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UK ABWR Generic Design Assessment

Generic PCSR Chapter 2 : Generic Site Envelope

Hitachi-GE Nuclear Energy, Ltd.

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Executive Summary

This chapter describes the Generic Site Envelope (GSE) for the UK ABWR. This is a set of numerical values for each of the identified external hazards that will result due to the site upon which the UK ABWR is built. For GDA, as a specific site has not been selected, the GSE has assessed external hazards values that are representative of the UK. It should be noted that Chapter 2 is closely linked to Chapter 6: External Hazards, but that the two chapters have separate aims, as follows:

- Chapter 6: External Hazards

  This chapter derives the list of external hazards that are applicable to the GDA design of the UK ABWR and those which can only be finalised once a specific site is identified. Chapter 6 provides the justification for the identification of the individual external hazards and also relevant combinations of those hazards. Chapter 6 then provides links to the rest of this PCSR where the justification that the design of structures, systems and components provides the required protection against external hazards is given.

- Chapter 2: Generic Site Envelope

  This chapter provides numerical values for each of the external hazards in the list that is derived and justified in PCSR Chapter 6. Its main purpose is to justify that the GSE values presented are representative of the UK, robust and sufficiently conservative for use in the UK ABWR generic design and safety analysis. Chapter 2 does not refer to where these values are used in the design since this is done via Chapter 6.

The generic site envelope includes characteristics, such as the density and distribution of the assumed local population, seismic hazard, extreme weather events and other external hazards, which are representative of the known potential sites in the UK. The intention is that these characteristics should, as far as possible, include limiting values that envelope or bound the characteristics of these sites. Conversely, if the intended site has characteristics which lie outside the generic site envelope, the future licensee would need to undertake additional safety analysis.

This chapter explains how the GSE values have been derived using a combination of appropriate codes and standards, expert input, and Extreme Value Analysis (EVA). Many of the hazards considered are extreme weather conditions and so the EVA of these considers historical data from meteorological stations across the UK and also includes consideration of the impact of future climate change.

This chapter demonstrates that the Generic Site Envelope of the UK ABWR is appropriate for the purposes of GDA. It is acknowledged that further work will be required post-GDA to justify the specific characteristics of the chosen site. This work will be the responsibility of any future licensee and operator.

The specific applications of the generic values presented in the GSE in this chapter are described in the relevant PCSR chapters for the various structures, systems and components (SSCs).

2.1 Introduction

Hitachi-GE Nuclear Energy, Ltd. (Hitachi-GE) has developed the Advanced Boiling Water Reactor (ABWR) and is submitting the UK ABWR design to the UK Regulators under the generic design assessment process (GDA). The GDA safety case is described within the Generic Pre-construction Safety Report (PCSR). Refer to PCSR Chapter 1: Introduction, for the overview of the generic PCSR.

This chapter of the PCSR provides a summary and description of the Generic Site Envelope (GSE) and explains why this is representative for UK sites. In effect, this chapter and the GSE provide a specification of the site characteristics that are used in the generic design and safety analyses that have been undertaken in GDA. Chapter 2 does not specify where this information is used in the design; it is a specification of values to be used by the GDA design according to the safety functions of that particular structure, system or component. Therefore, Chapter 6 should be referred to for the links to the rest of the PCSR technical chapters where the justification is given by the relevant engineering chapter.

This chapter is supported by a set of reference documents, primarily the Level 2: Topic Report on Generic Site Envelope [Ref-2] which describes the arguments and evidence that substantiate the parameters chosen. The evidence of the value analyses is given in various Level 3 technical documents as described in the Topic Report.

This chapter should be read in conjunction with Chapter 6 to provide the holistic external hazards safety case for the UK ABWR. The list of individual external hazards derived by Chapter 6 are based on the “Topic Report on External Hazard Protection” [Ref-3] which describes the selection of hazards for inclusion in the GSE. The relationship between the key documents is provided within the document map in Appendix A.

The abbreviations and terms from the UK ABWR used in this chapter are referred from Appendix A of Chapter 1 ‘Abbreviations and Acronyms List’.

2.1.1 Background

The process for regulation of new nuclear power station development in the UK has been divided into two phases – Generic Design Assessment and the site specific stage assessment. In GDA, the proposed reactor design is assessed independent of any planned construction site, with the intention that it could be constructed later on a variety of sites within UK.

Although many details of a power station design will be independent of the location chosen for its construction, some assumptions about the characteristics of the plant's environment must be made in order to develop the design of certain safety related features.

Therefore, in order to ensure that a design submitted for GDA will be suitable for construction on a variety of sites within UK, a 'site envelope' needs to be specified within which the plant is designed to operate safely. So this 'generic site envelope' is a specification of the site characteristics that are used as the basis for the safety analysis for GDA. The GSE can include characteristics, such as the density and distribution of the assumed local population, seismic hazard, extreme weather events and other external hazards, which are typical for a range of sites in UK. The intention is that these characteristics should, as far as possible, envelope or bound the characteristics of known potential sites in the UK.

After GDA, when a subsequent site licence application is made for a site which has characteristics bounded by the generic site envelope, the time taken for regulatory assessment will be minimised. Conversely, if the intended site has characteristics which lie outside the GSE, the applicant would need to undertake additional safety analysis and/or plant redesign to demonstrate that the proposed plant is acceptable at the intended site.

This PCSR chapter sets out Hitachi-GE's definition of the characteristics that are included in its Generic Site Envelope for the GDA of the UK ABWR.

2.1.2 Document Structure

The following sections of PCSR Chapter 2 describe the Generic Site Envelope that has been used in GDA for the UK ABWR safety analysis.

Section 2.2 Purpose and Scope: This section sets out the purpose and scope for Chapter 2. It identifies the aspects that are included within scope, identifies what is not included in scope and identifies how this chapter links to other chapters of the PCSR.

Section 2.3 General Approach for Generic Site Envelope: This section describes the overall approach taken to define bounding representative parameters included within the UK ABWR GDA Generic Site Envelope. It describes the analysis methodology used to derive the parameters and how the effects of climate change have been taken into account and how demographics have been included.

Section 2.4 Generic Site Envelope: This section identifies the details of each parameter that has been included in the GSE and lists the bounding values for them.

Section 2.5 Conclusions: This section provides a summary of the main aspects of this chapter.

Section 2.6 References: This section lists documents referenced within this chapter.

Other relevant information is captured in appendix as follows:

Appendix A - Document Map for supporting evidence

Chapter 2 also has links to the following chapters of the generic PCSR:

- Chapter 6: External Hazards – which identifies the external hazards within the scope of GDA.
- The Technical Systems Chapters – Chapters 9 to 17, for details of the SSCs and design parameters based on the GSE where relevant.
- Chapter 24: Design Basis Analysis.
- Chapter 25: Probabilistic Safety Assessment (PSA) - GSE is conservative and so separate values are provided for PSA which needs best estimate.
- Chapter 26: Beyond Design Basis and Severe Accident Analysis.

