Form10/00

UK ABWR

Document ID	:	GA91-9101-0101-06000
Document Number	:	AE-GD-0168
Revision Number	:	C

UK ABWR Generic Design Assessment

Generic PCSR Chapter 6 : External Hazards

Hitachi-GE Nuclear Energy, Ltd.

DISCLAIMERS

Proprietary Information

Copyright

Table of Contents

Executive Summary

This chapter demonstrates that the UK ABWR is robustly protected against External Hazards. An External Hazard is any event originating outside the boundary of a nuclear licensed site that is capable of damaging the reactor or any of its supporting systems if they are not adequately protected, and which could prevent safety systems from delivering the nuclear safety functions required of them. These hazards fall into two main groups: those that occur naturally such as earthquakes and extreme weather, and those that are man-made, such as accidental aircraft impact, fires and explosions.

UK and international good practice has been used to identify all relevant External Hazards, and to assign them to hazard groups. There are 14 hazard groups applicable to GDA, which are listed and assessed in this chapter. A number of additional hazard groups have also been identified in the chapter, but not assessed as part of GDA. These hazards are considered to be specific to the exact location and nature of a future site (e.g. biological fouling, external transport accidents, etc.), and will be considered fully during the site specific stage.

Reasonably foreseeable combinations of External Hazards have also been identified and assessed. These combinations include coincidental events (e.g. an earthquake occurring during severe weather) and consequential events where one hazard causes another (e.g. severe weather causing Loss of Off-Site Power). The combined External Hazards assessment provides additional confidence in the design provisions of the UK ABWR in light of lessons learned from the Fukushima Daiichi event.

External Hazards can also occur in combination with Internal Hazards (e.g. an earthquake could lead to an on-site fire, explosion, or other Internal Hazard). Combinations of events when External Hazards lead to Internal Hazards are covered in PCSR Chapter 7: Internal Hazards.

This chapter systematically examines each of the fourteen generic External Hazard groups for GDA, and provides a summary of the detailed assessment work that underpins it. For all of the hazard groups, the analysis has shown that adequate protection is provided by the UK ABWR design, provided the Generic Site Envelope that is described in PCSR Chapter 2: Generic Site Envelope bound the severity of each hazard.

This chapter concludes that the risks due to External Hazards for UK ABWR have been reduced as low as reasonably practicable (ALARP). It is acknowledged that further work will be required post-GDA to develop the design and fully incorporate site specific aspects. This work will be the responsibility of the future licensee during the normal development to detailed design.

6.1 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 as part of 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.

External Hazards are hazards that arise outside the plant boundary, whether man-made or naturally occurring. Any event arising off-site that has the capability to damage the reactor or any of the supporting systems, or renders any of them inoperable or of reduced capability is a potential hazard. This chapter identifies all individual External Hazards that are appropriate to a UK ABWR, assesses credible combinations of these hazards, gives an overview of the protection provided and then shows links to the rest of the PCSR where the justification of the design is given. The evaluation of the hazards for each frequency of occurrence is presented in PCSR Chapter 2: Generic Site Envelope. The generic definition of design basis faults and the production of the UK ABWR Fault Schedule are described in PCSR Chapter 24: Design Basis Analysis. The Fault Schedule lists all the bounding design basis faults that require assessment for GDA, and includes the bounding events imitated by External Hazards.

Chapter 6 demonstrates that the safety systems provided in the design, as described in the PCSR systems chapters, successfully withstand all design basis External Hazards and that the UK ABWR is tolerant to all such hazards. It also demonstrates that the UK ABWR has sufficient beyond basis resilience and that risks have been reduced as low as reasonably practicable (ALARP).

This chapter relies on the “Topic Report on External Hazard Protection” [Ref-01] and on PCSR Chapter 2: Generic Site Envelope and the “Topic Report on Generic Site Envelope” [Ref-02]. The “Topic Report on External Hazard Protection” is itself supported by other Topic Reports, principally the “Derivation and Justification of the External Hazards for the GDA PCSR” [Ref-03] and the “Topic Report on Combined External Hazards” [Ref-04]. Refer to Appendix B for the document map for Chapter 6 and its supporting documents.

The abbreviations and terms without explanations in this chapter are referred from ‘Abbreviations and Acronyms List’ in the PSCR Chapter 1: Introduction and ‘UK ABWR Glossary of terms’ [Ref-36].

6.1.1 Background

An important part of the safety case is the demonstration that the nuclear safety related structures, systems and components (SSC) are fault tolerant. This means that the safety provisions are such that relevant dose targets on-site and off-site are met and the resilience of the UK ABWR to External Hazards reduces the risks to ALARP levels.

Faults may arise from failures of the reactor or supporting systems themselves, from failures of power generating systems or may arise from events outside those systems. Potential events outside the reactor, support systems and power generation systems are termed "hazards" and fall into two main groups:

Internal Hazards:	those hazards arising on-site and generally within the control of the station operating organisation;
External Hazards:	those hazards arising generally off-site and are outside the control of the station operating organisation. External Hazards fall into two main groups: man-made such as accidental aircraft crash, and naturally occurring such as earthquakes.

The process of demonstrating fault tolerance starts with the systematic identification of faults and other abnormal situations that might arise with a frequency above the Design Basis cut-off. An important part of this is the identification and assessment of hazards originating off-site, outside the control of station operator, which might have an effect on nuclear safety.

There is also the possibility that External Hazards may occur in combination. The combined hazards, which are classified into three categories (Consequential Hazards, Correlated Hazards and Independent Hazards), need to be considered.

6.1.2 Document Structure

The structure of Chapter 6 is as follows.

6.1	Introduction	This Section introduces the chapter, provides some background on External Hazards and describes the structure of the document.
6.2	Purpose and Scope	This Section defines the purpose of the chapter and the scope of External Hazards within GDA.
6.3	Identification of Individual External Hazards	This Section identifies individual External Hazards and groups them, both by type and by plant effect. These hazards have been screened to produce a list of individual hazards to be assessed.
6.4	Identification of Combined External Hazards	This Section identifies possible consequential or coincidental combinations of hazards (for example, fire caused by a seismic event) and does the same grouping and screening for the combinations as in Section 6.3. The remainder of the chapter then provides an assessment of the identified hazard groups. For assessment of the Design Basis

		(DB) magnitude events, refer to PCSR Chapter 2: Generic Site Envelope. For assessment of design margins afforded by the plant, refer to the appropriate systems chapters.
6.5	The Relationship between Safety Functions and External Hazards	This Section relates the screened hazards to Safety Functions and develops a plant effects matrix that relates the hazard groups to the specific safety functions that might be affected.
6.6	Hazard Definition and General Protection	This Section describes each hazard group and discusses the general protection afforded by the plant design. This Section provides a reference to PCSR Chapter 2: Generic Site Envelope, which quantifies the severity of the individual External Hazards for use in design.
6.7	Margin Evaluation for Beyond Design Basis Events	This Section provides the information on the margin evaluation for the Beyond Design Basis (BDB) External Hazards in the GDA phase and summarises the evaluation results.
6.8	Assumptions, Limits and Conditions for Operation	This Section provides assumptions, limits and condition for operations which are related to External Hazards.
6.9	Summary of ALARP Justification	This Section provides a summary of the design measures taken to ensure that risks due to External Hazards are ALARP.
6.10	Conclusion	Conclusions from this chapter.
6.11	References	List of references used in this chapter.
Appendix A:	Route Map from External Hazards to Related Safety Functions	The list shows the route map from individual External Hazard to Safety functions and Safety properties via the consequence of the hazard, and the chapter describing its protection design.
Appendix B:	Document Map	This illustrates the documents produced to underpin this chapter.

Links to PCSR Chapters

The identification of hazards is carried out in this chapter. This is closely linked to the assessment chapters as follows:

- Chapters 24: Design Basis Analysis, The identified hazards for the fault schedule are listed in the “Topic Report on Fault Assessment” [Ref-05].
- Chapter 25: Probabilistic Safety Analysis, for the Seismic, Flooding and Fire PSAs
- Chapter 26: Beyond Design Basis and Severe Accident Analysis and
- Chapter 28: ALARP Evaluation” to reflect Fukushima lessons in Beyond Design Basis Analysis.

- Chapter 7: Internal Hazards - External Hazards may be initiating events for some Internal Hazards, the combinations are assessed in Chapter 7.

For External Hazards, the main protection is provided by the civil structures. Some hazards, for example, extreme temperatures also potentially affect the operation of mechanical systems such as cooling systems and HVAC. Much of the demonstration that the reactor is tolerant of External Hazards is provided by the demonstration that these structures, systems and components (SSCs) do not fail when subject to these hazards. As stated above, Chapter 6 provides the design basis for the plant effects of External Hazards. The justification of the SSC design is given in the appropriate systems chapters below. Appendix A of this chapter links to the safety functional claims in these other chapters together with the safety provisions that make the reactor and support systems tolerant of those faults and hazards.

- Chapter 5: General Design Aspects of the PCSR provides the approach and method for safety categorisation and classification and for seismic categorisation of SSCs. The External Hazards applicable to SSCs will depend on their safety case.
- Chapter 10: Civil Works and Structures - given the relationship between External Hazards and civil structures, reference is made to Chapter 10 and its supporting topic reports and basis of safety cases (BSC).
- Chapter 13: Engineered Safety Features.
- Chapter 16: Auxiliary Systems.
- Chapter 17: Steam and Power Conversion Systems.
- Chapter 15: Electrical Power Supplies - the protection of the electrical power system against hazards such as Loss of Off-Site Power or lightning strike is described in Chapter 15.

The generic safety management and quality management arrangements put in place by Hitachi-GE for the UK ABWR are described in PCSR Chapter 4: Safety Management throughout Plant Lifecycle. These arrangements include general principles for safety in design, construction, commissioning, operation and decommissioning phase. General requirements for conventional safety aspects are also described.

For generic links to documentation for Generic Environmental Permit (GEP), and Conceptual Security Arrangement (CSA), refer to PCSR Chapter 1: Introduction. For GEP, where specific references are required, for example in Radioactive Waste Management, Radiation Protection and Decommissioning, these are included in the specific sections within relevant chapters.

The conceptual design of the Spent Fuel Interim Storage (SFIS) system, considering the External Hazards, has been performed in PCSR Chapter 32: Spent Fuel Interim Storage.

6.2 Purpose and Scope

6.2.1 Purpose

The purpose of this chapter is to identify External Hazards relevant to the UK ABWR and produce a comprehensive list of those hazards and credible combinations. This hazard listing is then used within the SSC design to demonstrate that the UK ABWR is tolerant to External Hazards, which are those hazards that arise outside the site boundary and that are outside the control of the plant operating organisation. Chapter 6 does not explicitly define the safety claims on the SSCs, these are presented within the relevant systems chapters (refer to Section 6.1.2) since they will be met by the design provisions of that SSC. Appendix A of this chapter is provided to link the External Hazards assessment to these claims in the other chapters.

External Hazards fall into two main groups: those that occur naturally such as earthquakes and extreme weather, and those that are man-made, such as accidental aircraft impact or fires and explosions. Any such event that has the capability to damage the reactor or any of the supporting systems, or render any of them inoperable or of reduced capability is a potential hazard. The chapter identifies all such events and groups them for analysis. The chapter provides an overview of the safety case; the detailed arguments and evidence are given in the “Topic Report on External Hazard Protection” [Ref-01] and its supporting documents.

For the majority of External Hazards, demonstrating that the plant is tolerant to the hazard involves demonstrating that the civil structures will adequately withstand the transient and other loads produced by the hazard. This chapter relates the External Hazards to the High Level Safety Functions (HLSF) defined in PCSR Chapter 5: General Design Aspects, Section 5.3.2 and the safety categorisation and classification of SSCs such that appropriate safety functional claims (SFC) or safety property claims (SPC) on the SSCs can be met.

6.2.2 Scope

This chapter provides the output of identification of all External Hazards appropriate to a nuclear licensed site within the UK, including off-site, man-made hazards and naturally occurring hazards. The full list of External Hazards can be found in “Derivation and Justification of the External Hazards for the GDA PCSR” [Ref-03]. These are then consolidated into the 22 hazard groups as listed below and shown in Table 6.3-3. Hazard groups 1 to 14 have been considered in the generic UK ABWR design, however hazard groups 15 to 21 are so dependent on the location and surroundings of the specific site that it is not practicable for the generic design to make detailed provision. These hazard groups may differ widely across potential new build sites, e.g. ground conditions, and so these will be dealt with in the site specific hazard assessment. The GDA design does not preclude future modifications if required for these specific hazards. The Extra-Terrestrial Objects, i.e. the 22nd hazard group, have subsequently been screened out on the basis of low frequency and will not be discussed further.

Generic Hazard Groups

1 Air Temperature
2 Wind
3 Rainfall and Ice
4 Drought
5 Snow
6 Electromagnetic Interference (EMI)
7 Sea or River Water Temperature
8 External Flooding
9 Seismic Activity
10 Loss of Off-Site Power
11 Aircraft Impact
12 External Fire
13 External Missile
14 External Explosion

Site Specific Hazard Groups

15 Cloud / Storms (Ash, Dust, Sand, Salt)
16 Ground Condition
17 External Transport Impacts
18 Industrial Environment
19 Water based Biological Fouling
20 Land and Air based Biological Fouling
21 Flotsam/ Jetsam/Log Jam

Screened out Hazard Groups

22 Extra-Terrestrial Objects

The scope of the buildings included in the GDA design is given in PSCR Chapter 10: Civil Works and Structures, Section 10.2.2. The generic site plan is presented in Chapter 9: General Description of the Unit, Section 9.4.1, which gives an overview of the conceptual site plan used in the generic design, and of the main buildings included in the scope of GDA. The generic site layout is based on one ABWR unit. The assessment of the resilience of buildings to External Hazards has focused on the main buildings and facilities which contribute to UK ABWR Fundamental Safety Functions (FSFs), as listed below.

- Reactor Building (R/B), including the reactor primary containment, or Reinforced Concrete Containment vessel (RCCV), and the Spent Fuel Pool (SFP) which are both enclosed by the R/B external structure.

- Control Building (C/B), including the Master Control Room (MCR) and the Main Steam Tunnel Room,
- Heat Exchanger Building (Hx/B),
- Main Stack,
- Emergency Diesel Generator Buildings (EDG/B),
- Filter Vent Building (FV/B),
- Backup Building (B/B),
- Turbine Building (T/B),
- Radwaste Building (Rw/B),
- Service Building (S/B),
- Condensate Water Storage Tank (CST) Structure,
- Light Oil Storage Tank (LOT) Structure,
- FLSS Water Storage Tank (WST) Structure (10 separate tanks),
- R/B-EDG/B Connecting Service Tunnels,
- Reactor Cooling Water (RCW) Tunnel,
- R/B-B/B Connecting Service Tunnel,
- R/B-CST Connecting Service Tunnel,
- B/B-LOT Connecting Service Tunnel,
- R/B-B/B Connecting Service Tunnel,
- B/B-FLSS Water Storage Tank Connecting Service Tunnel.

The assessment includes consideration of the effects of External Hazards through all operating phases of the reactor, as follows (Refer to Chapter 5: General Design Aspects, Section 5.4 for detail definition):

- Power operation,
- Start-up,
- Hot shutdown,
- Cold shutdown,
- Refuelling outage.

6.3 Identification of Individual External Hazards

In line with international good practice, a systematic process has been used to identify individual hazards, consisting of the following five steps as described in the "Topic report on External Hazards Protection" [Ref-01]:

(1) Listing
(2) Grouping by denomination
(3) Grouping by plant effect
(4) Screening
(5) Classification into GDA and site specific stage

Initially, the process involved derivation of a comprehensive list of individual External Hazards regardless of their potential effect on plant safety [Ref-03]. This list was then grouped in two different ways: 'Grouping by denomination' where the type of hazard is very similar, and 'Grouping by plant effect' based on the potential safety impact on the plant. Next, a 'Screening' process was executed to identify those hazards that have a demonstrably low frequency of occurrence and can reasonably be excluded from the analysis. The remaining hazard groups were then classified into those that can be considered during GDA, and those that are more appropriate to consider during the site specific stage.

6.3.1 Listing

The first step is the identification of a comprehensive list of individual External Hazards. External Hazards are those natural or man-made hazards to a site and its facilities that originate outside the facilities, the site and its processes, where the duty holder generally has no control over the initiating event. Natural hazards are those that take place at the site as a result of the geophysical location and prevailing meteorological conditions, (e.g. External Flooding, extreme Wind, Seismic Activity). Man-made hazards are those that may affect a plant as a result of human activities near or adjacent to the site, (e.g. External Explosions, External Fire, Aircraft Impact). The master list of External Hazards, its derivation and justification have been developed for GDA [Ref-03]. The list in [Ref-03] provided the initial basis for the production of the list of External Hazards.

As defined in PCSR Chapter 5: General Design Aspects, Section 5.3, the list of External Hazards should be comprehensive and should not be constrained by "size" or preconceived notions concerning hazard characteristics (i.e. intensity or probability).

Hitachi-GE has carried out a defined process for identifying a comprehensive list of External Hazards for the UK ABWR. This is based on Hitachi-GE's own experience on the Japanese operating fleet of nuclear power stations. Furthermore, studies have been carried out to identify international relevant good practice in this subject. Hazard reviews have also been undertaken with specialists in the UK nuclear industry, including those with knowledge of existing and potential nuclear licensed sites. Table 6.3-1 lists the international and regulatory guidance and standards used as reference sources to inform the production of the comprehensive list as explained in the "Derivation and Justification of the External Hazards for the GDA PCSR" [Ref-03].

