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E3S Case Chapter 2: Generic Site Characteristics

Executive Summary

This chapter of the Environment, Safety, Security, and Safeguards (E3S) Case presents the Generic Site Characteristics of the Rolls-Royce Small Modular Reactor (RR SMR). The chapter outlines the arguments and preliminary evidence available at the Preliminary Concept Definition (PCD) design stage to underpin the high-level Claim that the RR SMR is designed using bounding generic site characteristics and parameters to enable global deployment in suitable locations.

At PCD, a set of parameters for the Generic Site Envelope (GSE) supporting deployment in suitable locations in Great Britain (GB) were derived to inform the early design development and analysis of the RR SMR. Climate change projections up to the year 2100 have been considered in the development of parameters based on UK Climate Projections 2018 (UKCP18). It is assumed that a future Dutyholder/Licensee will use further refinements of climate models that will be developed in the future and adaptive management techniques in order to ensure that the operation of the plant remains safe beyond the year 2100.

This report also presents a summary of the Generic Site Description (GSD) that has been developed to support environmental assessments.

The generic site characteristics will continue to be developed to underpin the Claim, including refinement of a world GSE which includes the identification and selection of a set of global parameters which support global deployment of the RR SMR with minimal design impact.

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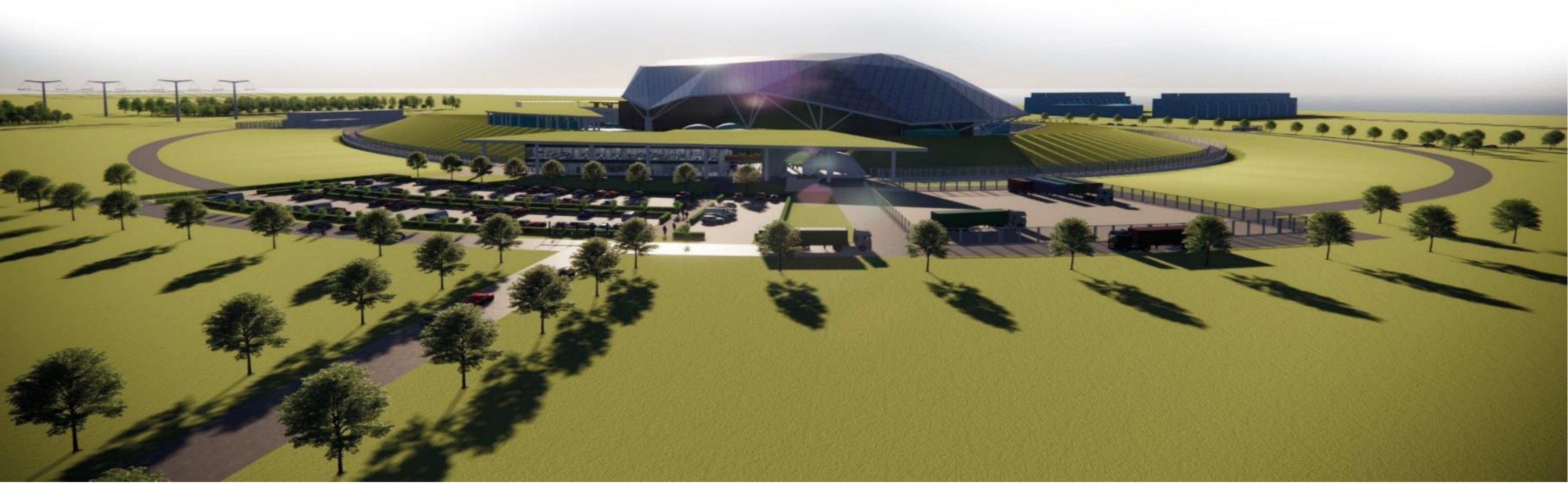

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2.1.1 Introduction to Chapter

Chapter 2 of the Rolls-Royce Small Modular Reactor (RR SMR) Environment, Safety, Security & Safeguards (E3S) Case forms part of the Pre-Construction Safety Report (PCSR) and the Generic Environment Report (GER) and is a supporting reference to the Generic Security Report (GSR), as defined in E3S Case Chapter 1: Introduction, Reference [1].

Chapter 2 presents the overarching summary and entry point to the Great Britain (GB) Generic Site Envelope (GSE) of the RR SMR. It provides details of the site bounding characteristics and parameters within which the RR SMR is designed, such that it is capable of being built and operated in a way that is acceptably safe, throughout its entire lifecycle.

2.1.2 Scope

The scope of this report is to provide a summary of the RR SMR GSE parameters developed to inform the design development and analysis at Preliminary Concept Definition (PCD) stage of the design programme, and in support of GB regulatory Generic Design Assessment (GDA) process, Reference [2]. This includes:

1. External hazards (Section 2.2)
2. Ultimate heat sink (Section 2.3.1)
3. Local population density and distribution (Section 2.3.2)
4. Connections to the electrical grid (Section 2.3.3)
5. Loss of off-site power (Section 2.3.4)
6. Soil properties (Section 2.3.5)
7. Generic Site Description (GSD) (Section 2.4)

The external hazards consider only those hazards that have been identified and screened as relevant to suitable locations in GB and applicable at the generic design stage. The hazard identification and screening process is described in Section 2.2. The effects of climate change on meteorological data have also been considered with the scope of this report.

The consideration of heat sinks is extended to the atmospheric conditions within which the forced draft cooling towers would operate. The sea water make-up supply temperatures for extraction and discharge are not covered within the scope of this report and will be defined at a later stage in the design process.

The density and distribution of the local population considers the acceptability criteria only and no specific site evaluations are carried out.

The electrical grid connections cover the export of power produced by the plant as well as the import needs for various operational conditions.

Only design basis values are provided in the GSE with an exception for the operating basis earthquake where an operating basis value is given.

Beyond design basis events and cliff edge events have been considered at a high level and some commentary is provided. Future revisions to this document will report in greater detail on the beyond design basis events, cliff edge events and their GSE criteria.

The GSE has been defined to encompass a wide range of potential current and former nuclear licensed sites as well as nearby locations around coastal GB. Future revisions to the GSE will be carried out when the relevant values to expand the geographic scope beyond GB have been defined. The values are referred to as the world GSE.