Out of scope items include the environmental and security aspects of the UK ABWR design. For links to the documentation for the Generic Environmental Permit (GEP) and Conceptual Security Arrangements (CSA), refer to PCSR Chapter 1: Introduction.

2.2 Purpose and Scope

2.2.1 Purpose

This chapter defines the site characteristics that are included within the GSE and justifies that the values used are robust, conservative and suitable for use in the generic design of the UK ABWR.

Specific objectives of the chapter are to:

- Identify which site characteristics are included and what the limiting values are for each characteristic.
- Identify links to relevant content of other GDA PCSR chapters, to ensure consistency across the whole safety case, and to ensure the overall safety case presented is complete.
- Describe where additional detailed supporting information can be found.

This chapter will not:

- justify the list of external hazards that are included within the Generic Site Envelope; refer to Chapter 6: External Hazards.
- provide a description or justification for the generic site layout; refer to Chapter 9: General Description of the Unit (Facility).
- provide justification for, or describe site operations based on the site layout, e.g. fuel transfer, construction activities, conventional materials transport (e.g. diesel, chemicals); these aspects are excluded from GDA.
- discuss security or environmental protection arrangements.

Out of scope items include the environmental and security aspects of the UK ABWR design. For links to the documentation for the Generic Environmental Permit (GEP) and Conceptual Security Arrangements (CSA), refer to PCSR Chapter 1: Introduction.

2.2.2 Scope

This chapter describes the generic site characteristics that have been used for the GDA of the UK ABWR and the bounding parameters that have been included in the GSE for each hazard. This chapter also provides, or references, the justification studies that show those values are robust and conservative and are therefore appropriate to be used in the generic design.

The generic site characteristics which are described in this chapter include the following:

- External hazards
- Heat sink (type, temperature range)
- Grid connections (type, reliability)
- Density and distribution of local population

It should be noted that PCSR Chapter 6: External Hazards describes the effective process used to identify the list of external hazards to be considered for characterisation in PCSR Chapter 2. A summary of that process is given in this chapter for ease of reference; however, the reader should refer to PCSR Chapter 6, Section 6.3 for details. Chapter 2 evaluates the magnitude of those hazards that have been determined as relevant to GDA. This includes potential environmental changes such as climate change which may affect sites in the UK.

Chapter 6 has identified the following 14 external hazard groups that are included in the scope of the GSE evaluation.

- Air Temperature
- Wind
- Rainfall & Ice
- Drought
- Snow
- Electromagnetic Interference (EMI)
- Sea or River Water Temperature
- External Flooding
- Seismic Activity
- Loss of Offsite Power
- Aircraft Impact
- External Fire
- External Missile
- External Explosion

2.2.3 Interface with other Documents

PCSR Chapter 6 defines the list of external hazards which include combination events to be considered in the UK ABWR Systems, Structures and Components (SSCs) design. The GDA hazard conditions are defined in this chapter (Chapter 2), and based on these conditions, the safety margin for each SSC and the safety case adaptability for each SSC will be described in the corresponding technical systems design chapters. The document structure for external hazards and GSE documents is shown in Appendix A. Links to the other PCSR chapters considering main hazard protection, PSA and Fault Assessment are explained in detail in Section 6.1.1.2 of PCSR Chapter 6.

2.3 General Approach for Generic Site Envelope

2.3.1 General Approach

The general approach taken to define representative parameters for the Generic Site Envelope has been to investigate the conditions at the eight candidate sites identified for the UK. These sites have been selected by the UK government's Department for Energy and Climate Change (DECC) as appropriate sites for nuclear new build [Ref-7]. These eight new build candidate sites cover most of the conditions that would envelope the UK in terms of UK external hazards conditions.

The flow chart presented in Figure 2.3-1 provides the step by step general approach for the development of GSE values. Figure 2.3-2 shows the locations of the eight candidate sites within the UK.

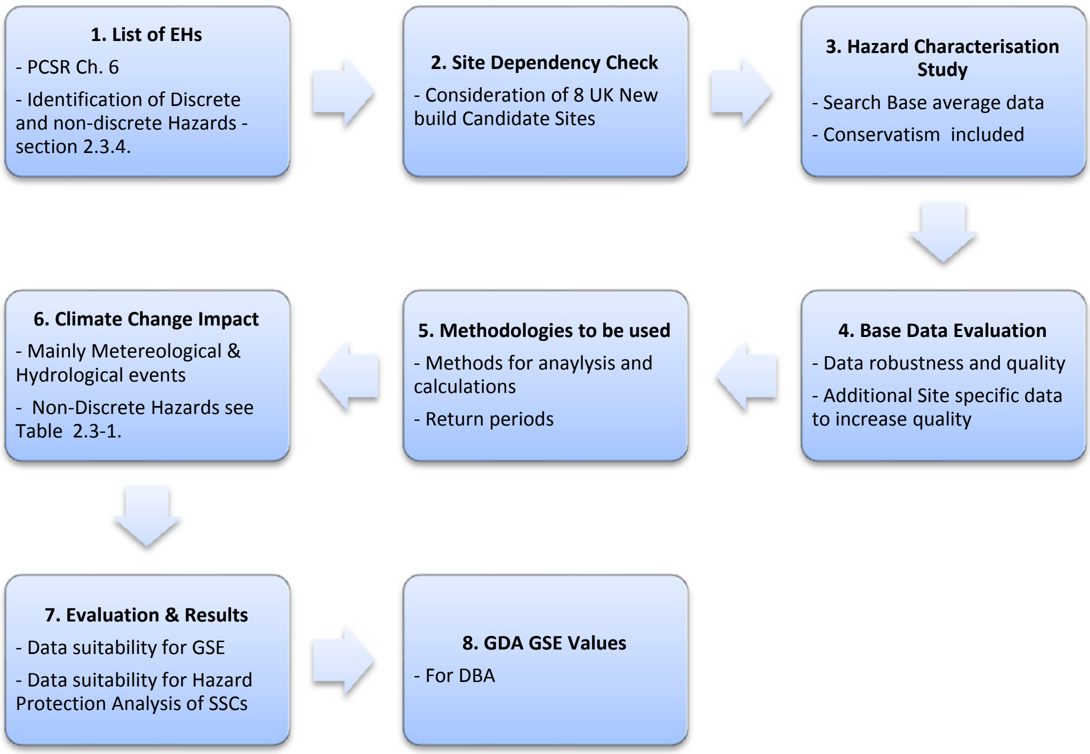

Figure 2.3-1 Generic Process Flow Chart for Development of GSE Values

The GSE is then defined by selecting a bounding value for each hazard group considering the values across the eight sites. It is envisaged that these bounding parameters would be assessed one by one in terms of their applicability to the specific site on which a future licensee would decide to build.