Table 6.3-1: Reference Source for Comprehensive List of External Hazards

Note: this table is an extract from [Ref-03]

No.	Reference Source
1	USNRC, "PRA Procedures Guide" (NUREG-CR-2300), January 1983
2	Pre-Construction Safety Report (Sizewell B PCSR), June 1995
3	OECD Nuclear Energy Agency (NEA), "Probabilistic Safety Analysis (PSA) of the Other External Events Than Earthquake", May 05, 2009
4	WENRA RHWG, "Report Safety of new NPP designs - Study by Reactor Harmonization Working Group RHWG", March 2013.
5	USNRC, "PRA Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities", June 1991
6	USNRC, "Evaluation of External Hazards to Nuclear Power Plants in the United States," (NUREG 1407 and NUREG/CR-5042), December 1987
7	IAEA, "External Events Excluding Earthquakes in the Design of Nuclear Power Plants" (IAEA Safety Guide, NS-G-1.5), 2003
8	European Utilities Requirements (EUR), Volume 2, Section 2.4, "Generic Nuclear Island Requirements: Design Basis", April, 2001
9	Swedish Nuclear Inspectorate (SKI), "Guidance for External Events Analysis", February 2003
10	HSE, "Technical Assessment Guide" 013, April 2009 *1
11	HSE, "Generic Design Assessment Guidance to Requesting Parties" (ONR-GDA-GD-001 Revision 4), August 2012 *1
12	NNB Gen Co LTD, "Hinkley Point C PCSR Assessment Guidance to Requesting Parties" (ONR-GDA-GD-001 Revision 0), Hazards Protection, A (HPC-NNBOSL-U0-000-RET-000046 Issue 2), 22/08/2012.

Note *1: these documents have since been updated but do not affect the outcome of the study in Ref-03.

6.3.2 Grouping by Denomination

Grouping of the various types of external events is useful for structuring the information hierarchically, and makes it more efficient to perform a complete check of the identified events.

Some hazards in the comprehensive list are duplicated, with similar hazards being described slightly differently [Ref-03]. For instance, Fog and Mist are slightly different but very similar in that both are related to high humidity. Accordingly, these two hazards are grouped into humidity. Therefore grouping by denomination avoids ‘double-counting’ of the same type of hazard.

6.3.3 Grouping by Plant Effect

External Hazards have also been grouped based on their potential effect on the plant. If the potential impact of the hazards on the safety of the plant is the same or very similar, hazards have been grouped to avoid repetition of the hazard definition and protection. Table 6.3-2 lists the categories of plant effect that have been used, which is based on the guidance provided in “Guidance for External Events Analysis” [Ref-09]. The applicability of this list has been reviewed in “Topic Report on External Hazard Protection” [Ref-01]. The relationship between the plant effects listed in Table 6.3-2 and the individual External Hazard groups is described in Section 6.5, which also identifies how the Plant Effects relate to the UK ABWR High Level Safety Functions (HLSF) defined in PCSR Chapter 5: General Design Aspects, Table 5.6-1.

Table 6.3-2: Plant Effect List

No.	Plant Effect Category	Possible Effects
1	Structural Load	The external event may apply structural loading to civil structures or external plant which may disable safety systems contained or such that the structure no longer performs its safety functions.
2	Cooling/ Ventilation	The external event may affect the ability to provide sufficient cooling ventilation to SSCs, which may cause partial or total loss of safety systems relying on air cooling.
3	Cooling/ UHS	The external event may affect the ultimate heat sink which may cause partial or total loss of secondary cooling and other safety systems relying on water cooling.
4	Power Supply	The external event may affect the external power connection of the plant, and may cause Loss of Off-Site Power.
5	Plant Flooding	The external event may affect the plant by disabling safety systems contained or by undermining the structure.
6	Thermal Load	The external event may affect the plant causing overheating or overcooling that may disable safety systems or such that equipment or structures can no longer perform their safety functions.

No.	Plant Effect Category	Possible Effects
7	Electric	The external event has indirect effects on the plant by generating electrical or magnetic fields, which may potentially affect transmission of power supply or control signals to safety systems.
8	Other Direct Impact	In a few cases, the event may work in a way that is not covered by the general categories. An example is plant isolation.

6.3.4 Screening

Any generic type of hazard with a total frequency that is demonstrably below once in ten million years may be excluded from the fault analysis. According to PCSR Chapter 5: General Design Aspects, Section 5.3, a cut off frequency of 10^{-7} yr^{-1} can be applied to screen out the hazard on the basis of frequency of occurrence. The applicability of screening has been reviewed for each hazard (refer to the "Topic Report on External Hazard Protection" [Ref-01]).

6.3.5 Classification of Hazards into either Generic Design Assessment (GDA) or Site Specific Stage

The hazard groups identified have been reviewed and classified into those that can be considered during GDA, and those that are more appropriate to consider during the site specific stage. This includes considering whether there is significant dependency on the site specific information required to categorise the hazards.

6.3.6 Master List of Individual External Hazards

Table 6.3-3 presents the list of individual External Hazard groups, which has been derived by the process described in Sections 6.3.1 to 6.3.5. Fourteen individual External Hazard groups have been selected for GDA, seven individual External Hazard groups have been selected for site specific stage and the Extra-Terrestrial Objects have subsequently been screened out on the basis of low frequency. Definition for the fourteen GDA hazard groups and relevant combined hazards are described in the Section 6.6 of this chapter.

Table 6.3-3: Individual Hazard Group List* [Ref-01].

Hazard Group #	Hazard Group Name	Individual Hazards within Group	Treatment
1	Air Temperature	[A10][A30] [CH 106] [A3][A20]	GDA
2	Wind	[A4][A3][A20]	
3	Rainfall and Ice	[A6][A8][A14][A15][A16][A22] [A3][A20]	
4	Drought	[C1][A3][A20]	
5	Snow	[A39][A44][A3][A20]	
6	Electromagnetic Interference (EMI)	[A17][D7] [A43][D8][D27]	
7	Sea or River Water Temperature	[A32][A3][A20]	
8	External Flooding	[A26][A29][B21][C3][C4][C9] [C11][A22][A3][A20]	
9	Seismic Activity	[B16][B4][B7][B36][B37][B15]	
10	Loss of Off-Site Power	[D19]	
11	Aircraft Impact	[D1]	
12	External Fire	[D2][D15][D34]	
13	External Missile	[D23][D24][A38][D2]	
14	External Explosion	[D13]	
15	Cloud / Storms (Ash, Dust, Sand, Salt)	[A34][A25][A28]	Site specific stage
16	Ground Condition	[A31][B1][B2][B3][B9][B11][B12] [B14][B17][B18][B19][B20][B30] [D10][D22][D37][D40][F3]	
17	External Transport Impacts	[D33]	
18	Industrial Environment	[D2][D3][D20][D25][D26][D31] [D32][D36][F1]	
19	Water based Biological Fouling	[E4][E2][E6][E8][E16]	
20	Land and Air based Biological Fouling	[E1][E2][E4][E6]	
21	Flotsam/ Jetsam/Log jam	[D4][D41][D42]	
22	Extra-Terrestrial Objects	[A19][D29]	Screened out based on occurrence frequency

*ID Numbers in [ ] is Hazard ID as per "Topic Report on External Hazard protection" Ref-01] and "Topic Report on Combined External Hazards" [Ref-04].

6.4 Identification of Combined External Hazards

A systematic approach has been used for the UK ABWR for the identification of combined External Hazards, in line with international good practice such as IAEA "Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants" [Ref-10], the American Society of Mechanical Engineers (ASME) [Ref-11] and the Swedish Nuclear Inspectorate (SKI) [Ref-09]. The process is described in the "Topic Report on Combined External Hazards" [Ref-04] and considers combinations of the individual External Hazards identified in Section 6.3.

Combinations of events when External Hazards lead to Internal Hazards are described in PCSR Chapter 7: Internal Hazards and in "Topic Report on Combined Internal Hazards" [Ref-28].

The process for combined External Hazards has used the following steps:

(1) Listing
(2) Categorisation
(3) Screening

The aim of this approach is to ensure that all combinations are effectively and exhaustively reviewed, and appropriately categorised and screened.

6.4.1 Listing

The starting point for the process is the list of potential individual external events identified in Section 6.3. To ensure completeness, all of the combination of the GDA individual External Hazards (i.e. hazard groups 1 to 14) have been considered, using a cross-checking matrix listing the GDA individual hazard groups on both the horizontal and vertical axes. As discussed in Section 6.3, each hazard group can contain multiple hazards that are closely related, but not identical. Where this is the case, individual hazard combinations within the same group have also been reviewed in the cross-checking matrix.

6.4.2 Categorisation

All the combination of derived individual External Hazards in Section 6.3 are reviewed and classified into three categories based on initiating correlation as shown in Table 6.4-1. The purpose of categorisation is to identify combinations that are causally linked as having a greater than random chance of concurrent occurrence. Events that occur concurrently at random are less likely to have sufficient intensity to adversely affect the safety functions of the SSCs. However, the classification process confirms if there are any combinations that could have a worse effect than individual External Hazards on the safety functions of the SSCs.

This categorisation is hierarchically applied to the two steps (firstly, between hazard groups and secondly, between hazards in a group). Fundamental treatments for the combined hazard load and the occurrence frequency are set for each category.

(1) Combination Hazard Category I: Consequential hazards

In this category, one hazard causes the other hazard to occur consecutively. As an example, a strong earthquake may cause a tsunami. The joint hazard effect has been considered in UK ABWR design.

(2) Combination Hazard Category II: Correlated hazards

In this category, occurrences of the two or more events are not independent; both have a common cause or individual initiating event. For example, more than one hazard may be derived from the same meteorological conditions.

(3) Combination Hazard Category III: Independent hazards

In this category, occurrences of the two or more hazards are independent from each other. One hazard occurs and the second hazard occurs simultaneously or within a given period of time after the first hazard.

6.4.3 Screening

A large number of potential hazard combinations were derived through the exhaustive paring of hazards. A screening approach, documented in “Topic Report on Combined External Hazards” [Ref-04], was used to derive those combined hazards that merit further consideration. Those combined hazards that were screened out, were excluded on the basis that:

- The joint event is not credible,
- The joint event has an acceptably low probability,
- The consequences of the joint event are bounded by another individual hazard event which generally has a higher magnitude.

Combination Category I/III in Table 6.4-1 means the complex case that the combined hazards can be Consequential External Hazards if the industrial facility is close to a nuclear power plant, otherwise they can be Independent External Hazards.

6.4.4 Master List of Combined External Hazards

As a result of the process described in Section 6.4.1 to 6.4.3, the list of combined External Hazards which needs to be considered is shown in Table 6.4-1 which is repeated from Table 3.3-1 in “Topic

Report on Combined External Hazards" [Ref-04]. The identified combined hazards are considered under each individual External Hazard group in Section 6.6.

Table 6.4-1: Screened In Combined Hazard List [Ref-04, Table 3.3-1]

CH ID#	Hazard 1	Hazard 2	CH Category	Further description
19	Wind	External Flooding	I	Section 6.6.8
24	Wind	External Missile	I	Section 6.6.13
30	Rainfall and Ice	External Flooding	I	Section 6.6.8
48	Snow	Sea or River Water Temperature	II	Section 6.6.7
49	Snow	External Flooding	I	Section 6.6.8
71	External Flooding	Seismic Activity (Earthquake)	I	Section 6.6.9
77	Seismic Activity (Earthquake)	Loss of Off-Site Power (LOOP)	I	Section 6.6.9
106	Humidity	Temperature Extremes (Air)	I	Section 6.6.1
107	Hail, Sleet, Snow and Icing	Ice (Frazil)	II	Section 6.6.3
108	Hail, Sleet, Snow and Icing	Ice (Rime)	II	Section 6.6.3
109	Hail, Sleet, Snow and Icing	Ice (Barriers)	II	Section 6.6.3
110	Hail, Sleet, Snow and Icing	Frost, Soil Frost	II	Section 6.6.3
111	Hail, Sleet, Snow and Icing	Rainfall (Extreme) and Intense Precipitation	II	Section 6.6.3
112	Ice (Frazil)	Ice (Rime)	II	Section 6.6.3
113	Ice (Frazil)	Ice (Barriers)	II	Section 6.6.3
114	Ice (Frazil)	Frost Soil Frost	II	Section 6.6.3
116	Ice (Rime)	Ice (Barriers)	II	Section 6.6.3
117	Ice (Rime)	Frost Soil Frost	II	Section 6.6.3
119	Ice (Barriers)	Frost Soil Frost	II	Section 6.6.3
132	Low / High Sea Water Level	Storm Surge	I	Section 6.6.8
133	Low / High Sea Water Level	Tidal Effects (Flooding)	I	Section 6.6.8
141	Storm Surge	Groundwater	I	Section 6.6.8

CH ID#	Hazard 1	Hazard 2	CH Category	Further description
143	Storm Surge	Dam Failure	I/III	Section 6.6.8
144	Storm Surge	Pipeline Accident (Gas, Oil, Water, etc.)	I/III	Section 6.6.8
148	Tidal Effects (Flooding)	Dam Failure	I/III	Section 6.6.8
152	Waves	Dam Failure	I/III	Section 6.6.8
153	Waves	Pipeline Accident (Gas, Oil, Water, etc.)	I/III	Section 6.6.8
154	Groundwater	High Tide, High Lake Level, or High River Stage	I/III	Section 6.6.8
155	Groundwater	Dam Failure	I/III	Section 6.6.8
156	Groundwater	Pipeline Accident (Gas, Oil, Water, etc.)	I/III	Section 6.6.8
158	High Tide, High Lake Level, or High River Stage	Pipeline Accident (Gas, Oil, Water, etc.)	I/III	Section 6.6.8
159	Dam Failure	Pipeline Accident (Gas, Oil, Water, etc.)	I/III	Section 6.6.8
161	Seismic Activity (Earthquake)	Geological faults	I	Section 6.6.9
175	Fire	Adjacent Installations, Transport Activities (Missiles, Gas Clouds, Explosions, etc.)	I	Section 6.6.12
176	Fire	Toxic Gas (and Asphyxiants)	I	Section 6.6.12
177	Adjacent Installations, Transport Activities (Missiles, Gas Clouds, Explosions, etc.)	Toxic Gas (and Asphyxiants)	I	Section 6.6.12

6.5 The Relationship between Safety Functions and External Hazards

6.5.1 Fundamental Safety Functions

The UK ABWR Fundamental Safety Functions (FSFs) are defined in PCSR Chapter 5: General Design Aspects, Section 5.3.2 as:

(1) Control of Reactivity
(2) Fuel Cooling
(3) Long Term Heat Removal
(4) Confinement/Containment of radioactive materials
(5) Others (largely for support functions whose support is required to enable one or more of the above safety functions)

These five FSFs must be met by the UK ABWR at all times to maintain nuclear safety and this includes maintaining functions against External Hazard events including the Combined External Hazards. The UK ABWR SSCs are designed to withstand the identified generic External Hazard conditions and combinations of hazards that are appropriate to the safety classification of the SSCs (see Section 6.5.2).

6.5.2 Safety Category and Class of SSCs

Based on the radiological consequences (risks) of faults and events, the safety functions are categorised as follows (see PCSR Chapter 5: General Design Aspects, Section 5.6.3 for detail):

- Category A: any function that plays a principal role in ensuring nuclear safety
- Category B: any function that makes a significant contribution to nuclear safety
- Category C: any other safety function

SSCs which deliver the safety functions are classified into three categories according to their importance in delivering the corresponding safety function (see PCSR Chapter 5: General Design Aspects, Section 5.6.4 for detail).

- Class 1: any structure, system, or component that forms a principal means of fulfilling a Category A safety function
- Class 2: any structure, system, or component that makes a significant contribution to fulfilling a Category A safety function, or forms a principal means of ensuring a Category B safety function
- Class 3: any other structure, system, or components

High Level Safety Functions (HLSFs) flowing down from the FSFs are summarised in PCSR Chapter 5: General Design Aspects, Section 5.6.2 and their safety categorisation can be found in [Ref-35].

In application of the Safety Category and Class to seismic design, the Seismic Categorisation, which is described below, has been used because earthquakes might result in common caused failures (see PCSR Chapter 5: General Design Aspects, Section 5.6.6 for detail).

- Seismic Category 1: Seismic Category 1 SSCs are designed to withstand the Design Basis Earthquake (DBE) and are required to maintain structural and functional integrity in combination with other appropriate loads.
- Seismic Category 1A: Seismic Category 1A SSCs are designed to withstand the DBE in combination with other appropriate loads without spatial interactions or any other interactions with Seismic Category 1 SSCs.
- Seismic Category 2: Seismic Category 2 SSCs are designed to withstand less than the DBE and are required to maintain structural and functional integrity in combination with other appropriate loads.
- Seismic Category 3: Nuclear safety related SSCs that are not categorized as Seismic Category 1, 1A or 2 are designated as Seismic Category 3

The safety classification process can be found in Figure 6.5-1, which is extracted from the "List of Safety Category and Class for UK ABWR" [Ref-35]. All functions required to prevent accidents and fulfil the main safety functions are identified. Then safety functions are categorised and the SSCs performing those safety functions are identified and categorised in accordance with the UK common practice. In addition, the faults schedule and design basis analysis are used to confirm the adequacy of the safety classification.