At the site-specific stage, the GSE will be combined with two different types of site-specific analyses. A rigorous comparison of the GSE against the characteristics of the proposed site will have to be undertaken to demonstrate that the site is bounded by the GSE criteria. The other set of analyses will be used to demonstrate the suitability of the site for items that are "out-of-scope" and considered to be site-specific factors in the GSE. These analyses are captured in the following two Commitments on the future Dutyholder/Licensee:

Commitment on Future Dutyholder/Licensee C2.1: *Carry out a rigorous comparison of any proposed site with the Generic Site Envelope criteria and determine if the site complies with the criteria laid down*

Commitment on Future Dutyholder/Licensee C2.2: *Carry out screening and analyses of the suitability of any proposed site against any "out-of-scope" and site-specific factors excluded from the Generic Site Envelope and determine if the site is acceptable*

The scope of this report also includes a summary of the GSD. This information will be used during regulatory assessment for environmental assessments including: the initial assessment of the dispersion of gaseous and particulate emissions to air from on-site combustion sources as well as radiological dose assessment (Section 2.4).

2.1.3 Claims, Arguments, Evidence Route Map

The Chapter level Claim for E3S Case Chapter 2: Generic Site Characteristics is:

Claim 2: The RR SMR is designed using bounding generic site characteristics and parameters to enable deployment in suitable locations in Great Britain and globally.

A decomposition of this Claim into Sub-Claims, Arguments, and link to the relevant Tier 2 Evidence is provided in Section 2.7, Appendix A. For each lowest level Sub-Claim, the sections of this report providing the Evidence summary are also identified.

The complete suite of evidence to underpin the Claims in the E3S Case will be generated through the RR SMR design and E3S Case programme and documented in the Claims, Arguments, Evidence (CAE) Route Map, Reference [3], described further in E3S Case Chapter 1: Introduction, Reference [1].

2.2 External Hazards

2.2.1 Method for Identification and Analysis of External Hazards

External hazards for RR SMR are identified by applying hazard identification methods; reviewing documents issued by nuclear licensing bodies; and reviewing previous Generic Design Assessment (GDA) submissions to the Office for Nuclear Regulation (ONR). Full details of the hazard identification methods employed and the reference materials reviewed are contained in Reference [4].

The external hazards that are identified are then screened. The screening is designed to remove those hazards that are: not relevant for a site in GB, of low frequency (estimated to be less than a frequency of one in ten million years), of low consequence (no significant consequential effect on the safety of the plant) or are covered by another hazard such that they could be grouped together. Full details of the screening methods employed are contained in Reference [4].

Values for the various parameters are developed based on Relevant Good Practice (RGP) and Operational Experience (OPEX). Full details of the development of parameters are contained in Reference [4]. Climatology modelling, aging, and cliff edge effects beyond the design basis are discussed in Sections 2.2.3 and 2.2.4 below.

2.2.2 Hazard Screening

Those external hazards screened in scope of the generic design with parameters defined in this section include:

1. Air temperature
2. Relative humidity
3. Wind
4. Tornado
5. Tornadic missiles
6. Rainfall
7. Hail, sleet and snow
8. Ice
9. Cooling water temperature
10. Lightning

There are a number of external hazards which at this stage of development have site specific elements. These include:

1. Seismic

2. Accidental aircraft crash
3. Landscape changes
4. Space weather
5. Flooding
6. Drought
7. Industrial
8. Biological

Apart from landscape changes (as defined in Reference [5]) and drought, the GB GSE, Reference [4], provides reassurance and mitigation measures for how these hazards will be dealt with.

2.2.3 Climate Change

Climate change values up to the year 2100 have been calculated using the UK Climate Projections 2018 (UKCP18) climate analysis tool, Reference [6]. If a parameter cannot be modelled using UKCP18 then best available data are used. It is assumed that a future Dutyholder/Licensee will use further refinements of climate models that will be developed in the future and adaptive management techniques in order to ensure that the operation of the plant remains safe beyond the year 2100.

Climate change is known to affect the following parameters, Reference [4]:

1. Air temperature
2. Rainfall intensity
3. Sea water temperature
4. Wind speed
5. Storm frequency and lightning
6. Snow loading and drifting
7. Humidity

UKCP18 uses Representative Concentration Pathways (RCPs) to develop climate change predictions. RCPs specify the concentrations of greenhouse gases that will result in the total radiative forcing increasing by a specified amount by 2100, relative to pre-industrial levels. RCP 6.0 scenario uses a high greenhouse gas emissions rate and the 90^{th} percentile is used to examine values. If RCP 6.0 has no value provided then RCP 8.0 at the 50^{th} percentile is used.

Climate change adjustment factors are taken into account for air temperature, wind speed, rainfall intensity and sea water temperature parameters, through an extrapolation modification of the historic meteorological data, if appropriate. Full details of the base data, the climate change adjustment factors and how these are taken into consideration are given in Reference [4].

Modelling of climate changes influences on storm frequency and lightning strike density is inconclusive at the current time and further research is necessary, Reference [4]. No climate change adjustment factors are applied to the snow loading and drifting hazard as the climate is expected to warm and the current values are considered to be conservative, Reference [4]. Relative humidity values are set as conservative but do not have any specific climate change adjustment factors applied, Reference [4].

2.2.4 Beyond Design Basis and Cliff Edge Effects

The determination of the severity of the design basis event for external hazards external hazards varies dependent on whether it is man-made or naturally occurring.

For man-made external hazards the design basis is defined in one of two ways: probabilistically, as a best estimate value of hazard severity and frequency of occurrence down to about 10E-5/year, or deterministically, as a maximum credible event, Reference [7].

For natural external hazards defined by hazard curves, the design basis is defined as follows: probabilistically, as a conservative estimate of hazard severity at the 10E-4/year frequency of exceedance point on the hazard curve, Reference [7].

The term 'beyond design basis external event' is used to indicate a level of external hazard exceeding those hazard levels considered for design, derived from the hazard evaluation for the site. The purpose of identifying beyond design basis external events is to ensure that the design incorporates features to enhance the capability of the installation to withstand such events. In addition, the identification of such events is used in evaluating the margins that exist in the design and in identifying potential cliff edge effects.