This chapter presents values of external hazards for the two main plant conditions below with corresponding probability of exceedance as defined in PCSR Chapter 5.

- Fault conditions 10^{-4} /year values for Design Basis Assessment (DBA) and
- Normal conditions 10^{-2} /year values for normal operating assessment, assuming operational and decommissioning timeframe of 100 years.

For non-discrete hazards which have a varying magnitude with frequency, the range of magnitudes is also evaluated for use in other safety assessment. For example the Beyond Design Basis (BDB) margins and “cliff edge” effects have been confirmed for each SSC design, based on the values presented here and further analysed in PCSR Chapter 25: PSA.

2.3.2 Analysis Methodology

Values of Generic Site Envelope have been derived in three basic ways, by considerations of codes and standards, by undertaking Extreme Value Analysis (EVA) which is based on historical data of meteorological stations across the UK, or standardised condition (such as EUR) to determine the appropriate level of the hazard. Further details can be found on analysis methodologies and climate change within the Topic Report for GSE [Ref-2].

2.3.3 Climate Change

The effects of climate change are considered for definition of the GSE values where appropriate. This is based upon the DEFRA's publication “UK Climate Projections” UKCP09 [Ref-8].

Taking into account an operational and decommissioning timeframe of 100 years (60 operational, 40 decommissioning), along with a predicted GDA and construction phase, it is suggested that a proposed site will be decommissioned within the 2120s and so climate change has been considered up to this time. It is recognised however that some external hazards will only impact the plant during the operational phase and that certain equipment will be periodically replaced. Therefore, climate change for the decades of 2040s and 2080s has also been assessed for certain hazards.

While the design basis is based on reasonably foreseeable climate change, designs should incorporate the principle of ‘managed adaptation’. This means that the designs should have the capacity to provide adaptive response to the extreme projection if required, i.e. the design option should allow the possibility of future upgrade. Further details can be found on analysis methodologies and climate change within the Topic Report on GSE [Ref-2].

NA to BS EN 1991-1-5:2003

Figure NA.2 **Isotherms of maximum shade air temperature (°C)**

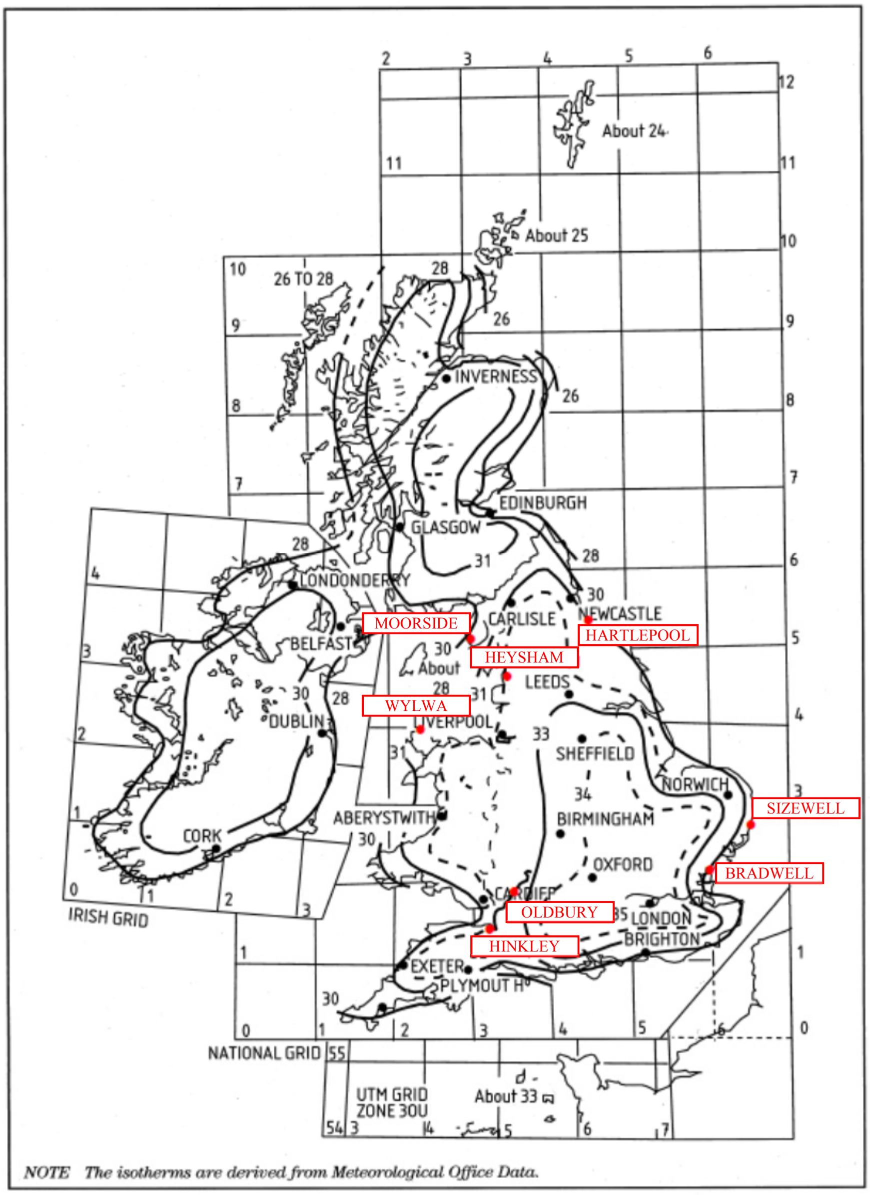

Figure 2.3-2 Map of Eight candidate sites identified as appropriate sites for nuclear new build [Ref-7]

2.3.4 External Hazard List for Generic Site Envelope

The first stage is to identify from the list of individual external hazards which events are likely to have a discrete frequency of occurrence (discrete hazards) or a continuous frequency-severity relation (non-discrete hazards). Non-discrete hazards are mainly climate related events whose trend can be identified and data is non-stochastic. Discrete hazards are independent in nature, and generally include man-made events and/or hazard events whose relevant data is stochastic. Discrete hazards also generally have no climate dependency. Table 2.3-1 below presents the list of hazard groups from PCSR Chapter 6 identifying which are discrete or non-discrete. The hazard ID Numbers are shown as defined in the “Topic Report on External Hazard Protection” [Ref-3] and the “Topic Report on Combined External Hazards” [Ref-5]. Hazards which has hazard ID 1-14 are addressed during GDA, 15-21 will be addressed during site licence application and 22 is eliminated on the basis of negligible frequency.

Therefore, the scope of GSE is to define representative parameters for each of the 14 EH groups identified for the GDA. The parameters are presented in Section 4, group by group.