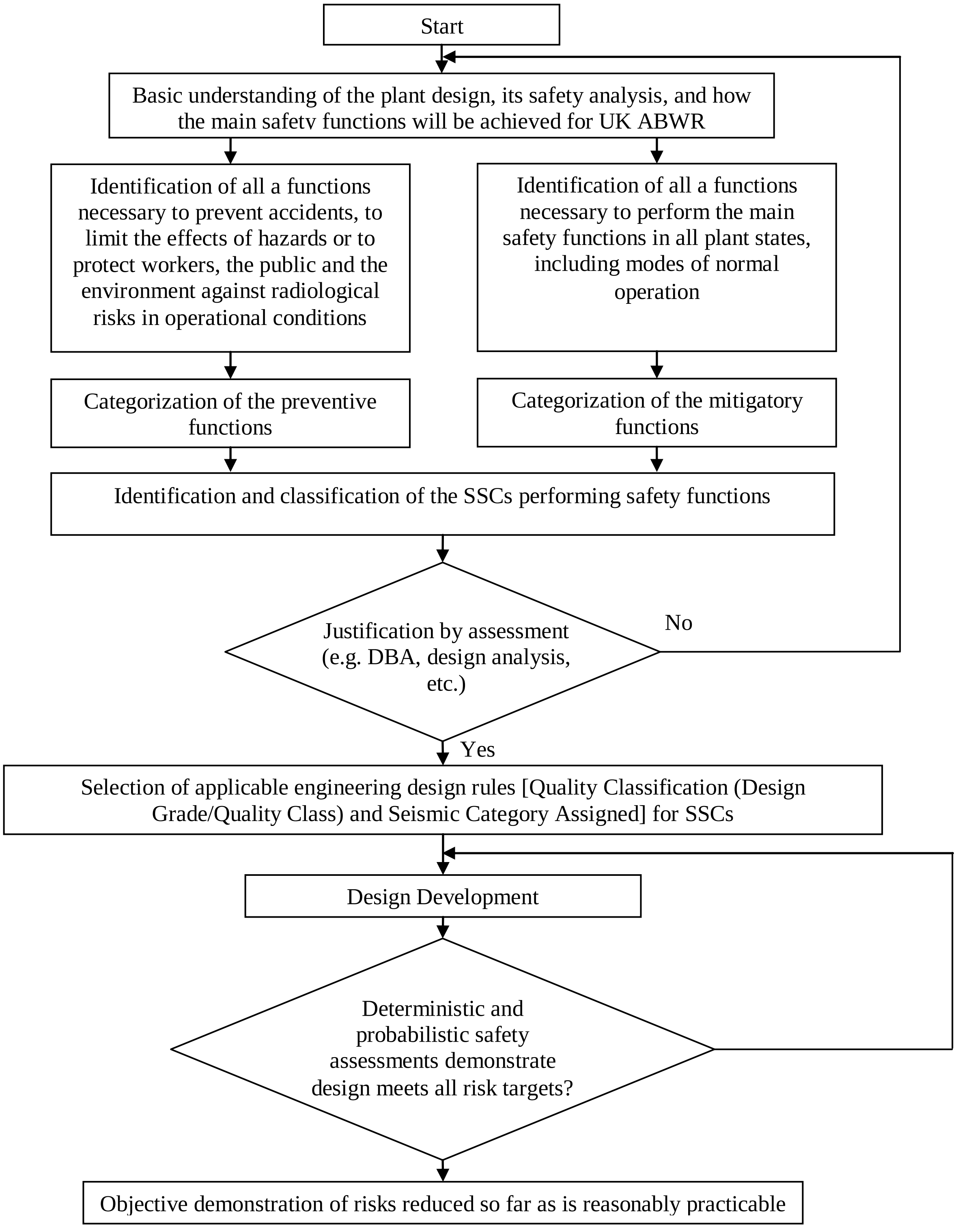

Figure 6.5-1: Flow chart of the safety classification process (Extracted from [Ref-35])

6.5.3 Interface with DBA and PSA

(1) Design Basis Analysis (DBA)

The process used to develop the Fault Schedule is presented in PCSR Chapter 24: Design Basis Analysis. This comprises identification of faults in a systematic way and assesses the initiating event frequency and the unmitigated consequences, that is, consequences with no safety systems operating. Any faults that have frequency and unmitigated consequences above the Basic Safety Level are designated as Design Basis Faults. The DBA then groups these Design Basis Faults according to the demands they place on SSCs and identifies the bounding or worst case for each group. Finally, the risks posed by each fault are evaluated and shown to be ALARP.

The External Hazards identified in Chapter 6 are an input to the DBA which considers the following:

- Reactor Faults
- Non-reactor faults
- Hazards (Internal and External)

The “Topic Report on Fault Assessment” [Ref-05] provides further information on the selection of faults and includes the resulting Fault Schedule which is given in Table 4.2-1 for External Hazards. Potential initiating events from External Hazards are identified in the “Topic Report on Fault Assessment” [Ref-05] Section 2.7. Chapter 6 provided generic External Hazards for the assessment. In addition, “Water based Biological Fouling” is considered since it is a substantive frequent design basis hazard for the UHS. The DBA concludes that the bounding External Hazards are as follows [Ref-05, Table 2.7-2]:

- Group #9 – Seismic Hazard

  The seismic hazard will affect the whole site at once and therefore protection is provided by a substantial margin for civil structural design. This hazard therefore bounds the rest of Groups 1 to 14 in terms of structural load.

- Group#10 – LOOP

  LOOP is already included as a DB fault since it is caused by other reasons, not just External Hazards.

- Group#19 – Water based Biological Fouling

  The DBA considers the fault scenario due to this event. It should be noted that Groups #15 to #21 except #19 are not included in the generic DBA due to their frequencies and magnitude being dependent on site-specific characteristics.

The above three fault scenarios are listed in the Table 2.9-1 [Ref-05]. These are expanded in the Fault Schedule, Table 4.2-1, where the fundamental safety functions are given for each initiating event.

In addition, the FMEA results for non-reactor faults in Appendix A of [Ref-05] lists the bounding fault for each system or component, whether the fault was caused by component failure, External Hazard or Internal Hazard. Therefore, all design basis effects, whether caused by External Hazards or not, are included.

(2) Probability Safety Analysis (PSA)

The PSA for the generic design of the UK ABWR is described in PCSR Chapter 25: Probabilistic Safety Analysis. PSA is the analysis used to quantify the overall risks represented by the facility and allow comparisons against the UK Risk Targets. It also assesses the potential vulnerabilities of the design to inform the designers of potential ALARP improvements. The PSA considers all types of initiating events, and this includes External Hazard events.

The External Hazards PSA provides an integrated, structured analysis that assesses plant risk and identifies potential plant vulnerabilities. The methodology and results are described in PCSR Chapter 25: Probabilistic Safety Analysis, Section 25.11. Twenty-two External Hazard groups provided by Chapter 6 were used as the starting point for the External Hazard prioritisation. The "Topic report on External Hazards PSA Prioritisation" [Ref-37] provides further details of how the PSA performed quantitative screening and prioritisation of External Hazards that then undergo a more detailed assessment within the PSA work.

This also includes identifying possible combinations of hazards that may result in more significant impact to plant than the cases being assessed individually. The PSA includes all hazards groups 1 to 22, and so includes consideration of site specific effects as far as can be performed during GDA.

The results of the hazard prioritisation are reported in "Topic report on External Hazards PSA Prioritisation" Section 8 of Appendix 1 [Ref-37]. This concludes the prioritisation assessments of External Hazards. The following individual hazard groups were identified for the GDA assessment:

- Seismic hazard group #9 – this is assessed independently in detail in the PSA including seismic margins assessment of all civil structures (PCSR Chapter 25: Probabilistic Safety Analysis, Section 25.11.2).

- Extreme Wind hazard Group #2, including wind borne missile.

- Accidental Aircraft Impact Group #11

The conclusions given in PCSR Chapter 25: Probabilistic Safety Analysis, Section 25.17 are as follows:

- The PSA Level 1 and Level 2 analyses concluded that the Seismic PSA results in GDA are based on generic system and component fragilities. Experiences with plant-specific evaluations have shown that high seismic capacities are achievable.

- Tornado Missiles and Accidental Aircraft Impact were found to have negligible contribution to risk.

- External Flooding and Water based Biological Fouling are assessed as a sensitivity analysis.

The GDA PSA results therefore demonstrate that the basic design and design features of the UK ABWR are ALARP.

6.5.4 Plant Effect Matrix

The fundamental safety functions in Section 6.5.1 are satisfied by the design of each SSC considering the effects of External Hazards as specifically applicable to that SSC. The magnitude of the External Hazard is defined by the safety classification. Class A1, A2 and B2 SSCs should be protected against the design basis External Hazards.

The relationship between the plant effect by individual External Hazards groups and the safety functions is shown in Table 6.5-1. There are two rows as headers of this table. The first row shows the plant effects directly derived from Table 6.3-2. The second row shows the corresponding HLSFs which are defined in Section 5.6.2 of PCSR Chapter 5: General Design Aspects. Multiple safety functions may relate to each plant effect.

Table 6.5-1 also shows fourteen GDA individual External Hazard groups accompanied with plant effects and safety functions. The corresponding legends for Table 6.5-1 are as follows:

- “X” means the External Hazard can affect that plant effect and
- “-” means the External Hazard does not affect that plant effect.

Relevant plant effects are described within the following Sections 6.6 for each hazard group.

Table 6.5-1: Relationship between the Plant Effect by External Hazards Groups and Safety Functions

Individ-ual Hazard Group	Plant Effect	Structural Load	Cooling /Ventilation	Cooling / UHS	Power Supply	Plant Flooding	Thermal Load	Electric
	HLSF	2-4, 4-7 5-7, 5-17	5-18	5-2	5-2, 5-3, 5-7	5-7	5-7, 5-17	See Appendix A1 of Chap. 14 and Appendix A of Chap.15
1	Air Temperature	X	X	X	-	-	-	-
2	Wind	X	-	-	-	-	-	-
3	Rainfall and Ice	X	-	X	X	-	-	-
4	Drought	-	-	X	-	-	-	-
5	Snow	X	X	X	X	-	-	-
6	EMI	X	-	-	-	-	-	X
7	Sea or River Water Temperature	-	-	X	-	-	-	-
8	External Flooding	X	-	-	X	X	-	-
9	Seismic Activity	See Section 6.6.9						
10	Loss of Off-Site Power	-	-	-	X	-	-	-
11	Aircraft Impact	See Section 6.6.11						
12	External Fire	-	X	-	-	-	X	-
13	External Missile	X	-	-	-	-	-	-
14	External Explosion	X	X	-	-	-	X	-

6.6 Hazard Definition and General Protection

This Section presents the definition of individual External Hazards and relevant combination hazards for each hazard group. The plant effect from External Hazards, the UK ABWR Fundamental Safety Functions (FSFs) and reference sources to identify safety measures are also provided.

6.6.1 Air Temperature

(1) Hazard definition and plant effect in this hazard group
Hazard Group #1 covers extreme high and low temperatures at generic UK site. The effect of humidity variations is also considered in this hazard group. Table 6.6-1 shows the individual hazards in this group.

Table 6.6-1: Air Temperature Group #1

Hazard ID #	Hazard Condition	Remarks
A10	Humidity	-
A30	Temperature Extremes (Air)	Includes ・ extremely high air temperature ・ extremely low air temperature
A3	Climate Change	This effect is included in the evaluation of hazards in Chapter 2.
A20	Extreme Meteorological Conditions	This effect duplicates A10 and A30 and so is not considered further.

The values of the maximum and minimum air temperature and the enthalpy can be found in PCSR Chapter 2: Generic Site Envelope, Section 2.4.1. The generic site envelope values for air temperature are based on the results of a set of Extreme Value Analyses (EVA) which have been undertaken based on historically recorded data. The combination of the humidity and the air temperature is considered through enthalpy. Further details on how these values have been derived can be found in the “Topic Report on Generic Site Envelope” [Ref-02].

This hazard group does not include the potential effects of ice, which is often associated with low air temperature. Ice has been assessed as part of Hazard Group #3 “Rainfall and Ice”. High and low sea water temperatures have been assessed as Hazard Group #7 “Sea or River Water Temperature”.

This hazard group has the potential to cause plant effects in the following categories:

- Structural Load
- Cooling/Ventilation
- Cooling/UHS

Structural Load

Extremely high or low air temperature may induce thermal gradients in the structural components of the building (concrete, steel rebar, steel liners, tanks, etc.). These gradients can impose structural loads on SSCs that are important to safety and, in the extreme, could lead to the SSCs failing to deliver their safety functions.

Cooling/Ventilation

Air temperature and humidity are the dependency parameters of enthalpy which is one of the key factors for Heating, Ventilation and Air Conditioning (HVAC) system design. Thus, extreme air temperature and humidity variation can affect the ability of the HVAC system to provide sufficient ventilation and prevent failure of temperature sensitive equipment. Failure of the HVAC system to provide cooling could lead to failure of SSCs to deliver their safety function.

Cooling/UHS

In case that decay heat is released to air (i.e. air is used as final heat sink), extremely high air-temperatures may cause reduction in the effectiveness of UHS.

(2) Hazards combinations with this group [Ref-04]

The combined hazard to be considered in this hazard group is shown in Table 6.6-2. Air temperature and humidity are the dependency parameters of enthalpy which is one of the key factors for HVAC design. Thus, the combined hazard may affect the ability of the HVAC system to provide sufficient ventilation and prevent failure of temperature sensitive equipment.

Table 6.6-2: Combined Hazards with Air Temperature Group # 1

CH ID #*	Hazard 1	Hazard 2	CH Categorisation
106	Humidity	Temperature Extremes (Air)	I

(3) General protection

Structural Load

In general, SSCs that are important to safety are protected from this hazard group by the civil structures. The integrity of the structural components of the building (concrete, steel rebar, steel liners, tanks, etc.) will not be challenged by the extreme air temperature postulated by the generic site envelope temperatures. The civil structures which contain safety relevant SSCs are designed to provide protection against External Hazards and environmental conditions [HLSF 5-7: Functions to limit the effect of hazard], to support SSCs [HLSF 5-17: Function to provide structural support to SSCs] and to confine radioactive materials [HLSF 4-7: Functions to confine radioactive materials, shield radiation, and reduce radioactive release]. For the spent fuel pool (SFP), the reactor building forms the SFP together with a stainless liner and cooling systems, to enable fuel cooling outside the reactor coolant system [HLSF 2-4: Function to cool spent fuel outside the reactor coolant system].

The design principles for the civil structures in GDA are described in PCSR Chapter 10: Civil Works and Structures, Section 10.3.4 and the "Basis of Safety case on Reactor Building Civil Design" [Ref-12].

Cooling/Ventilation

The HVAC systems will maintain the building environment within appropriate parameters for temperature sensitive SSCs even if the outside air temperature is extreme [HLSF 5-18: Function to maintain internal building environment appropriate for SSCs]. The design principles for HVAC in GDA are described in PCSR Chapter 16: Auxiliary Systems, Section 16.5.

The design basis air temperatures and enthalpies are given in PCSR Chapter 2: Generic Site Envelope. These are then used by the GDA HVAC design for Class 1, Class 2 and Class 3 HVAC systems which are described in PCSR Chapter16: Auxiliary Systems, Section 16.5 and in the "Topic Report on External Design Condition for Class 3 HVAC" Section 13.3 and 13.4 [Ref-26]. Not all Class 1 and Class 2 HVAC systems require intake of external air; some are total air recirculation systems and so are not directly affected by outside air temperature. The design margins of those that do require air intake have been assessed in the report "BDB Design Margins for the Class 1 and Class 2 HVAC Systems" [Ref-27] and the design is shown to have sufficient margins.

Cooling/UHS

In case that decay heat is released to air (i.e. air is used as final heat sink), the extremely high air-temperature may cause reduction in the effectiveness of the UHS. The UHS is the principal means to provide sufficient cooling water to the RSW to dissipate the heat from the plant auxiliaries. Thus, [HLSF 5-2 : Supporting functions especially important to safety] is linked to this Hazard Group.

6.6.2 Wind

(1) Hazard definition and plant effect in this hazard group

Hazard Group #2 covers extreme wind at generic UK site. Table 6.6-3 shows the individual hazards in this group. The generic design of the nuclear power station considers the weather conditions of the nominated UK sites.

Table 6.6-3: Wind Group #2

Hazard ID #	Hazard Condition	Remarks
A4	Extreme Winds, Tornadoes, Cyclones, Typhoon, Hurricane	-
A3	Climate Change	This effect is included in the evaluation of hazards in Chapter 2.
A20	Extreme Meteorological Conditions	This effect duplicates A4 and so is not considered further.

The evaluation of the extreme wind is presented in PCSR Chapter 2: Generic Site Envelope, Section 2.4.2. Further details on how these values have been derived is justified in the "Topic Report on Generic Site Envelope" [Ref-02].

This hazard group has the potential to cause plant effect in the following category:

- Structural Load

Structural Load

High winds cause loading on the outside of buildings or on equipment in the yard (e.g. light oil tanks) which should be designed to withstand local wind pressures and any wind-borne missiles. The structure most affected by wind loads is the main stack which is a lattice steel structure and has a height of 75m above ground level.

Tornadoes are violent funnel shaped vortices of wind created by certain meteorological conditions which damage properties through the pressures (both negative and positive) generated by the vortex itself and the associated wind-borne debris.

(2) Hazards combinations with this group [Ref-04]

Small missiles (e.g. idealised as solid steel spheres) generated by the high wind could enter the building through openings such as HVAC vents. Flying debris generated by strong wind including tornadoes and tropical storms are considered as an event consequence in Hazard Group #13: External Missile (See Section 6.6.13.).

For high wind scenario, LOOP may occur due to damage to the external electricity grid by causing failure of supports such as pylons. LOOP induced by extreme meteorological condition is already considered and the frequencies of "Weather-related LOOP" and/or "Plant-centred LOOP" are taken from NUREG/CR-6890 [Ref-13] referred in SBO Analysis in the PCSR Chapter 2: Generic Site Envelope. This combination event is considered in Hazard Group #10: LOOP (see Section 6.6.10.).

(3) General protection

In general, SSCs that are important to safety are protected from the wind hazard group by the civil structures in PCSR Chapter 10: Civil Works and Structures, Section 10.3.4. The civil structures which contain safety relevant SSCs are designed to provide protection against External Hazards and environmental conditions [HLSF 5-7: Functions to limit the effect of hazard], to support SSCs [HLSF 5-17: Function to provide structural support to SSCs] and to confine radioactive materials [HLSF 4-7: Functions to confine radioactive materials, shield radiation, and reduce radioactive release]. The design principles for the civil structures are given in the "Basis of Safety Case on Reactor Building Civil Design" [Ref-12], which includes the stack in Appendix B. The design of the stack for the 10^{-4} yr^{-1} wind loading is described in "Civil Engineering Supporting Report Stack, Structural Design Report" [Ref-16].