A cliff edge is defined in Reference [7] as "where a small change in analysis assumptions, such as those relating to design basis hazard severity, facility response, or design basis analyses is predicted to lead to a disproportionate increase in radiological consequence."

The exact challenge the plant is subjected to cannot be determined until the site is known. For some criteria hazard curves will need to be generated e.g., seismicity. The philosophy behind the RR SMR design is that bounding values have been used for all hazards. Therefore, it is anticipated that as conservative values have been used to encompass a wide range of sites that there will be a margin between the design values and the site-specific requirements. This margin will be explored as the design progresses with sensitivity studies to show that there are no cliff edge effects and there is adequacy beyond the design basis.

The structure of the plant, particularly the hazard shield, will be designed to allow for a margin beyond the design basis for many of the external hazards.

2.2.5 Air Temperature

The ambient air temperature values are defined for the bounding maximum and minimum values for the lifetime of the plant. The derivation of the values are given in Reference [4].

The value chosen for the maximum hourly dry bulb air temperature is 49.0°C.

The value chosen for the maximum hourly wet bulb air temperature is 32.3°C.

The minimum dry air hourly average temperature is -35˚C. Table 2.2-1 provides a summary of the air temperature criteria.

Table 2.2-1: Air Temperature Criteria

Parameter	GSE Value
Maximum dry bulb air temperature (hourly)	49.0˚C
Maximum wet bulb air temperature (hourly)	32.3˚C
Minimum dry bulb air temperature (hourly)	-35˚C

2.2.6 Relative Humidity

Extremes of relative humidity have been considered. The derivation of the values used are given in Reference [5]. Whilst it may be possible in some circumstances for supersaturation to be a phenomenon, this is discounted from being a significant issue. Therefore, the maximum relative humidity is set at 100%, Reference [4]. The hazards associated with fog, freezing fog and mist are all considered to be within this classification.

The minimum relative humidity value is selected as 12%, Reference [4]. Whilst humidity is discussed in UKCP18, Reference [7], no climate change adjustment is necessary as the minimum humidity value is for a 100% design basis envelope. The average relative humidity is selected as 84%, Reference [4].

Table 2.2-2: Relative Humidity Criteria

Parameter	GSE Value
Maximum relative humidity	100%
Minimum relative humidity	12%
Average relative humidity	84%

2.2.7 Wind

The wind speeds under consideration in the design of the plant include a maximum ten-minute average wind speed of 46.5 metres/second, as shown in Table 2.2-3. The derivation of this value is given in Reference [4]. It should be noted that this value is bounded by the peak wind value for a tornado. The ten-minute average is published in accordance with the Eurocode 1 design standard, Reference [8].

Table 2.2-3: Wind Criterion

Parameter	GSE Value
Maximum ten-minute average wind speed	46.5m/s

2.2.8 Tornado

The United States Nuclear Regulatory Commission (US NRC) defines three classes of tornado, Reference [9]. Class three tornadoes are found on the western seaboard of the US and are the closest in type to those found affecting GB, Reference [4].

The Met Office has produced a UKCP storm projection technical note, Reference [10], which concludes that there are no clear trends suggesting that the impact of climate change on tornadoes is unknown. Therefore, climate change adjustment values are not applied to tornado parameters. The peak wind speed within the chosen class of tornado is 72 metres/second. The derivation of the value used is given in Reference [5].

The static air pressure variations tend to be relatively small over time. Rapid transients occur during tornadoes and lower wind speed storms. The maximum rate of static pressure drop is set as 13mbar/s and a maximum pressure drop trough value of 40mbar. The derivation of the values used are given in Reference [5].

Table 2.2-4 presents a summary of the wind and tornado wind speed and pressure variations.

Table 2.2-4: Tornado Criteria

Parameter	**GSE Value**
Tornadic wind speed	72m/s
Maximum pressure drop	40mbar
Pressure drop rate	13mbar/s

2.2.9 Tornadic Missiles

Impacts from external missiles could occur from off-site explosions as well as military missiles. High inertia rotating machinery, such as steam turbines, could disintegrate and provide significant mass and energy missiles. Disintegration of transport infrastructure, such as pipelines, ships and trains could also provide a source of missiles. Wind-blown debris may impact the plant or block inlets and exhaust pathways. All of these are considered to be site-specific issues.

The only generic site envelope missile criteria that have been adopted are those generated by tornadoes. The derivation of the values are given in Reference [5]. The criteria are shown in Table 2.2-5.

Table 2.2-5: Tornadic Missile Criteria

Type of Missile	GSE Values		
	Dimensions	Mass (kg)	Impact Speed (m/s)
Schedule 40 Pipe	0.168m diameter x 4.58m length	130	24
Vehicle	4.5m x 1.7m x 1.5m	1178	24
Solid Steel Sphere	0.0254m diameter	0.0669	6

2.2.10 Rainfall

Various forms of precipitation are recognised as being a hazard. Rain, sleet, snow and hail stones falling onto the plant as well as icing accumulating on the plant are recognised as having structural effects.

The derivation of the rainfall values are given in Reference [5]. The values are a one-hour peak rainfall rate of 0.221 metres in one-hour and a 24-hour average rainfall rate of 0.400 metres in a 24-hour period. Table 2.2-6 below presents a summary of the rainfall criteria.

Table 2.2-6: Rainfall Criteria

Parameter	GSE Value
Rainfall in one hour	0.221m
Rainfall in 24-hours	0.400m

2.2.11 Hail, Snow and Sleet

Hail, snow and sleet loading on buildings are compared for structural load design purposes, Reference [4]. Snow presents the worst-case structural loading of the three types of precipitation. The maximum structural snow loading is taken to be 1.5kN/m^2, as shown in Table 2.2-7 .

Table 2.2-7: Ground Snow Load Criterion

Parameter	GSE Value
Ground snow load	1.5kN/m^2

2.2.12 Ice

Clear ice, rime ice and glaze ice are compared for structural load design purposes, Reference [5]. Clear ice presents the worst-case structural loading of the three types of ice.