Table 2.3-1 – List of external hazard groups identified for EH assessment.

Hazard Group #	Hazard Group Name	Individual External Hazards	Treatment	Hazard Characteristics
1	Air Temperature	[A10][A30][CH 106][A3][A20]	GDA	Non-Discrete
2	Wind	[A4][A3][A20]		Non-Discrete
3	Rainfall & Ice	[A6][A8][A14][A15][A16][A22][A3] [A20]		Non-Discrete
4	Drought	[C1][A3][A20]		Discrete
5	Snow	[A39][A44][A3][A20]		Non-Discrete
6	Electromagnetic Interference (EMI)	[A17][D7]		Non-Discrete & Discrete
7	Sea or River Water Temperature	[A32][A3][A20]		Non-Discrete
8	External Flooding	[A26][A29][B21][C3][C4][C9][C11] [A22] [C15] [D26] [A3][A20]		Non-Discrete
9	Seismic Activity	[B16][B4][B7][B36][B37][B15]		Non-Discrete
10	Loss of Offsite Power	[D19]		Discrete
11	Aircraft Impact	[D1]		Discrete
12	External Fire	[D2][D15][D34]		Discrete
13	External Missile	[D23][D24][A38][D2]		Discrete
14	External Explosion	[D13]		Discrete
15	Cloud / Storms (Ash, Dust, Sand, Salt)	[A34][A25][A28]	Site Specific	Discrete
16	Ground Condition	[A31][B1][B2][B3][B9][B11][B12][B14] [B17][B18][B19][B20][B30] [D10][D22][D37][D40][F3]		Discrete
17	External Transport Impacts	[D33]		Discrete
18	Industrial Environment	[D2][D3][D20][D25][D26][D31][D3 2] [D36][F1]		Discrete
19	Water based Biological Fouling	[E4][E2][E6][E8][E16]		Non-Discrete
20	Land & Air-based Biological Fouling	[E1][E2][E4][E6]		Non-Discrete
21	Flotsam/ Jetsam/Log Jam	[D4][D41][D42]		Discrete
22	Extra-terrestrial Object	[A19][D29]	Screen out based on occurrence frequency [Ref-3]	Non-Discrete & Discrete

2.3.5 Demographics

The details of the local population around the generic site, which have not been derived in PCSR Chapter 6: External Hazards, are described in the GEP E2 report "Generic Site Description" [Ref- 6]. This document presents the assumed demographics in the UK and applicable justification for the range of possible sites where a UK ABWR could feasibly be built. It also describes the generic site characteristics used in Hitachi-GE's radiological dose assessments, including short-term, annual and collective dose assessments to humans and dose assessments on non-human species. Note that no data on local population distribution is required for radiological dose assessment at GDA. Collective dose assessment for demographics of the UK, EU and world is based on the figures shown in Table 2.3-2 below [Ref-6]. These values are used in GEP E8 document "Prospective Dose Modelling" [Ref-29].

Table 2.3-2: UK, EU and World Population Figures [Ref-6]

Country/Region	**Population**
UK	5.96×10^{7}
EU25*1	4.56×10^{8}
World	1.00×10^{10}

*1: Those in the EU from 2004: As EU 15 plus Cyprus, Czech Republic, Estonia, Hungary Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia.

2.4 Generic Site Envelope

Section 2.4 presents, in the following 12 sub-sections, the characteristics of the 14 external hazards considered during GDA.

2.4.1 Air Temperature

Hazard Group: [1]
Hazard ID: [A10][A30][CH 106] [A3][A20]

2.4.1.1 Air Temperature [A30]

(a) Analysis Methodology

Extreme value analysis (EVA) has been carried out for evaluation of extremes of air temperature, identifying annual exceedance values of 10^{-2} and 10^{-4} events for minimum and maximum hourly dry bulb air temperatures.

(b) Climate Change

For maximum air temperature the effect of climate change is considered for the decades of the 2040s and 2080s based on the UKCP09 medium emission scenario. For minimum air temperatures, since air temperatures are projected to increase, climate change is not added as this is considered conservative.

(c) Conclusion

Maximum and minimum air temperatures for annual exceedances of 10^{-2} and 10^{-4} are summarised in the following tables.

Table 2.4-1: Maximum Air Temperature GSE Values [°C]

Probability of Exceedance	10^{-2}/year				10^{-4}/year			
Timescale	Present	2040s	2080s	2120s	Present	2040s	2080s	2120s
Maximum Hourly Air Temperature	34.7	37.8	39.6	41.5	41.0	44.1	45.9	47.8
Maximum 6h Mean Air Temperature	33.1	36.2	38.0	39.9	41.0	44.1	45.9	47.8
Maximum 12h Mean Air Temperature	30.4	33.5	35.3	37.2	36.3	39.4	41.2	43.1

Table 2.4-2: Minimum Air Temperature GSE Values [°C]

Probability of Exceedance	
10^{-2}/year	10^{-4}/year
-13.8	-22.5

2.4.1.2 Humidity [A10]

The meteorological parameter of humidity is a measure of the moisture content of the air. There are different measures of humidity including absolute humidity, specific humidity and relative humidity. The most significant effect is the combination of humidity and air temperature which is known as enthalpy of the atmosphere. Enthalpy is defined as thermodynamic quantity equivalent due to the total heat contents of a system. This has been identified as combination hazard in PCSR Chapter 6: External Hazards and given the combination hazard ID [CH 106] [Ref-5].

2.4.1.3 Enthalpy [CH 106]

(a) Analysis Methodology

Extreme Value Analysis has been carried out for evaluation of extremes of enthalpy, identifying annual exceedance values for the 10^{-2} and 10^{-4} events for maximum enthalpy.

(b) Climate Change

For maximum enthalpy the effect of climate change is considered for the decade of the 2080s based on the UKCP09 medium emission scenario.

(c) Conclusion

Maximum enthalpy for annual exceedances of 10^{-2} and 10^{-4} is shown in the following table.

Table 2.4-3 Enthalpy GSE Values [kJ/kg]

Probability of exceedance	10^{-2}/year	10^{-4}/year	10^{-2}/year	10^{-4}/year
Timescale	**Present**	**Present**	**2080s**	**2080s**
Maximum Hourly Enthalpy	68.1	78.4	80.2	90.5
Maximum 6h Mean Enthalpy	67.2	78.4	79.3	90.5
Maximum 12h Mean Enthalpy	64.2	78.1	76.3	90.2

2.4.2 Wind

Hazard Group: [2]
Hazard ID: [A4][A3][A20]

2.4.2.1 Extreme Wind [A4]

(a) Analysis Methodology

In the UK nuclear industry, wind speeds have historically been evaluated based on the UK national codes and extending the annual probability of exceedance up to 10^{-2} and 10^{-4}. This is seen as appropriately conservative. The basic data for wind velocity in the UK is defined in BS EN 1991-1-4, "Eurocode 1: Actions on structures Part 1-4: General Actions – Wind Actions" [Ref-9] and its UK National Annex. However, as the Eurocodes do not specifically include nuclear facilities, American design codes have been used within the UK nuclear sector and have been accepted by the UK Regulator. The relevant US code is ASCE 7-10 "Minimum Design Loads for Buildings and Other Structures" [Ref-10].

