & Pass Lift (3rd)
2090	Boiler Interspace 7/8 Southeast (lower)		2409	Lobby to NE Stairs
2099	External Ground Level		2410	Lobby to Goods Lift NE (4th)
2112	Gas Circ Basement Vent Plant Room - NE		2420	Lobby to NW Stairs (4th)
2114	East Corridor (1st)		2423	Access Corridor (West - South)
2122	Gas Circ Basement Vent Plant Room - NW		2430	Lobby to SW Stairs & Goods Lift (4th)
2130	Lobby to SW Stairs & Goods Lift (1st)		2440	Corridor SE (4th)
2132	West Corridor South		2507	Boiler Box - Northeast Cct 12 (upper)
2133	Gas Circ Basement Vent Plant Room - SW		2508	Boiler Box - North Cct 11 (upper)
2143	Gas Circ Basement Vent Plant Room - SE		2509	Boiler Box - Northwest Cct 10 (upper)
2210	Lobby to NE Stairs & Goods Lift		2510	Lobby to NE Goods Lift (5th)

	(2nd)			
2512	Boiler Interspace 10/11 Northwest (upper)		2733	Viewing Gallery (SW)
2514	Boiler Interspace 11/12 Northeast (upper)		2740	Lift Motor Room - Southeast
2525	NW Stairs Lobby (5th)		2751	Boiler Box - Southwest Cct 9 (upper)
2530	Lobby to SW Stairs & Goods Lift (5th)		2755	Boiler Interspace 7/8 Southeast (upper)
2535	SW Stairs Lobby (5th)		2761	Hot Duct Cell - Southwest Cct 9 (upper)
2545	Lobby to SE Stairs & Pass Lift (5th)		2762	Hot Duct Cell - South Cct 8 (upper)
2585	NE Stairs Lobby (5th)		2763	Hot Duct Cell - Southeast Cct 7 (upper)
2610	Charge Hall		2771	Shield Cooling Fan Room - South (upper)
2620	Vent/Vac Plant Filter Room (NW)		2801	Steam Pipe Race - North
2630	Lobby to SW Stairs (Sixth)		2802	Shield Cooling Discharge (Upper) Plenum - North
2633	Charge m/c Control Room Southwest (Upper)		2803	Lobby to North Steam Pipe Race - East
2634	Charge m/c Control Room (Upper)		2810	Maintenance Bay Vent Plant Room (NE)
2640	SE Stairs Lobby (Lower)		2811	FMMB Vent Room (Northeast)
2641	SE Plant Room (Upper)		2812	Maintenance Bay Higher Slab (NE)
2670	Maintenance Bay - East		2820	Vent Plant Room - Northwest
2710	Goods Lift Motor Room - Northeast		2830	Goods Lift Motor Room - Southwest
2720	Vent Plant Room (NW)		2840	Tank Room - Southeast
2730	Lobby to SW Stairs & Goods Lift (7th)		2851	Steam Pipe Race - South
2731	SW Plant Room (above Shield Fan Room)		2852	Shield Cooling Discharge (Upper) Plenum - South
2732	Vent Plant Room (for Control Room) SW		2901	Top Duct Area - North
2752	Boiler Box - South Cct 8 (upper)		2951	Top Duct Area - South
2753	Boiler Box - Southeast Cct 7 (upper)		2960	South Stack
2754	Boiler Interspace 8/9 Southwest (upper)		2970	North Stack

Appendix C

Illustration of areas within the reactor buildings that will be directly impacted by height reduction works





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