The maximum thickness of clear ice that would accumulate at the plant is calculated to be a depth of 0.117 metre. The density of the clear ice is calculated to be 9kN/m^3. Table 2.2-8 presents a summary of the critical hail, sleet, snow and ice bounding values.

Table 2.2-8: Ice Loading Criteria

Parameter	GSE Value
Clear ice density	9kN/m^3
Clear ice thickness	0.117m

2.2.13 Cooling Water Temperature and Salinity

The town water supply (or potable water supply) is used to feed the make-up of the Essential Service Water System (ESWS) [PB]. The derivation of the values used are given in Reference [5]. The maximum temperature is set at 30˚C and the minimum water temperature is set at 0˚C.

The sea water supply temperature is set at a maximum of 32.3˚C. The minimum temperature is set at -1.9˚C in order to avoid frazil ice related hazards. However, frazil ice formation will have to be considered on a site-specific basis in order to account for local salinity levels, etc. Further details are given in Reference [4].

The maximum salinity of sea water taken into the plant is set as 3.5%.

A summary of the cooling water temperature and salinity values are stated in Table 2.2-9.

Table 2.2-9: Cooling Water Temperature and Salinity Criteria

Parameter	GSE Value
Town water supply maximum temperature	30˚C
Town water supply minimum temperature	0˚C
Maximum sea water temperature	32.3˚C
Minimum sea water temperature	-1.9˚C
Maximum salinity of sea water	3.5%

2.2.14 Lightning

Lightning strikes may occur at any location across GB. The maximum credible peak current for lightning strike is set at 300kA, References [4] and [11]. This value exceeds the 290kA value for the Sizewell B stress test level for a frequency of 10E-4/year, Reference [12]. Appropriate surge protection for electrical and electronic equipment associated with this power of lightning strike in the vicinity of the plant will be provided. The lightning parameter used is shown in Table 2.2-10.

Table 2.2-10: Lightning Strike Criterion

Parameter	GSE Value
Lightning Current	300kA

2.2.15 Seismic

Seismic criteria are set in terms of the Operating Basis Earthquake (OBE) and the Design Basis Earthquake (DBE). The OBE level is defined such that no structure, system or component (required to perform an E3S function) should be impaired by the repeated occurrence of ground motions at that level, Reference [7]. The derivation of the values are given in Reference [4].

The OBE has a Peak Ground Acceleration (PGA) value of 0.08g, References [4] and [13].

The DBE has a PGA value of 0.3g, References [4] and [13]. The spectra shapes are shown in Figure 2.2-1.

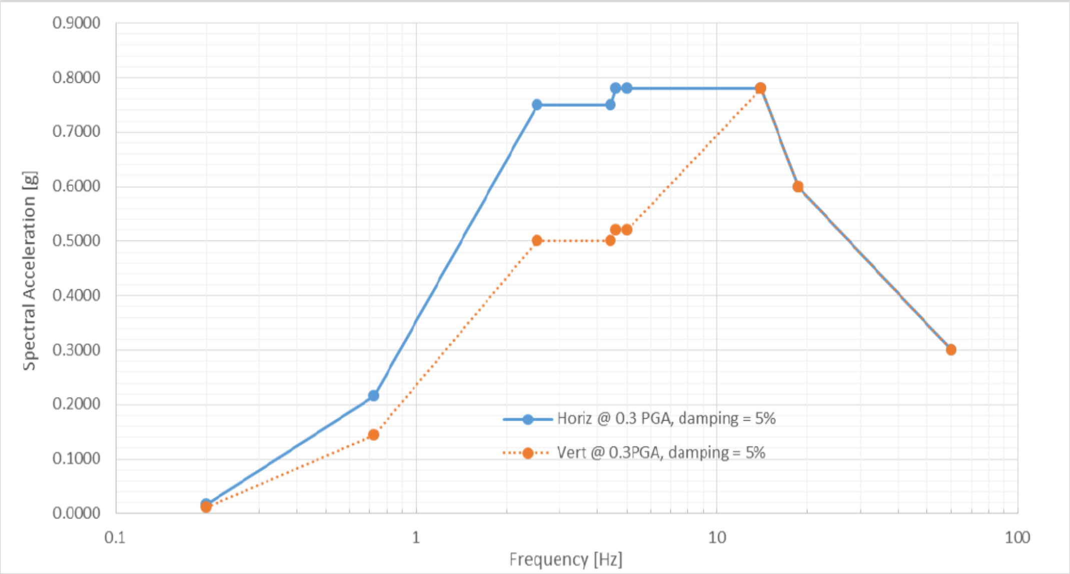

Figure 2.2-1: Adopted Design Basis Earthquake Spectra

A summary of the seismic criteria values adopted for GSE is presented in Table 2.2-11.

Table 2.2-11: Seismic Criteria

Parameter	GSE Value
Design basis earthquake peak ground acceleration	0.3g
Operating basis earthquake peak ground acceleration	0.08g

2.2.16 Accidental Aircraft Crash

There are two components to the consideration of accidental aircraft crash. Firstly, the accidental aircraft crash frequency onto, and adjacent to, the site (which could lead to the wreckage skidding or flying ballistically into the site). Secondly, the resulting impact load-time function upon the structure that is hit.

The accidental aircraft crash frequency is site-specific. The frequency of an accident in a given area depends upon the number of aircraft overflying the area as well as the mix of aircraft types and their individual crash rates. Other factors, such as terrain, also affect the crash rates.

Five groups of aircraft have been defined as part of the design basis and accident rates determined for the period 1990 to 2013, Reference [14]. The groups are light aircraft, small transport aircraft, large transport aircraft, helicopters and military combat aircraft. The sites being considered are outside areas of high military crash concentrations and the normal military activity area values are used. The crash frequencies are presented in Table 2.2-12.

Table 2.2-12 : Background aircraft crash rates for the period 1990 to 2013 for Great Britain

Aircraft type	Mean (10E-6/km^2/yr)	Lower confidence limit (10E-6/km^2/yr)	Upper confidence limit (10E-6/km^2/yr)
Light aircraft	18.5	15.1	22.4
Small transport aircraft	2.2	1.1	3.8
Large transport aircraft	0.7	0.2	1.9
Helicopters	10.3	7.8	13.4
Military Combat Aircraft (MCA)	6.7	4.7	9.2
Total	38.4	28.9	50.7

All the aircraft crash frequency values are being reviewed and will be reported as the GSE is developed. The representative aircraft types, their mass at impact, impact velocity (speed, direction and angle of travel just prior to impact) and resulting load-time graphs are security classified for the design of the RR SMR. For this reason, no further data are provided in this Chapter.