6.6.3 Rainfall and Ice

(1) Hazard definition and plant effect in this hazard group

Hazard group #3 covers extreme precipitation at generic UK site. This hazard group also includes sleet and hail as well as quantities of ice such as frazil ice, rime ice and barrier ice. Ground frost is also included. Table 6.6-4 shows the individual hazards in this group.

Table 6.6-4: Rainfall and Ice Group #3

Hazard ID #	Hazard Condition	Remarks
A8	Hail, Sleet, Snow and Icing	-
A14	Ice (Frazil)	-
A15	Ice (Rime)	-
A16	Ice (Barrier)	-
A6	Frost, Soil Frost	-
A22	Rainfall (Extreme) and Intense Precipitation	-
A3	Climate Change	This effect is included in the evaluation of hazards in Chapter 2.
A20	Extreme Meteorological Conditions	This effect duplicates the above hazards and so is not considered further.

The generic site envelope values for the extreme precipitation are evaluated using the Ecology and Hydrology’s Flood Estimation Handbook [Ref-14] and Flood Studies Report [Ref-15]. The ice thickness which is relevant to loading on structures is also evaluated in this hazard group. The values of the extreme precipitation and the ice thickness are derived in PCSR Chapter 2: Generic Site Envelope, Section 2.4.3. Further details on how these values have been justified can be found in the “Topic Report on Generic Site Envelope” [Ref-02].

This hazard group has the potential to cause plant effects in the following categories:

- Structural Load
- Cooling/UHS
- Power Supply

Structural Load

The extreme precipitation of rain or hail may result in damage of the roofs of the building. The extreme precipitation and the accumulation of the ice can impose structural loads on SSCs and, in the extreme, could lead to the SSCs failing to deliver their safety functions. The structure most affected by rime ice is the main stack, which is a steel lattice structure.

Cooling/UHS

Frazil ice could form plates of ice suspended in water which result in blockage of the water intake. The blockage of the water intake could result in loss of ultimate heat sink (LUHS) because the flowrate of cooling water required for heat removal systems, such as RHR or the SFP cooling systems, may be affected by the water intake blockage.

Power Supply

Ice forming on transmission lines or transformers might result in problems on the transmission network.

Heavy precipitation may contribute to risk of flooding on the site, especially if combined with high sea water level. It is therefore considered in Hazard Group #8: External Flooding (Section 6.6.8).

(2) Hazards combinations with this group [Ref-04]

The combined hazards to be considered in this hazard group are shown in Table 6.6-5. In the UK ABWR, total precipitation (including snow, sleet, hail, frazil, rime and frost) is considered collectively on generic site condition, which is the worst credible event for those hazards [Ref-02]. These combined hazards result in structural load.

Table 6.6-5: Combined Hazards with Rainfall and Ice Group #3

CH ID #	Hazard 1	Hazard 2	CH Categorisation
107	Hail, Sleet, Snow and Icing	Ice (Frazil)	II
108	Hail, Sleet, Snow and Icing	Ice (Rime)	II
109	Hail, Sleet, Snow and Icing	Ice (Barriers)	II
110	Hail, Sleet, Snow and Icing	Frost, Soil Frost	II
111	Hail, Sleet, Snow and Icing	Rainfall (Extreme) and Intense Precipitation	II
112	Ice (Frazil)	Ice (Rime)	II
113	Ice (Frazil)	Ice (Barriers)	II

CH ID #	Hazard 1	Hazard 2	CH Categorisation
114	Ice (Frazil)	Frost Soil Frost	II
116	Ice (Rime)	Ice (Barriers)	II
117	Ice (Rime)	Frost Soil Frost	II
119	Ice (Barriers)	Frost Soil Frost	II

(3) General protection

Structural Load

In general, SSCs that are important to safety are protected from this hazard group by the civil structures in PCSR Chapter 10: Civil Works and Structures, Section 10.3.4. The civil structures which contain safety relevant SSCs are designed to provide protection against External Hazards and environmental conditions [HLSF 5-7: Functions to limit the effect of hazard], to support SSCs [HLSF 5-17: Function to provide structural support to SSCs] and to confine radioactive materials [HLSF 4-7: Functions to confine radioactive materials, shield radiation, and reduce radioactive release]. For spent fuel pool (SFP), the reactor building forms SFP together with stainless liner and cooling systems, to enable fuel cooling outside the reactor coolant system [HLSF 2-4: Function to cool spent fuel outside the reactor coolant system].

The design of the stack for the 10^{-4} yr^{-1} rime ice loading is described in "Civil Engineering Supporting Report Stack, Structural Design Report" [Ref-16].

Cooling/UHS

The UHS is the principal means to provide sufficient cooling water to the RSW to dissipate the heat from the plant auxiliaries. Thus, [HLSF 5-2: Supporting functions especially important to safety] is linked to this hazard group. The UHS is designed to provide an adequate source of cooling water which is available at all times for reactor operation, shutdown cooling and for accident mitigation. The detail is described in PCSR Chapter 16: Auxiliary Systems, Section 16.3.

Power Supply

The export electrical systems of the UK ABWR are designed to protect against failure due to the ice forming. The design principle of Electrical Power Supplies is described in PCSR Chapter 15: Electrical Power Supplies. The safety claim against the External Hazard can be found in Section 15.3.

6.6.4 Drought

(1) Hazard definition

Hazard Group #4 covers extreme drought at generic UK site. Table 6.6-6 shows the individual hazards in this group. A severe drought may cause drawdown of water level from local bodies of water used for supply, (e.g. reservoirs or groundwater). Drought would have no effect on sea water supply. The drawdown poses the loss of cooling water from main supplies. Thus, the severe drought may affect the ultimate heat sink, depending on what supply was used for a specific site, which may cause partial or total loss of secondary cooling and other safety systems relying on water cooling.

Table 6.6-6: Drought Group #4

Hazard ID #	Hazard Condition	Remarks
C1	Drought	-
A3	Climate Change	This effect is included in the evaluation of hazards in Chapter 2.
A20	Extreme Meteorological Conditions	This effect duplicates C1 and so is not considered further.

(2) Hazards combinations with this group [Ref-04]
The combined hazards which are relevant to this hazard group have been evaluated in the "Topic Report on Combined External Hazards" [Ref-04]. As a result of the evaluation, effective combinations with this hazard group are not specified.

(3) General protection
Drought is a slowly developing hazard, and the very long timescales for this event is in months. Therefore, although drought may impact sources of water there is significant time and resources to mitigate this event through temporary measures if necessary. For coastal sites which use seawater as the UHS, drought is not a significant hazard. Where the UHS is land based, such as cooling tower systems, these are not vulnerable to drought effects. The hazard from drought is not expected to result in a plant trip (manual or automatic) or require a controlled manual shutdown due to plant Limits and Conditions.

6.6.5 Snow

(1) Hazard definition and plant effect in this hazard group
Hazard Group #5 covers extreme snow at the generic UK site. Table 6.6-7 shows the individual hazards in this group.

Table 6.6-7: Snow Group #5

Hazard ID #	Hazard Condition	Remarks
A39	Snow Pack and Snow Melt	-
A44	Extreme Snow	This includes snow drift loading as well as uniform distribution.

Hazard ID #	Hazard Condition	Remarks
A3	Climate Change	This effect is included in the evaluation of hazards in Chapter 2.
A20	Extreme Meteorological Conditions	This effect duplicates A39 and A44 and so is not considered further.

The generic site envelope values for snow load are set based on the European Code BS EN 1991-1-3. The values of the snow load are evaluated in PCSR Chapter 2: Generic Site Envelope, Section 2.4.5. Further details on how these values have been derived can be found in the "Topic Report on Generic Site Envelope" [Ref-02].

This hazard group has the potential to cause plant effects in the following categories:

- Structural Load
- Cooling/Ventilation
- Cooling/UHS
- Power Supply

Structural Load
The extreme snow may result in extreme snow depth loading the roofs of buildings, including drifting patterns. The extreme snow loading the roof can impose structural loads on SSCs that are important to safety and, in the extreme, could lead to the SSCs failing to deliver their safety functions.

Cooling/Ventilation
The extreme snow may result in the blockage of the HVAC inlets which are installed on the civil structures. Thus, extreme snow can affect the ability of the HVAC system to provide sufficient ventilation and prevent failure of temperature sensitive equipment. Failure of the HVAC system to provide cooling could lead to failure of SSCs to deliver their safety function.

Cooling/UHS
The other effect of the extreme snow may be blockage of the water intake. The blockage of the water intake could impact UHS because amount of cooling water required for the heat removal system such as Residual Heat Removal System (RHR) may be affected by the water intake blockage.

Power Supply
The accumulation of snow on transmission lines might result in problem on the transmission network, e.g. failure of cables, structural supports and shorting of electrical connections.

(2) Hazards combinations with this group [Ref-04]

The combined hazards which are relevant to this hazard group have been evaluated in the "Topic Report on Combined External Hazards" [Ref-04]. As a result of the evaluation, effective combinations with this hazard group have been identified under CH ID # 48 and #49. These are discussed under Sections 6.6.7 and 6.6.8 respectively.

(3) General protection

Structural Load

In general, SSCs that are important to safety are protected from this hazard group by the civil structures in PCSR Chapter 10: Civil Works and Structures, Section 10.3.4. The civil structures which contain safety relevant SSCs are designed to provide protection against External Hazards and environmental conditions [HLSF 5-7: Functions to limit the effect of hazard], to support SSCs [HLSF 5-17: Function to provide structural support to SSCs] and to confine radioactive materials [HLSF 4-7: Functions to confine radioactive materials, shield radiation, and reduce radioactive release]. The design principles for how snow loading is applied to structural design are described in the "Basis of Safety case on Reactor Building Civil Design" [Ref-12].

Cooling/Ventilation

The snow drift height which is relevant to the blockage of HVAC inlets is not confirmed in the GDA phase because it highly depends on the local surroundings (e.g. strength of wind, air temperature, etc.). Thus, snow drift is considered in site specific stage and HVAC inlets will be properly designed to avoid blockage due to the snow. The HVAC systems maintain the building environment within appropriate parameters for temperature sensitive SSCs even if the air temperature is extreme [HLSF 5-18: Function to maintain internal building environment appropriate for SSCs]. The design principles for HVAC in GDA are described in PCSR Chapter 16: Auxiliary Systems, Section 16.5.

Cooling/UHS

The UHS is the principal means to provide sufficient cooling water to the RSW to dissipate the heat from the plant auxiliaries. Thus, [HLSF 5-2: Supporting functions especially important to safety] is linked to this hazard group. The UHS is designed to provide an adequate source of cooling water which is available at all times for reactor operation, shutdown cooling and for accident mitigation. The detail is described in PCSR Chapter 16: Auxiliary Systems, Section 16.3.

Power Supply

The export electrical systems of the UK ABWR are designed to protect against failure due to snow accumulation. The design principle of Electrical Power Supplies is described in PCSR Chapter 15: Electrical Power Supplies. The safety claim against External Hazards is presented in Section 15.3.

6.6.6 Electromagnetic Interference (EMI)

(1) Hazard definition
EMI can cause disturbances that affect electrical systems by interrupting, obstructing or degrading their performance. Table 6.6-8 shows the individual hazards in this group. EMI can originate from both natural sources (e.g., lightning and solar flares) and artificial sources (i.e., communication systems). Solar EMI, which is one of the natural originated EMI sources, is considered to be of significant risk to the National Grid. The network absorbs Electromagnetic Pulse (EMP) and this can give rise to a voltage/current spike which could lead to failure or shutdown of key transformers and switchyards in the national grid, leading to wide scale power outages. The impact of Solar EMI on nuclear power plant would be similar to a lightning strike in the switchyard or on the power lines connected directly to the nuclear power plant. The switchyard and generator breakers are designed to disconnect the power plant from these potential surges and provide protection from these events. A Direct strike of the lightning to R/B or any Safety Class 1 buildings may result in the structural load.

EMI originating from artificial sources is likely to change over the lifespan of the plant due to advancement in technology. The assessment of this effect has been deferred to site specific stage. A43: Solar flares, D8: Electromagnetic pulse and D27: Radio-frequency interference are grouped into D7: Electromagnetic Interference (EMI).

Table 6.6-8: EMI Group #6

Hazard ID #	Hazard Condition	Remarks
A17	Lightning	-
D7	Electromagnetic Interference (EMI)	-

(2) Hazards combinations within the group [Ref-04]
The combined hazards which are relevant to this hazard group have been evaluated in the "Topic Report on Combined External Hazards" [Ref-04]. As a result of the evaluation, effective combinations with this hazard group are screened out.

(3) Plant effects in this hazard group and general protection
As a result of the above discussion, the plant effect related to this hazard group is identified as follows:

- Structural Load
- Electric

EMI can cause disturbances that affect C&I system by interrupting, obstructing or degrading their performance. Regarding EMI effect, the relevant HLSFs are reviewed in the table on Appendix A1 of PCSR Chapter 14: Control and Instrumentation for C&I and Appendix A of PCSR Chapter 15:

Electrical Power Supplies for Electrical Power Supplies. The electrical system will be designed to be robust to External Hazards. The design principles for the C&I systems and the Electrical Power Supplies can be found in PCSR Chapter 14: Control and Instrumentation and PCSR Chapter 15: Electrical Power Supplies. The lightning protection strategy to protect structures is described in "Topic Report on Lightning Protection Strategy" [Ref-17]. The walls and doors are shielded to prevent from artificial EMI

6.6.7 Sea or River Water Temperature

(1) Hazard definition and plant effect in this hazard group
Hazard Group #7 covers extreme sea or river water temperature at generic UK site. Table 6.6-9 shows the individual hazards in this group.

Table 6.6-9: Sea or River Water Temperature Group #7

Hazard ID #	Hazard Condition	Remarks
A32	Temperature Extremes (Sea / River)	-
A3	Climate Change	This effect is included in the evaluation of hazards in Chapter 2.
A20	Extreme Meteorological Conditions	This effect duplicates A32 and so is not considered further.

The values of the extreme sea water temperature are derived in PCSR Chapter 2: Generic Site Envelope", Section 2.4.7. Further details on how these values have been justified can be found in the "Topic Report on Generic Site Envelope" [Ref-02].

This hazard group has the potential to cause plant effect in the following category:

- Cooling/UHS

Cooling/UHS
Sea is one of the primary candidate UHS of UK ABWR. Thus, the extremely high sea water temperature may cause reduction in the effectiveness of UHS.

(2) Hazards combinations with this group [Ref-04]
The combined hazards to be considered in this hazard group are shown in Table 6.6-10. Snowmelt sometimes may affect low sea water temperature, and it may be possible that sheets of ice gather at the intake of the water. The blockage of the water intake could impact the UHS because the flowrate of cooling water required for heat removal systems, such as RHR, may be affected by the water intake blockage.

Table 6.6-10: Combined Hazards with Sea or River Water Temperature Group #7

CH ID #	Hazard 1	Hazard 2	CH Categorisation
48	Snow	Sea or River Water Temperature	II

(3) General protection

Cooling/UHS

The UHS is designed to provide an adequate source of cooling water which is available at all times for reactor operation, shutdown cooling and for accident mitigation. The cooling water systems such as RCW and RSW and the heat removal systems including RHR are also designed based on this minimum and maximum cooling water temperature for the UHS. The detail is described in PCSR Chapter 16: Auxiliary Systems, Section 16.3 .

6.6.8 External Flooding

(1) Hazard definition

Hazard Group #8 covers extreme external flooding at generic UK site. Table 6.6-11 shows the individual hazards in this group. External flooding is considered as flooding from a local water body such as the sea, a lake or a river. This can result from tidal effects, storm surge, upstream dam failures, wave effect and local intense precipitation. Groundwater will be also considered in this event. Coastal flooding is usually a result of a combination of different factors such as sea water levels, storm surge, tides and tsunami. Storm surges are short-lived local increases in water level above that of the tide and are driven by wind and atmospheric pressure gradients. Some of these effects greatly depend on the site location and local topography.

In this hazard group, C15: Dam failure and D26: Pipeline Accident (Gas, Oil, Water, etc.) are included since facilities such as dams or large pipeline may exist very close to the plant. However, the site specific External Hazards assessment must confirm this.

The safety of nuclear power plants can be seriously affected by flooding. The external flooding poses potential failure of structures, systems and components by the infiltration of water into internal areas of the plant. The local intense precipitation may result in damage of the roofs of buildings. This effect is considered as structural load. The heavy precipitation on site may also lead to flooding of the site.

The external flood level and its occurrence frequency is highly site specific since determination of the potential flooding sources depends on the local surroundings and topography. Thus, the design basis flood level and credible beyond design basis flood level are site-dependent. Under this situation, exact design margin for each postulated flooding condition is reviewed based on allowable relative height of external flood level [Ref-18].

In case of extreme external flood conditions, water from pluvial/fluvial sources may affect the nuclear island. When the external flood level is higher than Heat Exchanger Building (Hx/B) foundation level, water may flow into Hx/B through opening on the outer wall of Hx/B, and then waterproof area inside Hx/B may be submerged. In this case, RSW pump may fail to function immediately and the site may lose the UHS function. When the external flood level is higher than the foundation of the transformer level, the transformer facility may fail its function immediately. This may result in loss of power supply from off-site power and EDGs.