Extreme wind values have been evaluated for the eight sites using these US and European codes. The European code Eurocode 1 [Ref-9] is used for evaluation of the 10 minutes mean wind speed applicable to the UK. ASCE 7-10 [Ref-10] is used for evaluation of 3 seconds gust wind speed.

In addition to the code values, an Extreme Value Analysis was carried out for the Wylfa site using historical Meteorological Office records. Wylfa was chosen since it had the highest basic wind speed from Eurocode 1, of all the eight sites.

(b) Climate Change

Based on UKCP09, changes in 30-year mean wind speeds relative to the 1961-1990 baselines were produced. These projections suggest that the central estimates of change are very small (less than 0.2 m/s), projected changes in winter wind speeds are more or less symmetrical about a near-zero change and there is a slight reduction in average wind speed in summer. Although uncertainty is high (considered to be up to 20% of the present day values dependent upon scenario, time period and location) the projections suggest a reduction in summer and winter wind speeds of up to 0.6 m/s by the 2080s (10% probability level, high emissions). Estimates of change are very small with high uncertainty, as such values including future climate change for wind data are not considered significant.

(c) Conclusion

The GSE values for three second gust and 10 minute mean wind values for annual exceedances of 10^{-2} and 10^{-4} are summarised in the following table. These are not directly comparable and must be used in the appropriate design code as shown.

Table 2.4-4 Wind Speed, GSE Values [m/s]

Probability of Exceedance	10^{-2}/year	10^{-4}/year
3-Second Gust (ASCE 7-10)	43.4	50.7
10 Minute Mean (BS EN 1994-1-4)	33.1	38.6

2.4.2.2 Tornado [A4]

Tornados are violent funnel shaped vortices of wind created by certain meteorological conditions which damage property through the pressures (both negative and positive) generated by the vortex itself and the associated wind-born debris. Although Tornados are a rare external hazard event, consideration has still been given to them when defining the GSE.

The UK Tornado and Storm Research Organisation (TORRO) publication "A Study of Tornados in Britain with Assessments of the General Risk Potential and the Specific Risk Potential at Particular Regional Sites" [Ref-11] provides the most recognised source of data. It ascribes a tornado on the TORRO scale T2 as having a minimum tornadic wind speed of 33m/s. The annual probability of exceedance for a T2 tornado at most UK candidate sites can be shown to be less than 10^{-4}. The T2 33m/s wind speed is bounded by all the conventional wind speeds calculated above so for the purpose of defining the GSE it can be considered to be bounded by maximum wind speed.

2.4.3 Rainfall & Ice

Hazard Group: [3]
Hazard ID: [A6][A8][A14][A15][A16][A22][A3][A20]

2.4.3.1 Rainfall [A22]

(a) Analysis Methodology

The maximum precipitation is evaluated using the UK Centre for Ecology and Hydrology's "Flood Estimation Handbook" (FEH) [Ref-12] and its predecessor the Natural Environment Research Council's "Flood Studies Report" (FSR) [Ref-13]. These methods are both recognised as relevant good practice in the UK, both in nuclear and conventional industries for rainfall estimation.

In the Environment Agency guidelines [Ref-14] it is recommended that the FSR methodology is used to predict rainfall for annual exceedance less frequent than 10^{-3} as the FSR is recognised as more robust than the FEH model for these events. Therefore the FSR method has been used in the GDA evaluation for the 10^{-4} /year values. Values for an annual exceedance of 10^{-2} are a common requirement for UK flooding estimates and are provided by the FEH model.

Thirty minutes and one hour durations are calculated using methods within the FEH. The FEH rainfall model does not give robust values for storm durations shorter than 30 minutes or for return periods greater than the annual exceedance event of 10^{-3}. Therefore, the GDA evaluation uses the older FSR methods, in conjunction with the FEH to determine rainfall depths, for other durations and frequencies.

(b) Climate Change

For maximum precipitation, the effect of climate change is considered up to the 2120s decade, based upon the Environment Agency's publication, "Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities" [Ref-15], which is based on the data provided within UKCP09 [Ref-8].

(c) Conclusion

Precipitation values for a UK generic site, for annual exceedance of 10^{-2} and 10^{-4} and for periods of 15mins, 30mins, 1h and 24h are summarised in Table 2.4-5. These values are representative of all the UK sites and are conservative.

Table 2.4-5: Rainfall for Generic Site Envelope [mm]

Probability of Exceedance	**10^{-2} /year**				**10^{-4} /year**			
Rainfall Duration	**15min**	**30min**	**1 h**	**24h**	**15min**	**30min**	**1 h**	**24h**
Present Day	30.2	47.4	53.7	97.9	61.8	91.2	116.0	220.5
2120s	42.2	66.4	75.2	137.1	86.5	127.7	162.4	308.7

2.4.3.2 Ice (Frazil) [A14]

Frazil ice is the initial formation of ice crystals within a body of water turning it into slush. This type of ice formation has been attributed to a number of cooling water issues at nuclear power facilities, typically blocking screening systems within the water intake. The formation of ice within seawater is dependent on the salinity of the water. Salinity can vary between local marine climates. Freezing point of the sea water temperature is considered as minimum seawater temperature in Section 2.4.7.

The eight candidate sites shown in Figure 2.3-2 are all on the coast of the UK, although some are on large estuaries. The GDA evaluation predicts 10^{-4}/year seawater temperatures to be low enough for all sites, except Hartlepool, to experience frazil ice of some form within the seawater around the plant. However, the design of the cooling water intake is not included in the scope of GDA and so further evaluation of frazil ice formations is more appropriately carried out during site specific design (refer to PCSR Chapter 6).

2.4.3.3 Ice (Rime) [A15]

(a) Analysis Methodology

The accumulation of ice on specific types of lightweight structures exposed to the atmosphere, (e.g. lattice trusses, guyed masts, overhead lines, etc.) is needed as part of the GSE as the load associated with an iced condition may govern the design of such structures, especially when combined with wind effects. BS EN 1993-3-1:2006, “Eurocode 3 - Design of steel structures - Part 3-1: Towers, masts and chimneys - Towers and masts” [Ref-16], in conjunction with the NA to BS EN 1993-3-1:2006, “UK National Annex to Eurocode 3: Design of steel structures Part 3-1: Towers, masts and chimneys - Towers and masts” [Ref-17] have been used to determine the rime ice load.