2.2.17 Summary of External Hazards Parameters and GSE Values

A summary of the external hazard parameters is given in Table 2.2-13 below.

Table 2.2-13: Summary of External Hazard Parameters and GSE Values

External Hazard	Parameter	GSE Value
Air Temperature	Maximum dry bulb air temperature (hourly)	49.0˚C
	Maximum wet bulb air temperature (hourly)	32.3˚C
	Minimum dry bulb air temperature (hourly)	-35˚C
Relative Humidity	Maximum relative humidity	100%
	Minimum relative humidity	12%
	Average relative humidity	84%

External Hazard	Parameter	GSE Value
Wind	Maximum 10-minute mean wind speed	46.5m/s
Tornado	Tornadic wind speed	72m/s
	Maximum pressure drop	40mbar
	Pressure drop rate	13mbar/s
Tornadic Missiles	Schedule 40 Pipe 0.168m diameter x 4.58m length, 130kg	24m/s
	Vehicle 4.5m x 1.7m x 1.5m, 1178kg	24m/s
	Solid steel sphere 0.0254m diameter, 0.0669kg	6m/s
Rainfall	Rainfall in one hour	0.221m
	Rainfall in 24-hours	0.400m
Hail, Snow and Sleet	Ground snow load	1.5kN/m^2
Ice	Clear ice density	9kN/m^3
	Clear ice thickness	0.117m
Cooling Water Temperature	Maximum towns water supply temperature	30°C
	Minimum towns water supply temperature	0°C
	Maximum sea water temperature	32.3°C
	Minimum sea water temperature	-1.9°C
	Salinity concentration	3.5%
Lightning	Lightning current	300kA
Seismic	Design basis earthquake peak ground acceleration	0.3g
	Operating basis earthquake peak ground acceleration	0.08g

2.3 Site Information

2.3.1 Ultimate Heat Sink

The GSE considers a single unit site, that is deployed at a coastal location, with an indirect cooling system, utilising forced draft cooling towers. Sea water is used to provide makeup water for the mass evaporated from the cooling towers.

There are four different systems which interact with the ultimate heat sink associated with RR SMR. These are the Main Cooling Water System (MCWS) [PA] (to cool the turbines' condensers), the Auxiliary Cooling and Make-up System (ACMS) [PE] (to cool the turbine island's other systems), the ESWS [PB] (to cool elements of the primary circuit and other systems within the containment) and the Local Ultimate Heat Sink system (LUHS) [JNK] (used as part of emergency measures and for passive decay heat removal from the secondary side of the steam generators).

Further detailed descriptions of the design of the MCWS [PA], ACMS [PE] and ESWS [PB] are given in the E3S Case Chapter 9A: Auxiliary Systems, Reference [15]. Further detailed description of the LUHS [JNK] is given in the E3S Case Chapter 6: Engineered Safety Features, Reference [16].

The values selected as the design basis for the atmospheric properties of the ultimate heat sink are stated in Table 2.2-1 and Table 2.2-2.

The values for temperature and humidity match the general values stated for external hazards and are valid for all aspects of the plant. These values are valid for the three systems that use the indirect cooling towers as well as the LUHS that vents to atmosphere. There are no stated limits as to the temperature and humidity rise that can be tolerated by the atmosphere in the vicinity of the plant associated with using air as the ultimate heat sink.

The range of sea water extraction temperatures are derived in Reference [4] and given in Table 2.2-9.

2.3.2 Local Population Density and Distribution

The population density and distribution criterion adopted for RR SMR deployment in the UK is that the site's local population distribution shall be at or below the values given in the semi-urban criterion, Reference [17], stated in Table 2.3-14-1:

Table 2.3-14: Semi-Urban Population Density and Distribution Criterion

Semi-Urban Value Number or Criterion	**Site Population Factor Value or Criterion**
Site Population Factor Value One	The cumulative weighted population values for any 30° sector in the ranges 0 – R_i (where R_i is a circle of radius i km and i varies from 2 to 30 km) shall not exceed those for a hypothetical 30° sector with a uniform population density of 5000 persons per km^2 from 1 to 30 km and zero population within 1 km.
Site Population Factor Value Two	The cumulative weighted population values all around the site in the ranges 0 – R_i (where R_i is a circle of radius i km and i varies in 1 km increments from 2 to 30 km) shall not exceed those for a hypothetical circle with a uniform population density of 1000 persons per km^2 from 1 to 30 km with zero population within 1 km; where the weighting factors applied to the population within each radial band shall be proportional to $1/R^{1.5}$ and R is the area-weighted average distance between the radial band and the site centre point.
Criterion	A site shall be determined to be potentially suitable for the deployment of new nuclear power stations if all the ratios of the actual versus the hypothetical cumulative weighted population values ("Site Population Factors") are less than unity, i.e., $SPF_{MAX} < 1$

The treaties, laws, regulations, and guidance material that inform the design of the RR SMR to enable effective emergency preparedness and accident management have been collated in E3S Case Chapter 19: Emergency Preparedness and Response, Reference [18]. This covers the provision of infrastructure, equipment, and outline development of on-site control room procedures. The provision of effective emergency preparedness and accident management processes are issues for planning authorities and operating licensees to address on a site-specific basis.

2.3.3 Connections to the Electrical Grid

Two offsite power connections are intended in the design, a primary connection for the import/export of power and an auxiliary connection for redundancy. The primary and secondary connections are single 400kV connections and will interface with the Generator Transmission Main Connection [MS] and the Station Transformer [BCT] within the Power Transmission System [B]. The Grid Transmission System [A] and the Generator Transmission Main Connection [MS] are currently in development, Reference [19].

The output alternating current voltage and frequency of the RR SMR will comply with the UK specification standards, including the Grid Code, Reference [20], such that it can be connected to the National Electricity Transmission System (NETS).