Table 6.6-11: External Flooding Group #8

Hazard ID #	Hazard Condition	Remarks
A26	Low / High Seawater Level	-
A29	Storm Surge	-
B21	Tsunami	-
C3	Groundwater	-
C4	High Tide, High Lake Level, or High River Stage	-
C9	Tidal Effects (Flooding)	-
C11	Waves	-
A22	Rainfall (Extreme) and Intense Precipitation	-
C15	Dam Failure	To be confirmed in site specific stage
D26	Pipeline Accident (Gas, Oil, Water, etc.)	To be confirmed in site specific stage
A3	Climate Change	This effect is included in the evaluation of hazards in Chapter 2.
A20	Extreme Meteorological Conditions	This effect duplicates the above and so is not considered further.

(2) Hazards combinations with this group [Ref-04]
The combined hazards to be considered in this hazard group are shown in Table 6.6-12. The redundancy of UK ABWR against external flooding is considered both from sea water inundation

and from heavy precipitation exceeding the drainage capacity. For each, the worst credible event for those hazards will be considered. These combined hazards may result in an increase of the external flood level which could lead to structural load, loss of the UHS, loss of the power supply and plant flooding.

Table 6.6-12: Combined Hazards with External Flooding Group #8

CH ID#	Hazard 1	Hazard 2	CH Category
19	Wind	External Flooding	I
30	Rainfall and Ice	External Flooding	I
49	Snow	External Flooding	I
132	Low / High Seawater Level	Storm Surge	I
133	Low / High Seawater Level	Tidal Effects (Flooding)	I
141	Storm Surge	Groundwater	I
143	Storm Surge	Dam Failure	I/III
144	Storm Surge	Pipeline Accident (Gas, Oil, Water, etc.)	I/III
148	Tidal Effects (Flooding)	Dam Failure	I/III
152	Waves	Dam Failure	I/III
153	Waves	Pipeline Accident (Gas, Oil, Water, etc.)	I/III
154	Groundwater	High Tide, High Lake Level, or High River Stage	I/III
155	Groundwater	Dam Failure	I/III
156	Groundwater	Pipeline Accident (Gas, Oil, Water, etc.)	I/III
158	High Tide, High Lake Level, or High River Stage	Pipeline Accident (Gas, Oil, Water, etc.)	I/III
159	Dam Failure	Pipeline Accident (Gas, Oil, Water, etc.)	I/III

(3) Plant effects in this hazard group and general protection
As a result of the above discussion, the plant effect related to this hazard group is identified as follows:

- Structural Load
- Power Supply
- Plant flooding

The UK ABWR civil structures have the capacity to withstand the forces from external flood load and provide protection for the SSCs which are installed inside safety related buildings, thus the following HLSFs ([HLSF 4-7: Functions to confine radioactive materials, shield radiation, and reduce radioactive release], [HLSF 5-7: Functions to limit the effect of hazard], [HLSF 5-17: Function to provide structural support to SSCs], [HLSF 2-4: Function to cool spent fuel outside the reactor coolant system]) are linked to this wind hazard group. The design principles for the civil structures in GDA are described in PCSR Chapter 10: Civil Works and Structures.

When the external flood level is higher than the foundation of the transformer level, the site may lose off-site power resulting in the LOOP. In case that the external flood level is higher than Hx/B foundation level, water may flow into Hx/B through the opening on the outer wall of Hx/B, and then waterproof area inside Hx/B may be submerged resulting in the LUHS. Thus, it may be effective to implement appropriate water-sealing or elevation of the Hx/B and Transformer Bays for prevention of these initiating events (LOOP and LUHS) when the platform of a certain candidate site does not have enough margin against external flood level [HLSF 5-7: Functions to limit the effect of hazard].

UK ABWR will be designed based on (a) ‘dry site’ conditions where all items important to safety will be constructed above the level of the design basis flood and drainage system installed and/or (b) ‘permanent external barriers’ whose structural integrity is taken that appropriate design bases against External Hazard load, which is mentioned in IAEA SSG18 [Ref-19]. In the case that the permanent external barriers concept is applied, the structural integrity of the barriers should be considered for appropriate External Hazard loads (e.g. design basis seismic load) carefully. Standard details of measures (e.g. additional waterproof measure) are also proposed [Ref-20].

6.6.9 Seismic Activity

(1) Hazard definition
In this Section, the effects of a seismic event on the plant components are considered. The seismic event is treated in a different manner to the other External Hazards because all the components may be simultaneously affected by the seismic event.

Table 6.6-13 shows the individual hazards in this group. Evaluation conditions of B4, B36 and B37 are described in PCSR Chapter 2: Generic Site Envelope. The effects of B7 and B15 depend on the site condition. These effects are therefore considered in the site specific stage. The seismic design spectrum defined as input motion is described in Section 3 of “Supporting Document on Soil and Seismic Input for Generic Site Envelope” [Ref-21].

Table 6.6-13: Seismic Activity Group #9

Hazard ID #	Hazard Condition	Remarks
B16	Seismic Activity (Earthquake)	Described in Section 3 of [Ref-21]
B4	Dynamic Compaction (Earthquakes)	Described in Section 2.4.9 of PCSR Chapter 2: Generic Site Envelope.
B7	Geological Faults	This effect is considered in the site specific stage.
B36	Minimum Shear Wave Velocity	Described in Section 2 of [Ref-21]
B37	Minimum Static Bearing Capacity	Described in Section 2.4.9 PCSR Chapter 2: Generic Site Envelope.
B15	Liquefaction (Earthquake)	This effect is considered in the site specific stage.

(2) Hazards combinations within the group [Ref-04]
The combined hazards to be considered in this hazard group are shown in Table 6.6-14 below.

Table 6.6-14: Combined Hazards with Seismic Activity Group #9

CH ID#	Hazard 1	Hazard 2	CH Category
71	External Flooding	Seismic Activity (Earthquake)	I
77	Seismic Activity (Earthquake)	Loss of Off-Site Power (LOOP)	I
161	Seismic Activity (Earthquake)	Geological Faults	I

The beyond design basis assessment includes the combination event consisting of seismic activity, external flooding and LOOP. This is described under Fukushima accident countermeasures in PCSR Chapter 26: Beyond Design Basis and Severe Accident Analysis.

(3) General Protection

Seismic loads on SSCs are evaluated by performing seismic analysis using ground motion defined in PCSR Chapter 2: General Site Envelope. Each SSC is classified into seismic category. Details are described in PCSR Chapter 5: General Design Aspects, and SSCs are designed to withstand seismic loads corresponding to seismic category of each SSC.

6.6.10 Loss of Off-Site Power

(1) Hazard definition and plant effect in this hazard group

Hazard Group #10 covers Loss of Off-Site Power (LOOP) at the generic UK site. Table 6.6-15 shows the individual hazard in this group.

Table 6.6-15: LOOP Group #10

Hazard ID #	Hazard Condition	Remarks
D19	LOOP	Short Term LOOP is bounding (Chapter 24)

The LOOP duration for the UK ABWR generic design is presented in the PCSR Chapter 2: Generic Site Envelope, Section 2.4.10. Further details on how these values have been derived can be found in the “Topic Report on Generic Site Envelope” [Ref-02]. The Fault Studies assessment is given in PCSR Chapter 24: Design Basis Analysis, Section 24.7.3 and this concludes that Short Term LOOP is the bounding fault and is a frequent design basis fault.

This hazard group has the potential to cause plant effect in the following category:

- Power Supply

Power Supply

LOOP is defined in PCSR Chapter 2: Generic Site Envelope, Section 2.4.10 as a loss of electrical power from the off-site electrical power grid that causes the emergency diesel generators to start and supply power to the plant. The causes of this are either because of a failure of the external grid or of the on-site power facilities. PCSR Chapter 24: Design Basis Analysis, Section 24.7.3 provides a description of the plant normal response for the Short Term LOOP scenario.

Potential External Hazards that could be initiating events for this hazard are those which could affect the export transmission lines or the on-site emergency power supplies, e.g. seismic, high winds or external flooding. However, the protection provided by the ABWR against LOOP will include these effects.

(2) Hazards combinations within the group [Ref-04]

The effects of the potential consequences of meteorological hazards such as wind, snow, precipitation resulting in LOOP are identified in the Table A-1 of Appendix A in the "Topic Report on Combined External Hazards" [Ref-04]. The effects of these hazards on the SSCs providing the emergency electrical supply in the event of LOOP are already included as DB events for those SSCs and therefore the combination of LOOP with wind, snow, etc. is included.

(3) General protection

Power Supply

LOOP could lead to the risk of common cause failure for systems important to safety, such as the emergency power supply systems. Main protection against a LOOP is the introduction of Alternating Current (AC) power supply via Emergency Diesel Generators (EDGs). The design for the UK ABWR consists of three divisions of Class 1 EDGs. The EDGs supply power to secure the high level safety in the event of LOOP as described in PCSR Chapter 15: Electrical Power Supplies, Section 15.4.5. The UK ABWR Electrical Power System provides many high level safety functions as shown in Appendix A of PCSR Chapter 15: Electrical Power Supplies. However, the key ones for External Hazards are [HLSF 5-2: Supporting functions especially important to safety] and [HLSF 5-7: Functions to limit the effect of hazard].

The event of LOOP and common cause failure of all three EDGs occurring simultaneously is known as station blackout (SBO, see [Ref-22] for detail) and is considered as an infrequent Design Basis Fault (refer to PCSR Chapter 24: Design Basis Analysis, Section 24.9.2 and 24.9.3). In this case, the Backup Building Generator (BBG) can supply backup power to cooling systems. The BBG supplies power to diverse provisions which are necessary for reactor safety in the event of a LOOP [HLSF 5-3: Function of alternative supporting system]. Therefore the SBO event will not occur due to loss of EDG function as long as the BBG is available and the HLSFs will be maintained. For defence in depth the Diverse Additional Generator (DAG) is also capable of supplying the RHR (Residual Heat Removal system) in one of the Class 1 divisions (refer to PCSR Chapter 15: Electrical Power Supplies, Section 15.4.7).

The main loads connected to each of EDG and BBG are described in PCSR Chapter 15: Electrical Power Supplies, Section 15.4. The Fault Schedule regarding the SBO due to LOOP and the protection against it are described in PCSR Chapter 24: Design Basis Analysis and the "Topic Report on Fault Assessment" [Ref-05].

The EDG Buildings have robust concrete external walls and roofs, designed to withstand the GDA External Hazard groups including the seismic category 1 hazard (refer to PCSR Chapter 10: Civil Works and Structures). Therefore, there is sufficient protection such that common cause failure of the EDGs from External Hazards is not credible. However, the BBGs are sited in the B/B which is physically separated from the power island, both horizontally and vertically. This ensures the B/B is not affected by the same External Hazards such as flooding, missiles and fires as the main plant buildings.

6.6.11 Aircraft Impact

(1) Hazard definition and plant effect in this hazard group

The potential hazard of aircraft impact is a man-made hazard occurs in from the two sources below.

- Accidental aircraft impact – the assessment strategy is summarised in "Accidental AIA Strategy Document" [Ref-23].
- Malicious aircraft impact – the assessment strategy is summarised in "Malicious AIA Strategy Document" [Ref-38]

Table 6.6-16 shows the individual hazards in this group. Malicious aircraft impact is considered in the UK ABWR design. The following direct and indirect effects of an aircraft crash, whatever the cause, are considered:

- Effects of direct and secondary impacts on mechanical resistance of safety structures and systems required to bring and maintain the plant in a safe state after airplane crash. These effects are considered as structural load. In case that the HVAC system is damaged, the ability of the HVAC system may be reduced. The electrical system may be damaged by the aircraft impact.
- Effects of vibrations on safety structures and systems required to bring and maintain the plant in a safe state after airplane crash. These effects are also considered as structural load.
- Effects of combustion and/or explosion of airplane fuel on the integrity of the necessary structures and on the systems required to bring and maintain the plant in a safe state after airplane crash. These effects are considered as thermal load.

Table 6.6-16: Aircraft Impact Group #11

Hazard ID #	Hazard Condition	Remarks
D1	Aircraft Impact (Accidental)	Accidental AI is BDB. Malicious AI is included in design measures.

(2) Hazards combinations within the group [Ref-04]
The effects of the potential consequences of aircraft impact for the following three hazards are identified in the "Topic Report of Combined External Hazards" [Ref-04] and are considered as the consequence of aircraft impact:

- Direct impact of aircraft corresponding to Hazard group #13: External Missile
- External and internal fire with deflagration corresponding to Hazard group #12: External Fire and #14: External Explosion
- Shock effect on electrical equipment corresponding to Hazard group #10: LOOP

(3) General protection

For accidental aircraft impact, the crash frequency is calculated as the total predicted frequency of aircraft crash, including helicopters and other airborne vehicles, on or near any facility housing structures, systems and components important to review the need to develop design assessments/ undertake protective measures. The crash frequency of each building within GDA scope has been calculated as lower than 10^{-5} yr^{-1}, thus accidental aircraft impacts are treated as beyond design basis event [Ref-23].

The hazard from malicious aircraft impact is a beyond design basis event, but in accordance with UK regulatory expectations, the UK ABWR civil structures is designed to provide sufficient protection so that the reactor can be safely shut down. The objective of this protection is to prevent core melt and therefore not to cause more than a minor radiological impact as noted in the WENRA RHWG report [Ref-06]. The civil structures are designed to withstand the physical damage due to the aircraft impact. This is described in PCSR Chapter 10: Civil Works and Structures, Section 10.6.3. Safety functions required to bring and maintain the plant in a safe state after such a crash are designed accordingly and protected adequately by the civil structures.

6.6.12 External Fire

(1) Hazard definition and plant effect in this hazard group

Hazard Group #12 covers external fire at generic UK site. Table 6.6-17 shows the individual hazards in this group. Any combustible substance that can reach an appropriate fuel-air ratio is a potential source of external fire hazard. The hazard sources of external fire are considered to be external industrial installations including stockpiles of petroleum products and other flammable liquid and gaseous chemicals as well as flammable materials, natural sources including bushes and forests and transport sources such as road, railway and ships.

Table 6.6-17: External Fire Group #12

Hazard ID #	Hazard Condition	Remarks
D2	Adjacent Installations, Transport Activities (Missiles, Gas Clouds, Explosions, etc.)	-
D15	Fire	-
D34	Toxic Gas (and Asphyxiants)	-

Screening Distance Value (SDV), where the hazard poses a credible threat to nuclear safety, is determined using a conservative approach. The value of the SDV for this hazard group is derived in the PCSR Chapter 2: Generic Site Envelope, Section 2.4.12. Further detail on how this value has been justified can be found in the "Support Document on Manmade Hazard for Generic Site Envelope" [Ref-24].

This hazard group has the potential to cause plant effects in the following categories:

- Cooling/Ventilation
- Thermal Load

Cooling/Ventilation
Smoke generated by the extreme fire can affect the performance of the HVAC system and, in the extreme, could lead to the SSCs failing to deliver their safety functions.

Thermal Load
Extreme fire can impose thermal loads on SSCs that are important to safety and, in the extreme, could lead to the SSCs failing to deliver their safety functions.

(2) Hazards combinations with this group [Ref-04]
The combined hazards to be considered in this hazard group are shown in Table 6.6-18. One of the sources of Toxic Gases and Asphyxiants is fires; however, pipe accidents leading to gas leakages should be taken into consideration. Adjacent installations, transport activities in the vicinity can lead to release of Toxic Gases and Asphyxiants and impact plant. As described in Hazard Group #18: Industrial Environment, External Hazard from industrial sites is highly specific to the site and site selection criteria should prevent a site being selected with a risk from neighbouring industrial accidents. Therefore, this hazard is screened for GDA assuming that the event cannot occur close enough to the site to affect the plant (i.e. screening distance value: SDV). At site specific stage, the potential sources of hazard from industrial facilities around the site will be examined. If there are credible sources within the SDV, the hazard characterisation will be investigated and considered on the UK ABWR design.

Table 6.6-18: Combined Hazards with External Fire Group #12

CH ID #	Hazard 1	Hazard 2	CH Categorisation
175	Fire	Adjacent Installations, Transport Activities (Missiles, Gas Clouds, Explosions, etc.)	I
176	Fire	Toxic Gas (and Asphyxiants)	I
177	Adjacent Installations, Transport Activities (Missiles, Gas Clouds, Explosions, etc.)	Toxic Gas (and Asphyxiants)	I

(3) General protection

Cooling/Ventilation

Filters are installed in the HVAC systems to avoid the effect of the smoke generated by potential external fire, as described in Section 16.5 of PCSR Chapter 16: Auxiliary Systems. The control rooms (MCR and B/B ECR) both have independent HVAC systems to protect the operators inside. Since the behaviour of the smoke depends on the site environment such as topography and prevailing wind, the detailed assessment will be performed in the site specific stage.

Thermal Load

The civil structures which contain safety relevant SSCs are designed to provide protection against External Hazards and environmental conditions [HLSF 5-7: Functions to limit the effect of hazard] and support SSCs [HLSF 5-17: Function to provide structural support to SSCs].

Thermal radiation from external fire is assumed to be limited as a safe distance from the plant boundary to any safety significant buildings or equipment will be maintained. HVAC system will contain filters for removal of dust in PCSR Chapter 16: Auxiliary Systems, Section 16.5 , and will maintain the required cooling/heating functions. The design principles for the civil structures in GDA are described in PCSR Chapter 10: Civil Works and Structures.

6.6.13 External Missile

(1) Hazard definition and plant effect in this hazard group

Hazard Group #13 covers external missiles at generic UK site. Table 6.6-19 shows the individual hazards in this group. External missile is classified into two categories; natural missile and man-made missile. Natural missile is defined as windblown debris generated by strong wind including tornadoes. High horizontal wind-speed together with its characteristic but lesser vertical speeds may produce unusual and dangerous airborne missiles. Man-made missile is produced as a secondary consequence of nearby explosions. Industrial environments contain many potential sources of missiles; in a generic sense, any high speed rotating machinery can destructively malfunction and emit high energy projectiles of significant mass, pressure vessels or pressurised pipe work can fail explosively and emit missiles in the form of fragments, explosions can energetically impel objects to generate missile hazards.