(b) Climate Change

Climate projections are not available for rime ice (or indeed ice) within the UKCP09 climate projections [Ref-8]. However, it is known that ice accumulation is dependent on air temperature and wind speed. As indicated in UKCP09, the mean wind speed and the mean winter temperatures are projected to rise. However, the percentage rise (around 15%) in temperature is significantly larger than that of wind speed (around 2%). From this comparison the thickness of accumulated ice is likely to be thinner in the future due to the rise in temperature and a conservative approach of disregarding climate change for the maximum values have been taken.

(c) Conclusion

The GSE values for ice thickness are presented within Table 2.4-6. These are representative of the eight UK sites and appropriate to use in the GDA structural design.

Table 2.4-6 Ice Thickness GSE Values [mm]

Probability of Exceedance	10^{-2}/year	10^{-4}/year
Ice Thickness	71.1	117.1

2.4.3.4 Ice (Barrier) [A16]

Barrier ice describes the formation of solid masses of ice within the sea. These are formed from frazil ice combining together during extended periods of time when the sea water is below its freezing point. The extreme 10^{-4} /year seawater temperature of -1.9°C suggests that barrier ice could form within these events. However the temperatures provided are minimum daily temperatures and are not envisaged to be maintained for long periods of time. It is envisaged that rare event ice formation will still only occur in autumn or winter. As extreme average seasonal temperatures can only be defined for a specific site, GDA has not estimated barrier ice thicknesses. The Baltic Sea experiences seasonal ice formation where the thickest recorded coastal ice in the gulf of Riga was 900mm in 1941/1942 which was recorded as an extraordinarily cold winter.

The design of the cooling water intake is not included in the scope of GDA, however the depth of the intake culverts will be significantly deeper than 900mm. Further evaluation of barrier ice formations is more appropriately carried out during site specific design (refer to PCSR Chapter 6).

2.4.4 Drought

Hazard Group: [4]
Hazard ID: [C1][A3][A20]

2.4.4.1 Drought [C1]

The basic cause of all drought is insufficient rainfall. Often this is prolonged over a long period of lack of rain combined with high air temperatures. Short term drought, mainly experienced in the UK, can occur during prolonged periods of high air pressure systems. Drought is a slowly developing hazard, therefore it allows for operator actions to take place and mitigation activities to be implemented. This hazard is not amenable to quantification but it is considered qualitatively in Chapter 6.

2.4.5 Snow

Hazard Group: [5]
Hazard ID: [A44][A39][A3][A20]

2.4.5.1 Snow [A44]

(a) Analysis Methodology

The GDA evaluation considered the historical Meteorological Office snow records for the eight candidate sites in order to carry out an Extreme Value Analysis. However, due to the fact that snow is not a common occurrence, the limited datasets and poor quality of these snow records meant a meaningful EVA could not be completed since the results would include a high level of uncertainty. Instead a design code method based on European codes EC1-1-3 [Ref-18] was used for the snow load evaluation. A comparison of EC1 and Chapter 7 of the US code, ASCE 7-10 [Ref-10] was also carried out to confirm if there were any implications for the GDA civil engineering design, which is based on US codes. This study concluded that as the snow load data in both codes is provided on the same basis it was reasonable to use the EC1 base data for UK locations for loading calculations in accordance with either code.

(b) Climate Change

Climate change effect on snow load is not available in the UKCP09 scenarios. The UKCIP02 projections (published in 2002) [Ref-19] show that snowfall amounts are expected to decrease across the UK (high confidence in this outcome) while large parts of the country are expected to experience long runs of winters without any snow fall (medium confidence). Therefore the effect of climate change on snow load is conservatively neglected within the GDA evaluation.

(c) Conclusion

Maximum snow values for annual exceedance of 10^{-2} and 10^{-4} are summarised in Table 2.4-7.

Table 2.4-7: Snow Load for Generic Site Envelope [kN/m^2]

Probability of Exceedance	10^{-2} /year	10^{-4} /year
Snow Load on Plan	0.68	1.50

2.4.6 Electromagnetic Interference (EMI)

Hazard Group: [6]
Hazard ID: [A17][D7]

2.4.6.1 EMI [D7]

Electromagnetic Interference (EMI) is a disturbance generated by radio-frequency inference that affects electrical equipment and control and instrumentation by electromagnetic induction, electrostatic or conduction. EMI can originate from both natural events and man-made events. The potential sources of EMI have been identified in the Topic Report on Generic Site Envelope" [Ref-2]. Hazard ID [D7] bounds all of these for the GDA assessment, except for lightning which is treated as a separate hazard as described below in Section 2.4.6.2.

The GDA assessment has carried out general characterisation of the identified potential sources of EMI. It should be noted that this is based on the best available information but that it is still a developing field in both nuclear and conventional industry. Therefore, the GDA takes a pragmatic approach using current codes and standards, ONR and IAEA guidance and relevant good practice where available.

International standards from the International Electrotechnical Commission (IEC) provide classification of equipment for EM environments, and the resultant specification and testing required. The electromagnetic emissions from equipment are limited by European Directives. Therefore, in terms of setting the generic site envelope, it is expected that the effect of internal sources of EMI will bound the effect of any external sources of man-made EMI.

Natural sources of EMI, other than lightning, such as geomagnetic storms and solar activity, are considered in the GDA assessment. Characterisation of these hazards is uncertain although they are known phenomena which can cause damage to electrical power grids. Therefore, this hazard is considered bounded by the Loss Of Off-site Power (LOOP) hazard (refer to Section 2.4.10).

The above assessment should be confirmed at the site specific stage. Sources of man-made EMI are likely to change over the lifetime of the plant due to advancement in technology and so should be continually reviewed.

2.4.6.2 Lightning [A17]

Lightning is a natural source of electrical current and external EMI hazard which occurs throughout the UK. Lightning produces EM fields in adjacent equipment, generated from the current flowing in the lightning conductor. The peak lightning strike intensity is used as the magnitude of the external hazard for design of lightning protection systems, as defined by IEC standards. In GDA, the lightning ground flash density, taking into account 2080s climate change, has been calculated for the eight candidate sites. This is used to confirm the peak lightning strike as 200kA, and so the maximum Lightning Protection Level I defined by IEC/BS EN 62305-1 [Ref-20] would be appropriate. However, other research has indicated that 300kA may be the maximum credible peak current associated with lightning in the UK with probability of 10^{-4}/year [Ref-26].

Therefore, the GDA assessment for lightning for the UK ABWR, has taken the conservative 300kA lightning strike as the 10^{-4} /year design basis event.