2.3.4 Loss of Off-Site Power

The ability to import electrical power (for example, from the national grid is dependent upon the functioning of the grid to provide power to the site's switch yard and the internal ability to transform and distribute the imported power.

In relation to Loss Of Off-site Power (LOOP) faults, the frequencies of grid-related loss adopted for RR SMR, defined in Reference [21], are given in Table 2.3-2 below.

Table 2.3-2: Loss of Off-Site Power Criteria

Description	**Duration (hours)**	**Frequency (per year)**
Short-term loss of off-site power	2	5 x 10E-2
Medium-term loss of off-site power	24	5 x 10E-3
Long-term loss of off-site power	168	5 x 10E-5

2.3.5 Soil Properties

The plant design considers that stiff clay, dense sand, weak rock, and strong rock are the geological classification design basis for the load bearing ground underneath the plant. These cover the range of geological and geotechnical conditions found at typical UK nuclear power station sites, Reference [22].

Organic soils, soft cohesive soils and loose granular soils are deemed unsuitable founding materials for the RR SMR raft structures as they are unlikely to provide adequate bearing capacity, settlement, or seismic performance, Reference [4].

Seismic ground performance hazards, such as liquefaction or cyclic soil softening, are screened out from further consideration because they only occur in the geological classifications scoped out of the design basis, Reference [4].

2.4 Generic Site Description

2.4.1 Introduction

The GSD, Reference [23], describes the set of characteristics which define the range of sites that the environmental assessments, E3S Case Chapter 30: Prospective Radiological Assessment at the Proposed Limits for Discharges and for any On-Site Incineration, Reference [24], and E3S Case Chapter 31: Conventional Impact Assessment, Reference [25] for RR SMR will be carried out against. These characteristics will also ultimately be those against which a Statement of Design Acceptability (SoDA) would be issued by the Environment Agency (EA) – in conjunction with Natural Resources Wales (NRW) – on completion of the GDA process.

The simplest approach to the definition of the GSD is adopted at this stage of the design programme, to use a representative coastal site with a single design, noting that other types of site and site-specific technological options are available and can be considered for individual sites.

The report describes the philosophy underlying the selection of the GSD, and provides specific information with respect to:

1. Meteorological and other parameters which affect gaseous dispersion and deposition
2. Hydrographic and other parameters which affect aqueous dispersion
3. Local exposure groups (for the purposes of dose assessment)
4. Food consumption rates and other human habits data
5. Reference organisms (for the assessment of radiological impacts on non-human biota)
6. Availability of water for abstraction

The generic site characteristics (Section 2.4.1) will be used for radiological dose assessment, and the initial assessment of the dispersion of gaseous and particulate emissions to air from on-site combustion sources for the RR SMR.

This appendix contains a summary of the generic site characteristics. Full descriptions are contained in Reference [23].

2.4.1 Generic Site Characteristics

Overview

At PCD, the generic site is assumed to be coastal, with the site being located approximately 100m from the sea. The RR SMR will be cooled using induced draft cooling towers, with the cooling water demand being met by abstracted seawater (noting this is a conservative assumption for environmental purposes).

The following general assumptions have been made with regards to the generic site:

1. The site and its surrounding area are assumed to lie on a flat plain with no large buildings in the immediate vicinity other than the RR SMR nuclear power plant

2. The site is not located on an aquifer

3. There is no standing water at the site

4. No water bodies or watercourses cross the site

5. There is no ground or groundwater contamination present on the site

Meteorological and Associated Parameters

The effects of atmospheric emissions will be assessed at PCD subject to the following assumptions:

1. The bulk of gaseous radioactive discharges to the atmosphere will be released from a single stack situated above the shell structure. The design and optimisation of the RR SMR stack is currently in progress. A conservative effective release height of 15m has been adopted for purposes of assessing the impacts of gaseous radioactive discharges to the atmosphere, based on the maximum height of the RR SMR shell structure (approximately 45m). This is consistent with the cautious approach for modelling the wake effects of structures on the dispersion of gaseous discharges recommended by the National Radiological Protection Board (NRPB), Reference [26].

2. Factors such as plume rise, and coastal wind effects will not be considered explicitly. The actual effects of how neighbouring buildings are laid out and local terrain will be considered at the site-specific permitting stage.

Initial radiological assessment at PCD will be based upon meteorological conditions associated with 50% Pasquill stability category D (see Table 2.4-15) and will adopt a uniform wind rose. The assumed atmospheric stability conditions are based on average UK meteorological conditions and have been chosen emphasising those in which dispersion is more limited at the distances of interest, leading to cautious estimates of air concentrations and deposition rates.

Table 2.4-15: Atmospheric Conditions

Pasquill Stability Category	**Initial Radiological Assessment**	
	Frequency of Occurrence	**Wind Speed at 10 m Height**
	(%)	**(m/s)**
A	1	1
B	9	2
C	21	5
D	50	5
E	8	3
F	10	2
G	2	1

Future detailed radiological assessments will be based on meteorological conditions associated with 70% Pasquill stability category D. This datum corresponds with prevailing conditions typical of a large proportion of the UK's coastline.

The surface roughness (an air dispersion modelling parameter) is assumed to be 0.3m, a generic value typical of agricultural areas. This surface roughness value is deemed to be representative of the rural surroundings assumed for the generic site.

Geographical Information

Geographical information for the generic site, pertinent to the radiological dose assessments, is presented in Table 2.4-2.

Table 2.4-2: Geographical Information Used in the Radiological Dose Assessments

Item	Unit	Initial Radiological Assessment
Residential dwelling location	m	100 from discharge point
Food production location	m	500 from discharge point
Surface roughness	m	0.3
Marine Module	-	Not applicable
Regional compartment	-	Not applicable
Local compartment volumetric exchange rate	m^3/yr	9.5 × 10E+8
Local compartment volume	m^3	10E+8
Local compartment depth	m	10
Local compartment coastline length	m	10E+4
Local compartment suspended sediment load	te/m^3	10E-5
Local compartment sediment rate	$te/m^2/yr$	4.9 × 10E-3
Local compartment dry sediment density	te/m^3	2.6
Local compartment bioturbation rate	m^2/yr	3.6 × 10E-5
Local compartment diffusion rate	m^2/yr	3.15 × 10E-2

Hydrographic and Associated Parameters

Marine data relevant to dose modelling has been included in the geographical information presented in Table 2.4-2.