Small missiles (e.g. idealised as solid steel spheres) generated by the high wind could enter the building through openings such as HVAC vents. To prevent this, the openings are covered with grating which will prevent the small missiles.

Table 6.6-19: External Missile Group #13

Hazard ID #	Hazard Condition	Remarks
D23	Missiles from Military Activities	-
D24	Missiles (Turbines, Bottles BLEVE)	-
A38	Windblown Debris	-
D2	Adjacent Installations, Transport Activities (Missiles, Gas Clouds, Explosions, etc.)	

For man-made missile, Screening Distance Value (SDV), where the hazard poses a credible threat to nuclear safety, is determined using a conservative approach. The value of the SDV for this hazard group can be found in PCSR Chapter 2: Generic Site Envelope, Section 2.4.12. Further detail on how this value have been derived can be found in the "Support Document on Manmade Hazard for Generic Site Envelope" [Ref-24].

This hazard has the potential to cause a plant effect in the following category:

- Structural Load

Structural Load
The impact of the missiles can impose structural loads on SSCs that are important to safety and, in the extreme, could lead to the SSCs failing to deliver their safety functions.

(2) Hazards combinations within the group [Ref-04]
The combined hazards to be considered in this hazard group are shown in Table 6.6-20. Flying debris generated by strong wind including tornado and the tropical storms should be considered in UK ABWR design.

Table 6.6-20: Combined Hazards with External Missile Group #13

CH ID #	Hazard 1	Hazard 2	CH Categorisation
24	Wind	External Missile	I

(3) General protection
Structural Load
In general, SSCs are protected from this hazard group by the civil structures. The civil structures which contain safety relevant SSCs are designed to provide protection against External Hazards and environmental conditions [HLSF 5-7: Functions to limit the effect of hazard], to support SSCs

[HLSF 5-17: Function to provide structural support to SSCs] and to confine radioactive materials [HLSF 4-7: Functions to confine radioactive materials, shield radiation, and reduce radioactive release]. For spent fuel pool (SFP), the reactor building forms SFP together with stainless liner and cooling systems, to enable fuel cooling outside the reactor coolant system [HLSF 2-4: Function to cool spent fuel outside the reactor coolant system]. The design principles for the civil structures in GDA are described in PCSR Chapter 10: Civil Works and Structures, Section 10.3.4 and "Basis of Safety case on Reactor Building Civil Design" [Ref-12]. In addition, openings such as HVAC vents will be provided with grating that will prevent small missiles (e.g. idealised as solid steel spheres) from passing through the opening and damaging the SSCs. This will be confirmed in site specific stage based on the site environmental conditions.

For man-made missile, SDV where the hazard poses a credible threat to nuclear safety is determined using a conservative approach [Ref-24]. The hazard sources in the vicinity of the candidate site that fall outside the SDV are dismissed. For the remaining hazard sources, the occurrence frequency and its load are assessed.

6.6.14 External Explosion

(1) Hazard definition and plant effect in this hazard group
Hazard Group #14 covers external explosion at generic UK site. Table 6.6-21 shows the individual hazard in this group. Any combustible substance that can reach an appropriate fuel-air ratio is a potential source of external explosion hazard. Missiles generated from external explosions should be considered in this hazards group.

Table 6.6-21: External Explosion Group #14

Hazard ID #	Hazard Condition	Remarks
D13	External Explosions (Blast Waves, Missiles)	-

SDV where the hazard poses a credible threat to nuclear safety is determined using a conservative approach. The value of the SDV for this hazard group can be found in the PCSR Chapter 2: Generic Site Envelope, Section 2.4.12. Further detail on how this value have been derived can be found in the "Support Document on Manmade Hazard for Generic Site Envelope" [Ref-24].

This hazard group has the potential to cause a plant effect in the following category:

- Structural Load
- Cooling/Ventilation
- Thermal Load

Structural Load

An explosion in air is accompanied with a very rapid rise in pressure and the formation of a blast wave. Large overpressures may injure people and damage equipment and buildings. An explosion can take the form of a deflagration, which generates moderate pressures, heat or fire, or a detonation, and which generates high near field pressures and associated drag loading but usually without significant thermal effects.

Cooling/Ventilation

An explosion wave may propagate to intakes of the HVAC. The HVAC components might be damaged by the explosion wave.

Thermal Load

Fire due to the explosion can impose thermal loads on SSCs that are important to safety and, in the extreme, could lead to the SSCs failing to deliver their safety functions.

(2) Hazards combinations within the group [Ref-04]

Combined hazards with this group have been screened out in the "Topic Report on Combined External Hazards" [Ref-04] and so are not considered further in GDA. The SDV derived for external explosion mean that this hazard is eliminated provided this SDV is maintained on the site. Explosion due to aircraft impact is considered bounding for the purposes of GDA.

(3) General protection

Structural Load

In general, SSCs that are important to safety are protected from this hazard group by the civil structures. The civil structures which contain safety relevant SSCs are designed to provide protection against External Hazards and environmental conditions [HLSF 5-7: Functions to limit the effect of hazard], to support SSCs [HLSF 5-17: Function to provide structural support to SSCs] and to confine radioactive materials [HLSF 4-7: Functions to confine radioactive materials, shield radiation, and reduce radioactive release]. For spent fuel pool (SFP), the reactor building forms SFP together with stainless liner and cooling systems, to enable fuel cooling outside the reactor coolant system [HLSF 2-4: Function to cool spent fuel outside the reactor coolant system].

The design principles for the civil structures in GDA are described in PCSR Chapter 10: Civil Works and Structures, Section 10.3.4 and "Basis of Safety case on Reactor Building Civil Design" [Ref-12]. The barrier substantiation is justified through the Internal Hazards Assessment. Refer to PCSR Chapter 7: Internal Hazards for claims on barriers.

Cooling/Ventilation

SDV where the hazard poses a credible threat to nuclear safety is determined using a conservative approach [Ref-18]. The hazard sources in the vicinity of the candidate site that fall outside the SDV are dismissed. For the remaining hazard sources, the occurrence frequency and its load are assessed.

Thermal Load

The civil structures which contain safety relevant SSCs are designed to provide protection against External Hazards and environmental conditions [HLSF 5-7: Functions to limit the effect of hazard] and support SSCs [HLSF 5-17: Function to provide structural support to SSCs].

6.7 Margin Evaluation for Beyond Design Basis Events

The UK ABWR design needs to provide adequate resilience to beyond design basis (BDB) External Hazards as far as practicable within the GDA scope. This Section provides information on the margin evaluation for the Beyond Design Basis (BDB) External Hazards in the GDA phase.

The ONR produced the UK regulatory recommendations following the Fukushima Daiichi accident. The key lessons learnt were about External Hazards protection. Hitachi-GE has assessed the applicability of these recommendations to the UK ABWR design in the report “Applicability of the HM Chief Inspector's Recommendations and ONR's Stress Test Findings to UK ABWR Design” [Ref-29]. Extreme flooding of a nuclear site has been identified as one of the major lessons learned; this is discussed below along with other BDB measures.

(1) Flooding

As described in Section 6.6.8, External Flooding might affect the safety of nuclear power plants (e.g. Fukushima accident). External Flooding may result from a number of potential causes (e.g. Tsunami, extreme rain, high river or tidal condition and so on) which depend on the site surroundings and topography. Thus, the DB and BDB external flood levels are highly site specific. Under this condition, the following evaluations have been performed [Ref-18]. These evaluations have been based on the several assumptions which are summarised in the Attachment 9 of [Ref-31]. It should be noted that these assumptions need to be confirmed at the site specific stage.

1) Identification of SSCs for extreme external flooding event
   Long-term LOOP and LUHS are assumed to be caused by extreme external flooding. The basic management strategy, including Fukushima countermeasures, is for the reactor to remain in a stable condition in a hot shutdown state following these fault conditions.
2) Review of potential cliff edge effects for external flooding based on the event tree
   Based on SSCs derived in 1), success paths (scenarios) for extreme external flooding have been identified. The allowable relative height of the flooding has been identified for each derived scenario.
3) BDB margin evaluation and ALARP demonstration for extreme external flooding
   The design margin for each postulated flooding condition for SSCs has been reviewed based on the allowable relative height of the flooding.

As a conclusion of [Ref-18], UK ABWR has effective success paths for safe shutdown in the event of extreme external flooding. The detail design information for flood protection will be confirmed in the site specific stage. UK ABWR will be designed based on (a) ‘dry site’ conditions where all items important to safety are constructed above the level of the design basis flood and drainage system installed and/or (b) ‘permanent external barriers’ will be provided as described in IAEA SSG18 [Ref-19]. In the case that permanent external barriers are required, the structural integrity of the barriers should be designed for appropriate External Hazard loads (e.g. design basis seismic load).

Standard details of measures (e.g. additional waterproof measure) have been considered in the GDA design [Ref-20].

(2) Civil Structures

For most External Hazards, of course including Seismic hazard and External Missile hazard by a tornado, the safety functions of UK ABWR are protected by the civil structures. Thus, BDB design margin and the cliff edge effect on the civil structures have been evaluated in [Ref-25]. As a conclusion of [Ref-25], the civil structures of UK ABWR have sufficient margin against the design basis load in GDA, and there are no disproportionate increases in risk due to BDB External Hazards. In the site specific stage, the evaluation of the remaining civil structures will be performed.

(3) HVAC Design

As described in Section 6.6.1, air temperature and humidity are the dependency parameters of enthalpy which is one of the key factors for HVAC design. Thus, extreme air temperature and humidity variation may affect the ability of the HVAC system to provide sufficient ventilation and prevent failure of temperature sensitive equipment. BDB design margin of the HVAC system is evaluated in [Ref-26] and [Ref-27]. As a conclusion of these documents, the HVAC system of UK ABWR has sufficient design margin against BDB event.

(4) Aircraft Impact Protection

Accidental Aircraft Impact has been demonstrated to be a beyond design basis event [Ref-01]. However, as required by the UK regulator, malicious aircraft impact is included in the design of civil structures which need to act as barriers to such impacts. The aircraft impact assessment (AIA) for GDA has demonstrated the risk of a severe accident due to aircraft impact has been reduced to ALARP. Refer to PCSR Chapter 10: Civil Works and Structures, Section 10.6.3.

6.8 Assumptions, Limits and Conditions for Operation

6.8.1 Purpose

One purpose of this generic PCSR is to identify constraints that must be applied by a future licensee of a UK ABWR plant to ensure safety during normal operation, fault and accident conditions. This applies to the scope of GDA, and primarily Class 1 and Class 2 SSCs. Some of these constraints are maximum or minimum limits on the values of system parameters, such as pressure or temperature, whilst others are conditional, such as prohibiting certain operational states or requiring a minimum level of availability of specified equipment. The LCOs, along with corresponding surveillance requirements, define the corrective actions (measures) to follow when the LCOs are not met. They are collectively described in this GDA PCSR as Assumptions, Limits and Conditions for Operation (LCOs).

The general principles for the identification of Assumptions, Limits and Conditions for Operation (LCOs) related to the systems, structures and components (SSCs) within the scope of this chapter are described in PCSR Chapter 4: Safety Management throughout Plant Lifecycle, Section 4.12.

This Section provides a summary of the Assumptions and LCOs that apply specifically to the External Hazards aspects of the generic UK ABWR design.

6.8.2 LCOs

To ensure that the facility can be operated within safety limits and the design requirements from the GDA safety case, it is necessary to define appropriate LCOs. The LCOs, along with corresponding surveillance requirements, define the corrective actions (measures) to follow when the LCOs are not met. These form the Generic Technical Specification (GTS) [Ref-30] and are specified in more detail within the appropriate systems chapters. LCOs depending on site condition require further consideration in the site specific stage.

This Section considers the LCOs that apply specifically to the External Hazards protection of the generic UK ABWR design reference. The limits associated with the plant are generally the design criteria applied to ensure that the plant fulfils its safety functions during normal operation. In order to maintain the validity of the External Hazards safety case, it may be necessary to take action if one or more of these parameters exceed the normal condition envelope.

The relevant parameters for each hazard group are as follows:

- High and low air temperature and humidity levels.
- High wind speed.
- High rainfall and formation of ice.
- Low water levels in local water bodies, specifically if used as UHS.
  This includes notifications from the water supply companies.

- High standing snow depth and snow drifting
- Lightning storms or other meteorological effects that is the case for EMI.
- High and low water temperatures in local water bodies if used as UHS, or contributing to the UHS system.
- High flood level or emerging flood conditions adjacent to the site.
- Seismic event and magnitude.
- Changes in off-site power supply
- Changes in man-made activities in the local area, e.g. new factories, aeroplane flight activities.

The above should include notifications about predictions of extreme conditions from the relevant UK authorities, as well as on-site monitoring of the parameters.

The LCOs given within [Ref-30] that relate specifically to External Hazards are summarised below in Table 6.8-1. Appendix B of [Ref-30] provides background information on the bases of the LCOs. These are the significant LCOs for SSC design, other than the inherent requirements of the design basis according to safety class. Also it is assumed that the future licensee will use arrangements for checking SSCs following an External Hazards event occurring at the magnitude defined as the "inspection" level (refer to Assumption 15 in Section 6.8.3).

Table 6.8-1: List of LCOs from Generic Technical Specifications relevant to External Hazards

SSC/Function	Description of LCO Requirement
Secondary Containment – pressure boundary	An LCO requires the secondary containment to be OPERABLE.
Secondary Containment - HVAC system SGTS	An LCO requires two SGTS trains to be OPERABLE.
RCW System, RSW System and UHS	An LCO requires three division of RCW/RSW and UHS to be OPERABLE.
MCR HVAC	An LCO requires two divisions of the MCR HVAC Emergency Filter Trains to be OPERABLE.

6.8.3 Assumptions

A number of working assumptions are made to demonstrate that the protection against External Hazards will achieve all safety claims and that nuclear safety issues have been adequately considered in the GDA process.

The key working assumptions for the External Hazards safety case include:

- The hazard evaluation of hazard groups 1 to 14, carried out for the generic site envelope (GSE) will be repeated at site specific stage in order to utilise the historical records, current data and local conditions specific to that location to carry out extreme value analyses.
- The hazard evaluation of hazard groups 15 to 21 will be completed at site specific stage. These hazards are so dependent on the location and surroundings of a site and so were classified as Site Specific Hazard Groups in GDA.
- The GSE, which corresponds to hazard groups 1 to 14, includes characteristics, such as seismic hazard, extreme weather events and other External Hazard, 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.
- The flooding hazard cannot be evaluated at generic stage. Therefore GDA has provided a design which has a margin for a hypothetical beyond design flood. Flood levels will need to be evaluated based on the local surroundings, topography, etc. The actual margin provided beyond design basis will therefore be confirmed at site specific stage.
- The seismic hazard has been based on standardised soil conditions and input spectra (EUR). Therefore, the seismic analyses must be confirmed for the seismicity of the specific site and its locations. The beyond design basis earthquake has been set at 1.5 x DBE [Ref-25] and so provides a significant margin for the GDA design.
- The GDA provides protection from certain hazards via a SDV (screening distance value). This is an exclusion zone applied to man-made activities which could be a source of external fire, external missile and external explosion. Therefore, the site specific design must verify if potential sources of these hazards are within the SDV and address as appropriate.
- The generic site is based on one unit of UK ABWR and so protection from an adjacent unit is not included.
- The generic site is assumed to be a flat, level platform with sufficient space to provide the distance separation between buildings required for External Hazards protection, and to allow the Backup Building to be sited at a higher level than the rest of the site platform.
- The ground conditions on the site are assumed to have the required properties for the global stability of civil structures, or that ground improvement techniques can be used. (Refer to Assumption 8 in PCSR Chapter 10: Civil Works and Structures).
- The ground water level is assumed to be at ground level for GDA.

- The snow drift height will be considered in site specific stage because it highly depends on the local surroundings.

The assumptions for UK ABWR PSA which are related to the External Hazards can be found in the Attachment 9 of [Ref-31]. In addition, it is assumed that the future licensee will have site arrangements and procedures to take action in the following circumstances:

- Site arrangements to monitor the required parameters at appropriate frequencies, including UK national advance warning systems where relevant.
- Site arrangements to protect personnel from meteorological hazards outside of buildings e.g. high winds, ultra-violet rays, etc.
- Site arrangements to control vehicle movements, including road layouts, impact barriers, operator procedures and speed limits, to ensure vehicular impact is within the safety case.
- Site arrangements to set the “inspection values” of External Hazards, i.e. the magnitude of hazard which requires operators to carry out inspections, take actions or put appropriate planning in place.

6.9 Summary of ALARP Justification

6.9.1 Overview

This Section presents a high level overview of how the ALARP principle has been applied to the External Hazards safety case, and how this contributes to the overall ALARP argument for the UK ABWR.

Chapter 28: ALARP Evaluation presents the high level approach taken for demonstrating ALARP across all aspects of the design and operation. It presents an overview of how the UK ABWR design has evolved, further options that have been considered across all technical areas resulting in a number of design changes and how these contribute to the overall ALARP case. The approach to undertaking ALARP Assessment during GDA is described in the GDA ALARP Methodology [Ref-07] and Safety Case Development Manual [Ref-08].

Hitachi-GE has undertaken a comprehensive programme of work, within the scope of GDA, to demonstrate that the SSCs are designed in an appropriately conservative manner to ensure that the risks to safety from External Hazards are reduced to be as low as reasonably practicable. The demonstration starts with using an established Japanese design as the reference design. The ABWR has been built and operated successfully in Japan such that there is relevant operational experience and knowledge of performance of structures in real events, e.g. earthquakes of greater magnitude than would be experienced in the UK. The GDA design has identified additional options to reduce risks using UK relevant good practice and further ALARP studies that are required by the UK regulatory regime. The outcome of the ALARP studies has confirmed that safety is not unduly reliant on a small set of particular safety features.