2.4.7 Sea or River Water Temperature

Hazard Group: [7]
Hazard ID: [A32][A3][A20]

2.4.7.1 Sea or River Water Temperature [A32]

(a) Analysis Methodology

Extreme Value Analysis has been carried out for the evaluation of extreme sea water temperature, identifying annual exceedance values of 10^{-2} and 10^{-4} events for minimum and maximum sea water temperatures. However, since the historical records were in different depths of seawater, at different time intervals and were not necessarily available for all eight candidate sites, the EVA had some limitations, particularly for minimum seawater temperature. Therefore, the code "Volume 2 Generic Nuclear Island requirements, Chapter 4 Design Basis" [Ref-21] issued by EUR (European Utility Requirements for LWR Nuclear Power Plants) has also been reviewed. This specifies values for a range of cooling water temperatures at the intake.

(b) Climate Change

For maximum sea water temperature, the effect of climate change is considered up to the 2080s decade which is the 60 year operational periods. Temperature increases are based on the UKCP09 medium emission scenario.

For the minimum sea water temperature, since sea water temperatures are projected to increase, climate change is not added as this is considered conservative.

(c) Conclusion

The EVA value estimated for maximum sea water temperature has been used for the 10^{-2}/year hazard, however the EUR [Ref-21] specifies a value of 30^{o}C for the maximum credible cooling water temperature. Therefore, 30°C is used for the GSE maximum sea water temperature for 10^{-4}/year as set from EUR.

The minimum temperature for the 10^{-2}/year hazard is set as that calculated by the EVA. However, the sea water freezing temperature that has been evaluated for UK is -1.9°C, and so this provides the minimum credible temperature and this is used for the 10^{-4}/year hazard.

Table 2.4-8: Maximum and minimum sea water temperature for Generic Site Envelope [°C]

Probability of Exceedance	10^{-2}/year	10^{-4}/year
Maximum Sea Water Temperature	27.7	30.0
Minimum Sea Water Temperature	-1.6	-1.9

2.4.8 External Flooding

Hazard Group: [8]
Hazard ID: [A26][A29][B21][C3][C4][C9][C11][A22] [C15] [D26] [A3][A20]

The main causes of flooding on a site will be initiated by sea water (or river) inundation [A26] [A29] [B21][C4][C9][C11] and exacerbated by high rainfall [A22] or water surge [C15][D6] on land.

The flooding water levels for different scenarios cannot be estimated at GDA stage, and can only be confirmed at site specific stage. Therefore, GDA adopts the following principles which will need to be developed during site specific stage:

- Setting of the platform level will be above the design basis flood for the site with suitable margin to the beyond design basis flood. This is known as the "dry site" concept and is the preferred option.
- Where for a specific site, the dry site cannot be achieved within ALARP principles, then permanent external flood barriers will need to be provided.
- Suitably robust water drainage systems will be designed for the site infrastructure to control the overland flows resulting from the extreme rainfall falling onto the site, with sufficient margin to mitigate against beyond design basis rainfall.
- In addition off-site rainfall will be evaluated and suitably robust water drainage systems and diversions will be provided to prevent the flows flooding onto the site.
- Flooding water from groundwater springing will be included in the above measures.

As far as is reasonably practicable the UK ABWR design will provide the means to achieve a 'dry site'. If the protection from this hazard for a specific site cannot be achieved by the dry site concept then permanent external barriers will need to be provided. Therefore, the GDA external hazards assessment for flooding has considered a postulated scenario of a flood level above the site platform level. The buildings have been assessed for the potential floodwater pathways and the associated risk to plant and equipment. Adequate provision has been made in the GDA design, as described in the "Topic report on External Hazards Protection" [Ref-3].

2.4.9 Seismic Activity

Hazard Group: [9]
Hazard ID: [B16][B4][B7][B36][B37][B15]

2.4.9.1 Soil Properties [B36][B37][B15]

(a) Soil properties

The GDA design has adopted the EUR medium soil condition and EUR hard soil conditions for seismic analysis [Ref-21]. To ensure appropriate conservatism, the upper bound, best estimate and lower bound values of both soil types have been used for the main buildings.

(b) Allowable bearing capacity

Static and dynamic bearing demands on the ground formation underneath and around the sides of the structures are determined by the structural stress analysis and seismic analysis. This is described in the PCSR Chapter 10: Civils Works and Structures and its supporting reports. Demands for the main buildings have been calculated and shown to be reasonable for the UK.

The determination of allowable bearing capacity for a building requires a complex assessment considering rock mass bearing, sliding capacity and discontinuity of the building structures. Ground models for the capacity assessment will be based on the site specific ground investigation results. Loading will consider static and seismic loading from the building and adjacent buildings, using finite element numerical analysis.

Since the allowable bearing capacity is determined by extensive site specific information; the determination will be carried out in the site specific stage.

(c) Liquefaction potential

Liquefaction potential will not be considered in the GDA design, since it is not a common phenomenon in the UK and is unlikely to affect a site selected for a nuclear power plant. Evaluation of the liquefaction potential will be carried out in the site specific stage.

2.4.9.2 Seismic Input [B16][B4][B7]

The EUR hard and medium seismic design spectra for GDA are shown in Figure 2.4-1. These spectra are used as seismic input motions defined on the ground. European Utility Requirement (EUR) spectrum for hard soil (whose PGA shifts to 0.275G) and EUR spectrum for medium soil (PGA=0.250g) are defined as the DBE spectra used for Seismic Category 1 and 1A structures in the UK ABWR design. Seismic Category 2 uses design spectra for the 10^{-3}/year earthquake and Seismic category 3 uses the 10^{-2}/year earthquake. Description of the seismic categories is given in PCSR Chapter 5.

The Operating Basis Earthquake (OBE) is also defined as the 10^{-2}/year earthquake, and is used to confirm that any SSC is not impaired by the repeated occurrence of the OBE ground motion.

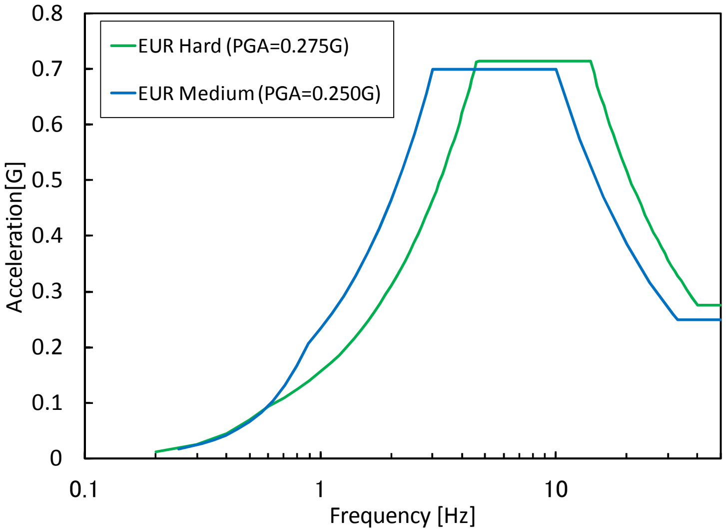

Figure 2.4-1 GDA Horizontal Seismic Spectra for 10^{-4}/year [Ref-2]

The Topic Report on Generic Site Envelope [Ref-2] provides further detail on the derivation of the GDA 10^{-3}/year and 10^{-2}/year seismic horizontal spectra. The V/H ratio of 0.8 is adopted for GDA to develop the vertical spectra from the horizontal spectra, which is relevant good practice in seismic engineering. Description of the seismic categories are given in PCSR Chapter 5.6.