The impact of cooling water discharges is site specific. Therefore, site data in support of cooling water discharge modelling are not provided at this stage.

Exposure Groups

Human Exposure Groups

The coastal site is situated in a rural setting, with the surroundings dominated by agricultural land use and fishing activities in the local sea. The local population are assumed to reside approximately 100m from the power station site and to source most of their food (meat and dairy products) from a local farm situated approximately 500m away from the site. Members of the local public are also assumed to grow fruit and vegetables in their gardens or nearby allotments. It is assumed that around 50% fish and 100% of other seafood consumed is sourced from the local marine waters adjacent to the site. The local population is also assumed to spend time on the local beach pursuing leisure activities.

The habits of the local population create potential pathways for exposure to aqueous and gaseous radioactivity, as well as direct radiation, originating from the power station site, as described in Table 2.4.3. Further information on the exposure pathways and details of the habits data are presented in the initial radiological assessment report, Reference [27].

Table 2.4.3: Exposure Groups

Releases to Air	For releases to air an exposure group of 'local inhabitant family' comprising an adult, a 10 year old child and a 1 year old infant will be selected. Members of this group are assumed to be exposed to the discharge plume and to radionuclides that have been deposited to the ground and subsequently incorporated into terrestrial foodstuffs. Relevant pathways are: • Internal irradiation from the inhalation of radionuclides in the effluent plume • External radiation from radionuclides in the effluent plume • External radiation from radionuclides deposited to the ground • Internal irradiation from consumption of terrestrial food containing radionuclides deposited to the ground (not considered for radionuclides with half-lives of less than 3 hours) Concentrations in air and deposition rates will be derived for a habitation distance of 100m and a food production distance of 500m from the release point.

Releases to coastal water	For releases to coastal water an exposure group of 'fisherman family' comprising an adult, a 10 year old child and a 1 year old infant will be selected. Members of this group are assumed to be exposed to activity in coastal discharges by consumption of seafood contaminated by radionuclides in seawater and by spending time on local beaches. Relevant pathways are: • Internal irradiation from the consumption of seafood contaminated with radionuclides • External radiation from radionuclides in beach and shore sediment during bait collection. Releases are assumed to take place into a local marine compartment characterised by a volumetric water exchange rate of 100m^3/s with the neighbouring regional compartment.

The assessment of human health impacts from combustion source emissions is based on maximum predicted ground level concentrations of pollutants, so discrete human presence/habitation receptors have not been identified at this stage.

Non-human Biota

The terrestrial and marine environments around the generic site are assumed to provide habitats for a wide range of non-human organisms. The reference organisms considered for the GDA are identified in Table 2.4-4. There will be no radioactive discharges to freshwater bodies so only marine and terrestrial species are considered. Table **2.4-4Table 2.4-4: Reference Organisms Considered in the Vicinity of the Generic Site**

Terrestrial	Marine
Amphibian	Zooplankton
Bird	Vascular plant
Bird egg	(Wading) bird
Detritivorous invertebrate	Benthic fish
Flying insect	Benthic mollusc
Gastropod	Crustacean
Grasses and herbs	Macroalgae
Lichen and bryophytes	Mammal
Mammal (rat)	Pelagic fish
Mammal (deer)	Phytoplankton
Reptile	Polychaete worm
Shrub	Reptile
Soil invertebrate (worm)	Sea anemones/true corals – colony
Tree	Sea anemones/true corals – polyp

Only the generic site characteristics needed for the radiological dose assessment have been included in this site description. The generic site is not assumed to encompass or lie adjacent to any designated site. Information on designated sites – Special Protection Areas (SPAs), Special Areas of Conservation (SACs), etc. – will be utilised in the site-specific Environmental Permitting process where relevant.

Food Consumption Rates and Other Human Habits Data

The local exposure groups are assumed to consume locally grown food and seafood, which incorporates a small fraction of the radioactivity released from the power station. Details of the types of food and seafood harvested from the local area, the food ingestion rates, time spent in the local area and other habits of the populace around the generic site that results in their exposure to radioactivity from the power station are presented in the radiological assessment methodology, Reference [27].

Availability of Water for Abstraction

The RR SMR will abstract seawater for cooling. There will be no freshwater abstraction for cooling or any other purposes.

2.5 Conclusions

2.5.1 Conclusions

Preliminary evidence is presented to support the overall claim that 'The RR SMR is designed using bounding generic site characteristics and parameters to enable deployment in suitable locations in Great Britain and globally', which contributes to the overall E3S objective to protect people and the environment from harm, and the demonstration that risks are reduced to be "As Low As Reasonably Practicable" (ALARP).

The generic site characteristics will continue to be developed in line with the CAE Route Map, including development of a world GSE, which includes the identification and selection of a set of global parameters to support global deployment of the RR SMR with minimal design impact.

2.5.2 Assumptions and Commitments on Future Dutyholder/Licensee

Table 2.5-1: Assumptions and Commitments on Future Dutyholder/Licensee

Assumption/Commitment	ID	Description
Commitment	C2.1	Carry out a rigorous comparison of any proposed site with the Generic Site Envelope criteria and determine if the site complies with the criteria laid down.
Commitment	C2.2	Carry out analyses of the suitability of any proposed site against any "out-of-scope" and site-specific factors excluded from the Generic Site Envelope and determine if the site is acceptable.

2.6 References

[1] **RR SMR Report, SMR0004294/001, "E3S Case Chapter 1: Introduction," March 2023.**

[2] ONR, "New Nuclear Power Plants: Generic Design Assessment Technical Guidance, ONR-GDA-GD-007 Revision 0," 2019.

[3] RR SMR Report, SMR0002155/001, "E3S Case CAE Route Map," March 2023.

[4] RR SMR Report, SMR0001535/001, "Generic Site Envelope," August 2022.

[5] ONR, "External Hazards, Nuclear Safety Technical Assessment Guide NS-TAST-GD-013 Issue 8.1," 2022.