The measures taken within the External Hazards topic are discussed below together with descriptions of the key studies which demonstrate that risks are reduced ALARP. Reference is made to the PCSR Chapter 5: General Design Aspects, which set down the design basis for nuclear safety, non-radiological and radiological environmental protection.

6.9.2 Classification of SSCs

The methodologies for the safety categorisation and classification, and seismic categorisation, of SSCs are described in the PCSR Chapter 5: General Design Aspects, Section 5.6 and in NSEDP Principle BP4.6 (Refer to NSEDP [Ref-39] for details). The magnitude of External Hazard loading is dependent on the safety classification of the SSC. The SSCs which act as barriers or physical separation will be designed to resist the magnitude of hazard required for the highest class of SSCs they protect [NSEDP Principle BP4.10]. This ensures that the SSCs have the appropriate withstand, with a margin of safety, to reduce risks ALARP.

6.9.3 Evaluation of External Hazards

The evaluation of External Hazards is described within Chapter 2: Generic Site Envelope of the GDA PCSR. The methods used to derive hazard values use relevant good practice and are sufficiently conservative to allow for uncertainties in the evaluation methods.

The listing of the individual External Hazards has been based on internationally recognised studies, including from regulatory bodies (refer to Section 6.3). Screening of these hazards has been carried out in accordance with NSEDP Principle BP4.7. Most External Hazards are those with a continuous frequency/severity hazard curve, rather than discrete frequency of occurrence. Therefore, after the credible hazard groups were identified by the review of standards, guidance and OPEX only one individual hazard was subsequently screened out at GDA stage. This is Group # 22, Extra-Terrestrial Objects such as meteorites which have a very low frequency of occurrence [Ref-01, Section 3.4].

6.9.4 Combination of External Hazards

The UK ABWR has developed the methodology for identifying credible combinations of individual External Hazards [Ref-04]. This is an emerging area following the Fukushima Daiichi Accident, and the worldwide nuclear industry focus on lessons learned. Therefore, the GDA External Hazards safety case includes consideration of recommendations from Japan’s domestic fleet. It also includes Hitachi-GE’s review of the UK Regulator’s stress tests, which is described in “Applicability of the HM Chief Inspector's Recommendations and ONR's Stress Test Findings to UK ABWR Design” [Ref-29].

6.9.5 Consideration of Site Plan

GDA is based on a generic site layout, or plot plan, which is described in the Figure 9.4-1 of PCSR Chapter 9: General Description of the unit (Facility). This is for a single unit ABWR, which is arranged in a cruciform. Positions of the other buildings are shown conceptually and are not intended to show final, exact locations of the structures.

The GDA safety case has included assessment of whether the risks from External Hazards can be reduced by changing the location of the buildings. These are described below.

(1) Location of Backup Building

The GDA safety case considers the Backup Building (B/B) to be sited at a higher level than the rest of the station to provide additional resilience against external flooding [Ref-18]. The B/B is also physically separated from the R/B by a sufficient horizontal distance such that there cannot be simultaneously affected by fire and impact type External Hazards. These measures reduce risks to safety functions, particularly in beyond design basis conditions, to ALARP levels.

(2) Location of EDG Buildings

The reference design for the emergency diesel generators (EDGs) placed them within the R/B because this provides advantages for seismic withstand and external fire, missile and explosion protection. Based on the ONR's requirements on the location of the EDGs in the UK ABWR design, Hitachi-GE has no other option than to relocate the EDGs outside of the R/B in the UK design to further reduce the risk from internal explosion and fire within the R/B further. As a result, Hitachi-GE has redesigned the layout of the R/B, and designed three additional seismically qualified, nuclear safety significant structures to house the three EDGs.

A multi-disciplinary, optioneering study was carried out to confirm the optimum locations of the EDGs. This considered External Hazards, Internal Hazards, overall nuclear safety, reliability, maintainability, construction and decommissioning and is described in the "Topic Report on EDG Relocation" [Ref-32]. This report justifies that the design change reduces risk to ALARP, as follows:

- Each EDG is segregated both from each other and from other primary and backup safety systems.
- Each EDG is located in its own substantial concrete building which protects the EDG from relevant internal/External Hazards. The EDG/Bs are seismic category 1.
- The locations of the EDG/B provided physical separation which reduces the risk of External Hazard groups 11 to 14 (Aircraft Impact, External Fire, External Missile, External Explosion) from simultaneously affecting two or more EDGs.

(3) Tunnels Optioneering study

A multi-disciplinary study was undertaken to determine the optimum solution for running the service connections between buildings e.g. electrical and piped mechanical services. The "Topic Report of the Service Connection between Buildings" [Ref-33] describes the study and provides justification that the use of service tunnels provides an ALARP solution for protection of these safety related services.

A separate but related optioneering study has been carried out on the accesses into service tunnels [Ref-34]. This concluded that access into the tunnels from the site yard areas was not preferable for External Hazard protection; it provides a potential route in for flooding. However, conventional safety aspects for inspection and maintenance access need to be carefully considered once the future licensee has defined the operational procedures. Also, as the final arrangement of the tunnels is so dependent on the site specific plot plan, these optioneering studies provide a basis for further consideration in the site specific stage.

6.9.6 Beyond Design Basis Events

The UK ABWR design has provided adequate resilience to beyond design basis (BDB) External Hazards. This is described in Section 6.7 of this chapter and the detailed justification is contained within the specific SSC documents.

(1) Flooding

Extreme flooding of a nuclear site has been identified as one of the major lessons learned from the Fukushima Daiichi Accident, particularly UK Regulatory finding IR-10 [Ref-29]. For the UK ABWR, the eight candidate sites are all coastal and so sea water inundation is considered to be the dominant risk. However, as sea water inundation can be exacerbated by maximum rainfall on land and the resulting flood levels are highly dependent on the site topography, the External Hazards safety case has carried out a BDB margin evaluation for external flood on GDA [Ref-18].

The margin evaluation has confirmed the UK ABWR can still perform the fundamental safety functions in the event of extreme external flooding and allow the reactor to shutdown safely. Allowable relative height of flooding has been identified for each scenario and this will need to be compared to the actual site levels during site specific stage.

(2) Civil Structures

The civil structures provide the main protection against significant External Hazards by providing a support function and a barrier function. Civil structures provide BDB resilience by being robust and passive up to a level of loading of sufficient margin past the design basis. The seismic hazard will occur across the site and the seismic response of the buildings is the dominant factor in the structural design (refer to PCSR Chapter 10: Civil Works and Structures). The BDB margin evaluation for External Hazards on civil structures, except flooding, is provided in [Ref-25]. This has demonstrated that the civil structures have sufficient capacity to reduce the risks from External Hazards to ALARP levels.

(3) Aircraft Impact Protection

Aircraft impact has been demonstrated to be a beyond design basis event [Ref-01]. However, as required by the UK regulator, accidental aircraft impact is included in the design of civil structures which need to act as barriers to such impacts. Due to the conceptual nature of the GDA site plan, the aircraft impact assessment (AIA) includes onerous criteria, such as low and level flight paths since there is no shielding from adjacent structures or topography. The AIA for GDA has demonstrated the risk of a severe accident due to aircraft impact has been reduced to ALARP.

6.9.7 Conclusion

The External Hazards safety case for the UK ABWR has demonstrated that it follows UK and international good practice, uses a systematic and comprehensive methodology for hazard identification and that all reasonably practicable risk reduction measures have been adopted within the scope of GDA, that is, it has been determined that there are no further reasonably practicable risk reduction measures that could be included in the design or plant layout. The work undertaken in support of this topic demonstrates that the UK ABWR design has been robustly carried out, has adequate resilience to beyond design basis events and does not preclude options for the future licensee to adopt alternative design details or change the site layout. The risks from External Hazards to the safety related SSCs are therefore reduced in line with the ALARP principle.

6.10 Conclusion

This chapter has demonstrated that the External Hazards safety case for the UK ABWR has used a systematic and comprehensive methodology for hazard identification and that it follows UK and international good practice. This has produced a master list of individual hazards which is representative of a generic site within the UK. The individual hazards have been collated into twenty-two hazard groups such that hazards with similar characteristics or plant effects are within the same group.

External Hazards that have been identified in GDA are the following.

- Fourteen individual External Hazards which have been considered in GDA design, and are described in the relevant sub-section of Section 6.6:

  1 - Air Temperature
  2 - Wind
  3 - Rainfall and Ice
  4 - Drought
  5 - Snow
  6 - Electromagnetic Interference (EMI)
  7 - Sea or River Water Temperature
  8 - External Flooding
  9 - Seismic Activity
  10 - Loss of Off-Site Power (LOOP)
  11 - Aircraft Impact
  12 - External Fire
  13 - External Missile
  14 - External Explosion

- Seven individual External Hazard groups have been selected for site specific stage:

  15 - Cloud / Storms (Ash, Dust, Sand, Salt)
  16 - Ground Condition
  17 - External Transport Impacts
  18 - Industrial Environment
  19 - Water based Biological Fouling
  20 - Land and Air based Biological Fouling
  21 - Flotsam/ Jetsam/Log Jam

- One External Hazard group has been screened out:

  22 – Extra-Terrestrial Objects

Combinations of the fourteen generic hazard groups have been identified and screened to ensure credible events are addressed. Combinations of events when External Hazards lead to Internal Hazards are described in PCSR Chapter 7: Internal Hazards.

The chapter describes the relationship between safety functions and external hazards and provides links to the safety functional claims which are defined in the relevant PCSR chapter for that SSC. A summary is given of the margin evaluation for beyond design basis events, and again, the detail is given in the relevant PCSR chapter. The summary of the ALARP justification demonstrates that all reasonably practicable risk reduction measures have been adopted within the scope of GDA.

Information provided for the future licensee on the basis of the External Hazards safety case is given, including assumptions used where site specific information was not available. The site specific design will need to confirm if that site has characteristics which lie outside the generic site envelope, and if the future licensee needs to undertake additional safety analysis.

The work undertaken in support of this topic demonstrates that the UK ABWR design has been robustly carried out, has adequate resilience to beyond design basis events and does not preclude options for the future licensee to adopt alternative design details or change the site layout. The risks from External Hazards to the safety related SSCs are therefore reduced in line with the ALARP principle.

6.11 References

[Ref-01] Hitachi-GE Nuclear Energy, Ltd., "Topic Report on External Hazard Protection", GA91-9201-0001-00031 (AE-GD-0126), Rev.5, June 2017.

[Ref-02] Hitachi-GE Nuclear Energy, Ltd., "Topic Report on Generic Site Envelope", GA91-9201-0001-00030 (XE-GD-0183), Rev. G, June 2017.

[Ref-03] Horizon Nuclear Power Ltd., "Derivation and Justification of the External Hazards for the GDA PCSR", HNP-S3-GDA-REP-00003, Rev.01, July 2014.

[Ref-04] Hitachi-GE, "Topic Report on Combined External Hazards", GA91-9201-0001-00118 (AE-GD-0201), Rev.3, June 2017.

[Ref-05] Hitachi-GE Nuclear Energy, Ltd., "Topic Report on Fault Assessment", GA91-9201-0001-00022 (UE-GD-0071), Rev.6, July 2017.

[Ref-06] WENRA RHWG, "Report Safety of new NPP designs - Study by Reactor Harmonization Working Group RHWG", March 2013.

[Ref-07] Hitachi-GE Nuclear Energy, Ltd., "GDA ALARP Methodology", GA10-0511-0004-00001 (XD-GD-0037), Rev.1, Nov. 2015.

[Ref-08] Hitachi-GE Nuclear Energy, Ltd., "GDA Safety Case Development Manual", GA10-0511-0006-00001 (XD-GD-0036), Rev.3, Jun. 2017.

[Ref-09] Swedish Nuclear Inspectorate (SKI), "Guidance for External Events Analysis", February 2003.

[Ref-10] International Atomic Energy Agency, Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants, SSG-3, April 2010.

[Ref-11] The American Society of Mechanical Engineers, Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications, ASME/ANS RA-Sa–2009, February 2009.

[Ref-12] Hitachi-GE Nuclear Energy, Ltd., "Basis of Safety Case on Reactor Building Civil Design", GA91-9201-0002-00001 (LE-GD-0021), Rev.6, June 2017.

[Ref-13] United States Nuclear Regulatory Commission, "Reevaluation of Station Blackout Risk at Nuclear Power Plants", NUREG/CR-6890, November 2005.

[Ref-14] Institute of Hydrology, Flood Estimation Handbook, 1999.

[Ref-15] Natural Environment Research Council, Flood Studies Report, 1975.

[Ref-16] Hitachi-GE Nuclear Energy, Ltd., "Civil Engineering Supporting Report Stack, Structural Design Report", GA91-9201-0003-00208 (LE-GD-0064) Rev.4, June 2017.

[Ref-17] Hitachi-GE Nuclear Energy, Ltd., "Topic Report on Lightning Protection Strategy", GA91-9201-0001-00257 (XE-GD-0696), Rev.0, Apr. 2017.

[Ref-18] Hitachi-GE Nuclear Energy, Ltd., "Beyond Design Basis Margin Evaluation for External Flood on GDA", GA91-9201-0003-01265 (AE-GD-0685), Rev.0, June 2016.

[Ref-19] IAEA SAFETY STANDARDS SERIES, Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations, SSG-18.

[Ref-20] Hitachi-GE Nuclear Energy, Ltd., "Response to RQ-ABWR-0660 (External Flooding (Generic Site Envelope))", GA91-9201-0003-01085(LE-GD-0184),Rev.0, December 2015.

[Ref-21] Hitachi-GE Nuclear Energy Ltd., "Supporting Document on Soil and Seismic Input for Generic Site Envelope", GA91-9201-0003-00567 (JE-GD-0086) Rev.3, Feb. 2017.

[Ref-22] Hitachi-GE Nuclear Energy, Ltd., "Topic Report on SBO Analysis", GA91-9201-0001-00114 (AE-GD-0265), Rev.7, June 2017.

[Ref-23] Hitachi-GE Nuclear Energy, Ltd., "Accidental AIA Strategy Document", GA91-9201-0003-00187 (AE-GD-0176), Rev.2, July 2016.

[Ref-24] Hitachi-GE Nuclear Energy, Ltd., "Support Document on Manmade Hazard for Generic Site Envelope", GA91-9201-0003-00535 (AE-GD-0300), Rev.1, June 2015.

[Ref-25] Hitachi-GE Nuclear Energy, Ltd., "Cliff edge effect on civil engineering (Response to RO-ABWR-0067)", GA91-9201-0003-01767 (LE-GD-0299), Rev.2, May 2017.

[Ref-26] Hitachi-GE Nuclear Energy, Ltd., "Topic Report on External Design Conditions for Class 3 HVAC System", GA91-9201-0001-00203 (HPE-GD-H052), Rev.1, July 2016.

[Ref-27] Hitachi-GE Nuclear Energy, Ltd., "BDB design margins for the Class 1 and 2 HVAC systems (Response to RQ-ABWR-1172)", GA91-9201-0003-01909 (HPE-GD-H061), Rev.0, Jan. 2017.

[Ref-28] Hitachi-GE Nuclear Energy, Ltd., "Topic Report on Combined Internal Hazards", GA91-9201-0001-00096 (SE-GD-0217), Rev.3, July 2017.

[Ref-29] Hitachi-GE Nuclear Energy Ltd., "Applicability of the HM Chief Inspector's Recommendations and ONR's Stress Test Findings to UK ABWR Design", GA91-9201-0003-00868 (AE-GD-0505), Rev.2, May 2017.

[Ref-30] Hitachi-GE Nuclear Energy, Ltd., "Generic Technical Specifications", GA80-1502-0002-00001 (SE-GD-0378), Rev.3, August 2017.

[Ref-31] Hitachi-GE Nuclear Energy Ltd., "Assumption List for UK ABWR PSA", GA91-9201-0003-00937 (AE-GD-0521), Rev.3, June 2017.

[Ref-32] Hitachi-GE Nuclear Energy Ltd, "Topic Report of the Emergency Diesel Generator Locations Optioneering Study", GA91-9201-0001-00170 (LE-GD-0192) Rev.0, December 2015.

[Ref-33] Hitachi-GE Nuclear Energy Ltd, "Topic Report of the Service Connection between Buildings", GA91-9201-0001-00231 (LE-GD-0287) Rev0, Oct. 2016.

[Ref-34] Hitachi-GE Nuclear Energy Ltd., "Topic Report of the Tunnel Access Optioneering Study" GA91-9201-0001-00230, (LE-GD-0244), Rev.0, October 2016.

[Ref-35] Hitachi-GE Nuclear Energy Ltd., "List of Safety Category and Class for UK ABWR" GA91-9201-0003-00266, (AE-GD-0224), Rev.4, Aug. 2017.

[Ref-36] Nuclear Site License Application – Glossary, Horizon Nuclear Power WD03.01.02-S5-NL-REP-00009.

[Ref-37] Hitachi-GE Nuclear Energy Ltd., "Topic Report on External Hazards PSA Prioritisation", GA91-9201-0001-00161, AE-GD-0559, Rev.3, Feb. 2017.

[Ref-38] Hitachi-GE, "Malicious AIA Strategy Document", GA91-9201-0003-00188 (AE-GD-0177), Rev.2, June 2016.

[Ref-39] Hitachi-GE Nuclear Energy, Ltd., "UK-ABWR Nuclear Safety and Environmental Design Principles (NSEDPs)", GA10-0511-0011-00001 (XD-GD-0046), Rev.1, July 2017.