2.4.10 Loss of Offsite Power

Hazard Group: [10]
Hazard ID: [D19]

2.4.10.1 LOOP [D19]

Loss of Off-site Power (LOOP) is generally defined as a loss of electrical power from the off-site electrical power grid that causes emergency power generators to start and supply power to the buses (electrical equipment). The off-site power boundary extends from the off-site electrical power grid and includes the output breaker of the step-down transformer that feeds the first bus with emergency power. The plant switchyard and service-type transformers are included within the off-site power boundary.

The "Topic Report on SBO Analysis" [Ref-22] describes the design basis analysis for station blackout (SBO) of the UK ABWR. This identifies the following scenarios and frequency of occurrence:

- Short term LOOP of 2 hours duration 5×10^{-2}/yr
- Medium term LOOP of 24 hours duration 5×10^{-3}/yr
- Long term LOOP of 168 hours duration 5×10^{-5}/yr

LOOP is therefore considered as a frequent fault and so protection against it is included in the design basis hazards.

2.4.10.2 Grid Connection

Grid Connection of the ABWR will be defined at site specific stage, considering the grid configuration of the site. Since the grid connection is likely to be different for each site, a detailed study and coordination with the National Grid Company will be needed and an appropriate grid connection will be defined.

A detailed description of the grid connection considered for the UK ABWR is provided within PCSR Chapter 15: Electrical Power Supplies.

2.4.11 Aircraft Impact

Hazard Group: [11]
Hazard ID: [D1]

2.4.11.1 Accidental Aircraft Impact [D1]

(a) Analysis Methodology

Aircraft impacts can cause damage to important SSCs and supporting systems needed to maintain cooling of the reactor following such an accident. The GDA methodology for calculating the crash frequency of accidental aircraft crashes is given in the "Accidental Aircraft Impact Assessment (AIA) Strategy Document" [Ref-23]. This is based on the UKAEA publication 150/1997 [Ref-24], which specifies the following factors to be considered to evaluate the crash rate of accidental aircraft:

- Most recent crash statistics
- Flight paths and flight movements for all types of aircraft
- Foreseeable changes

The detail of the calculation for each building and the process used is described in [Ref-23].

(b) Crash Frequency Estimation

Crash rate condition for GDA is calculated based on the background aircraft crash rates on the UK mainland. The recent crash statistics data is provided by the UK Air Accidents Investigation Branch (AAIB). The trend of aircraft crash rate, which depends on aircraft reliability and traffic volume, on crash rate over the UK operational lifetime is considered.

To determine the annual probability of an accidental aircraft crash at a facility, the crash rate is multiplied by the effective target area of the facility. The effective target area for these buildings as seen by an aircraft approaching from four different directions depends on the length, width, and height of the facility, the shadowing of one structure by another, as well as skid distance and impact angle.

(c) Conclusion

The crash frequency for each building has been calculated as less frequent than 10^{-5} /year [Ref-23]. Thus accidental aircraft impacts are treated as Beyond DBA (BDBA) for the GDA design.

2.4.11.2 Malicious Aircraft Impact

Malicious aircraft crash is included in the civil engineering design for the UK ABWR, as required as a security measure by the UK regulators. Therefore, even though accidental aircraft impact is beyond design basis, the plant is still protected from aeroplane crashes.

The aircraft impact assessment consists of three parts: physical, shock and fire footprint damage assessments. The methodology used is based on the US Nuclear Energy Institute publication NEI 07-13 "Methodology for Performing Aircraft Impact Assessments for New Plant Design" [Ref-25]. This is recognised internationally as relevant good practice.

The details of the malicious aircraft impact assessment is security classified and so is documented separately and is not discussed further in this chapter.

2.4.12 External Fire, External Missile, External Explosion

Hazard Group: [12] [13] [14]
Hazard ID: [D2][D15][D34] [D23][D24][A38][D2] [D13]

In general, there is great variability of man-made hazard magnitudes between UK candidate sites because man-made hazards may affect a plant in a particular location, as a result of human presence or utilisation of an area near or adjacent to that site. Thus it is reasonable to define the load for each site.

In GDA, the approach taken for these man-made hazards is setting the Screening Distance Value (SDV) at the distance where the hazard no longer poses a credible threat to nuclear safety. The hazard sources in the vicinity of the generic site that are further away than the SDV do not need to be included. Other sources within the SDV, but which are not credible since the hazard magnitude which could potentially threaten nuclear safety would occur very infrequently (taken to be < $1x10^{-7}$ /year) can also be excluded. The SDV values identified for GDA are shown in Table 2.4-9.

Table 2.4-9 SDV of external explosion, external fire and external missile

Hazard	Screening Distance Value (SDV)
External Explosion	10 km
External Fire	2.5 km
External Missile	2.5 km

In the site specific stage, it is recommended that a hazard identification and characterisation takes place to determine any potential hazard sources for external fire, missile and explosion. Nearby facilities should be taken into account as a potential source. The location of these hazard sources should be confirmed and compared with the SDVs above

Further details can be found in the “Topic Report on Generic Site Envelope” [Ref-2].

2.5 Conclusions

This chapter of the PCSR provides a summary and description of the approach taken to define bounding representative parameters included within the Generic Site Envelope (GSE) for the UK ABWR and explains why these are suitable for use in GDA. In effect, this chapter and the GSE provide a specification of the site characteristics that are used in the safety analyses that have been undertaken in GDA.

This chapter has described that the GSE includes characteristics, such as seismic hazard, extreme weather events and other external hazards that are typical of a range of sites in Great Britain. The intention is that these characteristics should, as far as possible, include limiting values that envelop or bound the characteristics of known potential sites in Great Britain so that a future nuclear site licensee can easily demonstrate that reactors of the proposed type could be built at their selected site locations.

This chapter defines the site characteristics that are included within the GSE, explains how the values used have been derived and justifies that they are robust, conservative and suitable for use in the GDA design and analysis that is described in other chapters of this PCSR.
It is acknowledged that further work will be required post-GDA to justify the specific characteristics of the chosen site. This work will be the responsibility of any future licensee. In particular, if the intended site has any characteristics which lie outside the GSE, then the future licensee would need to undertake additional safety analysis.

2.6 References

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Appendix A : Document Map