[6] Met Office, "UK Climate Projections (UKCP)," 2023.

[7] ONR, "Safety Assessment Principles for Nuclear Facilities, Revision 1," 2020.

[8] British Standards Institution, "BS EN 1991-1-4:2005+A1:2010 Eurocode 1. Actions on structures. General actions. Wind actions," April 2005.

[9] US NRC, "Regulatory Guide 1.76, Design Basis Tornado and Tornado Missiles for Nuclear Power Plants, Revision 1," 2007.

[10] Met Office, "Technical Notes on Storm Projections," 2009.

[11] Conseil International des Grands Réseaux Electriques (CIGRE), "Lightning Parameters for Engineering Applications," 2013.

[12] EDF Energy, "EU Stress Test - Sizewell B, Revision 001," January 2012.

[13] RR SMR Report, EDNS01000888380 Issue 1, "Design Input Spectra for UK Generic Design," April 2020.

[14] Health and Safety Executive (HSE), "RR1140 Update of aircraft crash rates used by HSE in assessing hazards from chemical, process and other major hazard installations," 2019.

[15] RR SMR Report, SMR0003863/001, "E3S Case Chapter 9A: Auxiliary Systems," March 2023.

[16] RR SMR Report, SMR0003771/001, "E3S Case Chapter 6: Engineered Safety Systems," March 2023.

[17] ONR, "Land Use Planning and the Siting of Nuclear Installations NS-LUP-GD-001 Revision 0," 2018.

[18] RR SMR Report, SMR0004571/001, "E3S Case Chapter 19: Emergency Preparedness & Response," March 2023.

[19] RR SMR Report, SMR0004010/001, "E3S Case Chapter 8: Electrical Power," March 2023.

[20] National Grid ESO, "The Grid Code, Issue 6, Revision 16," 2023.

[21] ONR, "Loss of offsite power events," 2014.

[22] RR SMR Report, EDNS0100921630 Issue 1, "Foundation Preliminary Concept Design Report," 2021.

[23] RR SMR Report, SMR0001541/001, "Generic Site Description," March 2023.

[24] RR SMR Report, SMR0004490/001, "Prospective Radiological Assessment at the Proposed Limit for Discharges and for any On-Site Incineration," March 2023.

[25] RR SMR Report, SMR0004514/001, "Conventional Impact Assessment," March 2023.

[26] NRPB Report, NRPB-R157, "The fifth report of a Working Group on Atmospheric Dispersion: Models to allow for the effects of coastal sites, plume rise and buildings on dispersion of radionuclides and guidance on teh value of deposition velocity and washout coefficients," December 1983.

[27] RR SMR Report, SMR0001542/001, "Initial Radiological Assessments," October 2022.

2.7 Appendix A: CAE Route Map

2.7.1 Chapter 2 Route Map

A preliminary Claims decomposition from the overall Chapter 2 Claim is summarised in 1, including the Tier 2 Evidence underpinning the Claims at PCD (i.e., summarised in Revision 1 of this report) and further Tier 2 Evidence still to be developed.

Table 2.7-1: CAE Route Map

<table>
<tr><th>Level 1 Claims</th><th>Level 2 Claims</th><th>Level 3 Claims</th><th>Arguments</th><th>Relevant Evidence Summary Sections within Chapter 2</th><th>Underpinning Tier 2 Evidence

*at PCD</th><th>Underpinning Tier 2 Evidence

*to be developed</th></tr>
<tr><td>-</td><td>-</td><td>-</td><td>Approach for GSE derivation is based on data using RGP and OPEX</td><td>Section 2.2</td><td rowspan="3">RR SMR Generic Site Envelope, Reference [4]</td><td rowspan="3">RR SMR World Generic Site Envelope</td></tr>
<tr><td>-</td><td>-</td><td>-</td><td>Derivation of GSE considers climate change for the expected life of the RR SMR</td><td>Section 2.2.3</td></tr>
<tr><td>-</td><td>-</td><td>-</td><td>GSE parameters are suitably bounding for GB locations</td><td>Sections 2.2 and 2.3</td></tr>
</table>

Level 1 Claims	**Level 2 Claims**	**Level 3 Claims**	**Arguments**	**Relevant Evidence Summary Sections within Chapter 2**	**Underpinning Tier 2 Evidence** ***at PCD**	**Underpinning Tier 2 Evidence** ***to be developed**
-	-	-	GSE parameters are suitably bounding for global locations	n/a	n/a	
-	-	-	Characteristics for generic site are suitable for initial environmental assessments	Section 2.4	Generic Site Description, Reference [23]	n/a

2.8 Acronyms and Abbreviations

ACMS	Auxiliary Cooling and Make-up System
ALARP	As Low As Reasonably Practicable
CAE	Claims, Arguments, Evidence
CIGRE	Conseil International des Grands Réseaux Electriques
DBE	Design Basis Earthquake
EA	Environment Agency
ESWS	Essential Services Water System
E3S	Environment, Safety, Security and Safeguards
GB	Great Britain
GDA	Generic Design Assessment
GER	Generic Environmental Report
GSD	Generic Site Description
GSE	Generic Site Envelope
GSR	Generic Security Report
HSE	Health and Safety Executive
LOOP	Loss of Off-Site Power
LUHS	Local Ultimate Heat Sink
MAX	Maximum
MCWS	Main Cooling Water System
NETS	National Electricity Transmission System
NRC	Nuclear Regulatory Commission
NRPB	National Radiological Protection Board
NRW	Natural Resources Wales
OBE	Operating Basis Earthquake

ONR	Office for Nuclear Regulation
OPEX	Operational Experience
PCD	Preliminary Concept Definition
PCSR	Pre-Construction Safety Report
PGA	Peak Ground Acceleration
RCP	Representative Concentration Pathway
RGP	Relevant Good Practice
R_i	Circle radius i kilometres
RR	Rolls-Royce
SAC	Special Area of Conservation
SMR	Small Modular Reactor
SoDA	Statement of Design Acceptability
SPA	Special Protection Area
SPF	Site Population Factor
UK	United Kingdom
UKCP18	United Kingdom Climate Projections 2018
US	United States