Appendix A: Route Map from External Hazards to Related Safety Functions

Table A-1: Route Map from External Hazards to Related Safety Functions

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety feature	HLSF	SFC	SPC	Comment
1 Air Temperature	GDA	-Humidity -Air Temperature Extremes	**Structural Load** The extremely high and low air temperature may induce thermal gradients in the structural components of the building (concrete, steel rebar, steel liners, tanks, etc.). These gradients can impose structural loads on SSCs.	Civil in PCSR Ch.10 Section 10.3	2-4, 4-7, 5-7, 5-17	R/B SFC 2-4.01~02, R/B SFC 4-7.01~05, R/B SFC 5-7.01~02, R/B SFC 5-17.01~02 (Refer PCSR Ch.10 for other buildings)	CE SPC04	
			Cooling/Ventilation Extreme air temperature and humidity variation can affect the ability of the HVAC system to provide sufficient ventilation.	HVAC in PCSR Ch.16 Section 16.5 Civil in PCSR Ch.10 Section 10.3	5-18	R/A HVAC SFC5-18.1~4 (Refer PCSR Ch.16 for other systems) R/B SFC 5-18.01~02 (Refer PCSR Ch.10 for other buildings)	ME SPC5 CE SPC04	
			Cooling/UHS In case that decay heat is released to air, the extremely high air temperature may cause reduction in the effectiveness of UHS.	UHS in PCSR Ch.16 Section 16.3	5-2	UHS SFC 5-2.1 (Refer PCSR Ch.16 for other systems. See also SFCs in Ch.19: Water based Biological Fouling.)	ME SPC5	

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
2 Wind	GDA	-Extreme winds -Tornadoes -Cyclones, -Typhoons, -Hurricanes	**Structural load** High winds could impact outside of buildings or equipment in the yard which should be also designed to withstand potential straight wind load and any wind-borne missiles. Tornadoes are violent funnel shaped vortices of wind which damage properties through the pressures generated by the vortex itself and the associated wind-born debris.	Civil in PCSR Ch.10 Section 10.3	2-4, 4-7, 5-7, 5-17	R/B SFC 2-4.01~02, R/B SFC 4-7.01~05, R/B SFC 5-7.01~02, R/B SFC 5-17.01~02 (Refer PCSR Ch.10 for other buildings)	CE SPC 04	

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
3 Rainfall and Ice	GDA	-Hail -Sleet -Snow -Icing -Ice (Frazil) -Ice (Rime) -Ice (Barriers) -Frost -Soil Frost -Rainfall (extreme) and Intense Precipitation	**Structural Load** The extreme precipitation of rain or hail may result in damage of the roofs of the building. The extreme precipitation and the accumulation of the ice can impose structural loads on SSCs.	Civil in PCSR Ch.10 Section 10.3	2-4, 4-7, 5-7, 5-17	R/B SFC 2-4.01~02, R/B SFC 4-7.01~05, R/B SFC 5-7.01~02, R/B SFC 5-17.01~02 (Refer PCSR Ch.10 for other buildings)	CE SPC 04	
			Cooling/UHS The frazil ice could form plates of ice suspended in water which result in blockage of the water intake. The blockage of the water intake could result in LUHS.	UHS in PCSR Ch.16 Section 16.3	5-2	UHS SFC 5-2.1 (Refer PCSR Ch.16 for other systems. See also SFCs in Ch.19: Water based Biological Fouling.)	ME SPC5	
			Power Supply The ice forming on the transmission line might result in problem on the transmission network.	Power in PCSR Ch.15 Section 15.4	5-2, 5-3, 5-7	EPS SFC5-2, EPS SFC5-3, EPS SFC5-7	SPC EPS 5	

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
4 Drought	GDA	-Drought	**Cooling/UHS** The severe drought may affect the ultimate heat sink which may cause partial or total loss of secondary cooling and other safety systems relying on water cooling.	UHS in PCSR Ch.16 Section 16.3	5-2	UHS SFC 5-2.1 (Refer PCSR Ch.16 for other systems. See also SFCs in PCSR Ch.19: Water based Biological Fouling.)	ME SPC5	

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group	Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
5 GDA Snow	-Snow Pack -Snow Melt -Extreme Snow	**Structural Load** The extreme snow may result in snow depth/drifting loading on the roofs of buildings or on external plant and thus impose structural loads on SSCs.	Civil in PCSR Ch.10 Section 10.3	2-4, 4-7, 5-7, 5-17	R/B SFC 2-4.01~02, R/B SFC 4-7.01~05, R/B SFC 5-7.01~02, R/B SFC 5-17.01~02 (Refer PCSR Ch.10 for other buildings)	CE SPC 04	
		Cooling/Ventilation The extreme snow may result in the blockage of the HVAC inlets. Extreme snow can affect the ability of the HVAC system to provide sufficient ventilation and prevent failure of temperature sensitive equipment.	HVAC in PCSR Ch.16 Section 16.5 Civil in PCSR Ch.10 Section 10.3	5-18	R/A HVAC SFC5-18.1~4 (Refer PCSR Ch.16 for other systems) R/B SFC 5-18.01~02 (Refer PCSR Ch.10 for other buildings)	ME SPC5 CE SPC04	
		Cooling/UHS The other effect of the extreme snow may be blockage of the water intake. The blockage of the water intake could impact UHS.	UHS in PCSR Ch.16 Section 16.3	5-2	UHS SFC 5-2.1 (Refer PCSR Ch.16 Section 16.3 for other systems. See also SFCs in Ch.19: Water based Biological Fouling.)	ME SPC5	
		Power Supply The accumulation of snow on the transmission line might result in problem on the transmission network.	Power in PCSR Ch.15 Section 15.4	5-2, 5-3, 5-7	EPS SFC5-2, EPS SFC5-3, EPS SFC5-7	SPC EPS 5	

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group	Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
6 GDA EMI	-Lightning -Electromagnetic Interference	**Electric** Solar EMI is considered to be of significant risk to the National Grid. The network absorbs Electromagnetic Pulse (EMP) and this can give rise to a voltage/current spike which could lead to failure or shutdown of key transformers and switchyards in the national grid. The impact of Solar EMI on nuclear power plant would be similar to a lightning strike in the switchyard or on the power lines. The substantial concrete external walls and roofs of the main buildings will protect the SSCs within from EMI and lightning protection system is provided to all buildings.	C&I in PCSR Ch.14 Section 14.3	See Appendix A1 of PCSR Ch.14	See Appendix A1 of PCSR Ch.14	C&I SPC 6	
			EPS in PCSR Ch.15 Section 15.6	See Appendix A of PCSR Ch.15	See Appendix A of PCSR Ch.15	SPC EPS 5	
			Civil structures in PCSR Ch.10 Section 10.4	5-7 5-17	R/B SFC 5-7.02, R/B SFC 5-17.01 (Refer PCSR Ch.10 for other buildings)	CE SPC 04	

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
7 Sea or River Water Temperature	GDA	Temperature Extremes (Sea or River)	**Cooling/UHS** Sea is one of the primary candidate UHS of UK ABWR. The extremely high seawater temperature may cause reduction in the effectiveness of UHS.	UHS in PCSR Ch.16 Section 16.3	5-2	UHS SFC 5-2.1 (Refer PCSR Ch.16 for other systems. See also SFCs in Ch.19: Water based Biological Fouling.)	ME SPC5	

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
8 External Flooding	GDA	-Low / High Seawater Level -Storm Surge -Tsunami -Groundwater -High Tide -High Lake Level, or High River Stage -Tidal Effects (Flooding) -Waves -Rainfall (Extreme) and Intense Precipitation -Dam Failure, -Pipeline Accident	**Structural load, Plant flooding** The external flooding poses potential failure of structures, systems and components by the infiltration of water into internal areas of the plant. The local intense precipitation may result in damage of the roofs of buildings.	Civil in PCSR Ch.10 Section 10.3	2-4, 4-7, 5-7, 5-17	R/B SFC 2-4.01~02, R/B SFC 4-7.01~05, R/B SFC 5-7.01~02, R/B SFC 5-17.01~02 (Refer PCSR Ch.10 for other buildings)	CE SPC 04	
			Power supply In case of extreme external flood condition, water from pluvial/ fluvial sources may affect the nuclear island. Waterproof area inside Hx/B may be submerged. RSW pump may fail and the site may lose the UHS. The transformer facility may fail its function immediately. This may result in loss of power supply.	Power in PCSR Ch.15 Section 15.4	5-2, 5-3, 5-7	EPS SFC5-2, EPS SFC5-3, EPS SFC5-7	SPC EPS 5	

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
9 Seismic Activity	GDA	-Seismic Activity (Earthquake)	Described in Section 3 of [Ref] below	Each SSC is designed to with-stand seismic loads defined in each seismic category.	2-1 2-4 3-1 3-2 4-7 5-7 5-17	**10^{-4} Earthquake** **Chapter 10** R/B SFC 2-4.02, R/B SFC 4-7.04~05, R/B SFC 5-7.02, R/B SFC 5-17.02 (Refer PCSR Ch.10 for other buildings) **Chapter 12** NB SFC 2-1.1~4, NB SFC 3-1.1~2, RPV SFC 2-1.1, RPV SFC 3-1.1, RIN SFC 2-1.1, RIN SFC 3-1.1, RHR SFC 2-1.1, RHR SFC 2-4.1, RHR SFC 3-1.1~5 (Refer PCSR Ch.12 for other systems)	-	Each SSC is catego-rised into seismic category 1, 1A, 2 and 3 in Chap.5.6.
		-Dynamic Compaction (Earthquake)	Section 2.4.9 “Seismic Activity” of PCSR Chap.2.					
		-Geological Faults	This effect is considered in site specific stage.					
		-Minimum Shear Wave Velocity	Described in Section 2 of [Ref] below					
		-Minimum Static Bearing Capacity	Section 2.4.9 “Seismic Activity” of PCSR Chap.2.					
		-Liquefaction (Earthquake)	This effect is considered in site specific stage.					

Hazard Group	Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
					Chapter 13 AC SFC 3-2.1, RHR SFC 3-1.3~5, RHR SFC 2-1.1, RCIC SFC 2-1.1~2, HPCF SFC 2-1.1~2 (Refer PCSR Ch.13 for other systems)		
				1-4 1-5 2-2 3-2 4-7 5-15 5-17	**10^{-3} Earthquake** **Chapter 10** T/B SFC 5-17.02 (Refer PCSR Ch.10 for other buildings) **Chapter 12** RIN SFC 1-4.1, RRS SFC 1-5.1, NB SFC 1-5.1, RHR SFC 4-7.2, CRD SFC 1-5.1, SLC SFC 1-5.1, SLC SFC 1-4.1 (Refer PCSR Ch.12 for other systems)	-	

Hazard Group	Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
					Chapter 13 FCS SFC 5-15.1, RHR SFC 4-7.2, AC SFC 3-2.1, FCVS SFC 3-2.1, SGTS SFC 4-7.2, FLSS SFC 2-2.1, RDCF SFC 2-2.1~2 (Refer PCSR Ch.13 for other systems)		

[Ref] Hitachi-GE, "Supporting Document on Soil and Seismic Input for Generic Site Envelope", GA91-9201-0003-00567 (JE-GD-0086) Rev.3, July 2015.

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
10 LOOP	GDA	Loss of Off-Site Power	**Power supply** LOOP is generally defined as a simultaneous loss of electrical power from off-site electrical power grid and supply power to the buses.	Power in PCSR Ch.15 Section 15.4	5-2, 5-3, 5-7	EPS SFC5-2, EPS SFC5-3, EPS SFC5-7 NB SFC 2-1.1, NB SFC 3-1.1, NB SFC 3-1.2, NB SFC 4-2.1, NB SFC 4-5.1, NB SFC 4-7.2, NB SFC 4-7.4, CUW SFC4.7-1, RHR SFC 3-1.2, RHR SFC 3-1.3, RHR SFC 3-1.4, RHR SFC 3-1.5, CRD SFC 1-3.1, CRD SFC 1-5.1, SLC SFC 1-5.1, etc.	SPC EPS 5	

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
11 Aircraft Impact	GDA	Aircraft Impact (Accidental)	Effects on mechanical resistance of safety structures and systems are considered as structural load. Effects of vibrations on safety structures and systems are also considered as structural load. The HVAC system may be damaged. Effects of combustion and/or explosion of airplane fuel on the integrity of the necessary structures and on the systems are considered as thermal load.	Accidental aircraft impacts are treated as beyond design basis event (See [Ref] below).	5-7	R/B SFC 5-7.02 (Refer PCSR Ch.10 for other buildings)	-	

[Ref] Hitachi-GE, “Accidental AIA Strategy Document”, GA91-9201-0003-00187 (AE-GD-0176), Rev.2, July 2016.

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group	Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
12 GDA External Fire	-Adjacent Installations -Transport Activities -Fire -Toxic Gas (and Asphyxiants)	**Cooling/Ventilation** Smoke generated by the extreme fire can affect the performance of the HVAC system and, in the extreme, could lead to the SSCs failing to deliver their safety functions.	HVAC in PCSR Ch.16 Section 16.5 Civil in PCSR Ch.10 Section 10.3	5-18	R/A HVAC SFC5-18.1~4 (Refer PCSR Ch.16 for other systems) R/B SFC 5-18.01~02 (Refer PCSR Ch.10 for other buildings)	ME SPC5 CE SPC04	The detail assessment of smoke is performed in site specific stage.
		Thermal load Extreme fire can impose thermal loads on SSCs that are important to safety and, in the extreme, could lead to the SSCs failing to deliver their safety functions.	Civil in PCSR Ch.10 Section 10.3	5-7, 5-17	R/B SFC 5-7.01~02, R/B SFC 5-17.01~02 (Refer PCSR Ch.10 for other buildings)	CE SPC 04	

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
13 External Missile	GDA	-Missiles from Military Activities -Missiles -Windblown Debris -Adjacent Installations -Transport Activities	**Structural Load** The impact of the missiles can impose structural loads on SSCs. Small missiles (e.g. idealised as solid steel spheres) may pass through the opening and damage the SSCs.	Civil in PCSR Ch.10 Section 10.3	2-4, 4-7, 5-7, 5-17	R/B SFC 2-4.01~02, R/B SFC 4-7.01~05, R/B SFC 5-7.01~02, R/B SFC 5-17.01~02 (Refer PCSR Ch.10 for other buildings)	CE SPC 04	Openings such as HVAC vents will be confirmed in site specific stage

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
14 External Explosion	GDA	External Explosions	**Structural Load** An explosion in air is accompanied with a very rapid rise in pressure and the formation of a blast wave. Large overpressures may injure people and damage equipment and buildings.	Civil in PCSR Ch.10 Section 10.3	2-4, 4-7, 5-7, 5-17	R/B SFC 2-4.01~02, R/B SFC 4-7.01~05, R/B SFC 5-7.01~02, R/B SFC 5-17.01~02 (Refer PCSR Ch.10 for other buildings)	CE SPC 04	
			Cooling/Ventilation An explosion wave may propagate to intakes of the HVAC. The HVAC components might be damaged by the explosion wave.	HVAC in PCSR Ch.16 Section 16.5 Civil in PCSR Ch.10 Section 10.3	5-18	R/A HVAC SFC5-18.1~4 (Refer PCSR Ch.16 for other systems) R/B SFC 5-18.01~02 (Refer PCSR Ch.10 for other buildings)	ME SPC5 CE SPC04	
			Thermal load Fire due to the explosion can impose thermal loads on SSCs and, in the extreme, could lead to the SSCs failing to deliver their safety functions.	Civil in PCSR Ch.10 Section 10.3	5-7, 5-17	R/B SFC 5-7.01~02, R/B SFC 5-17.01~02 (Refer PCSR Ch.10 for other buildings)	CE SPC 04	

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
15 Cloud / Storms	Site Specific	-Volcanic Activity -Sandstorm, -Dust Storm, -Volcanic Ash Cloud -Salt Spray	These hazards may pose potential failure of air intake and functional loss by corrosive damage.	-	-	-	-	

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
16 Ground Condition	Site Specific	-Temperature extremes (Ground) -Avalanche -Caverns -Coastal Erosion -Ground heave -Land Rise -Landslide -Leeching / Leaching -Settlement -Sedimentation / Siltation -Soil Shrink-Swell Consolidation -Subsidence -Unstable soils (Quick Clays, etc.) -Excavation Work -Mining (Inactive or Active) -Fracking (Hydraulic Fracturing) -Residual Artefacts from Previous Use (i.e. Munitions) -Radon Seepage and Accumulation	Reactivation of old landslides reflects unstable ground conditions or ground deformation. Techniques for determining ground deformation provide measurements of variations in elevation, angles and distances between points in a network at established times. The main radon source in most above ground workplaces with high radon concentrations is the soil. The potential for liquefaction of the subsurface materials of the proposed site should be evaluated by using parameters and values for the site specific ground motion.	-	-	--	-	

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
17 External Transport Impacts	Site Specific	-Fire and Smoke(*) -Explosion(*) -Direct Impact from Collision -Oil Spill from Ship -Release of Toxic(*) -Corrosive or Radioactive Sub-stances(*)	Direct Impact from Collision and Oil Spill from Ship may cause UHS blockage.	-	-	-	-	The hazards marked (*) are considered in other External Hazard group.

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
18 Industrial Environment	Site Specific	-Adjacent Installations, -Transport Activities (Missiles, Gas Clouds, Explosions, etc.) -Chemical Release -Industrial or Military Facility Accident -Acoustic Noise Levels and Frequencies -Pipeline Accident (Gas, Oil, Water, etc.) -Adjacent Nuclear Power Station(s) -Structural Failure -Water Pollution -Corrosive and Radioactive Gasses and Liquids	Adjacent Installations, transport activities, Industrial or military facility accident, Pipeline accident (gas, oil, water, etc.), Adjacent Nuclear Power Station(s) and Structural Failure may pose potential risk not only fire, explosion and missile events but also release of hazardous material such as toxic gas. Chemical release, water pollution and corrosive or radioactive gases/liquids pose potential risks to migrate into areas where operators or safety related equipment are placed, and prevent them from functioning. Acoustic Noise levels and frequencies also pose potential risks to damage the operator's ear.	-	-	-	-	

NOT PROTECTIVELY MARKED

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
19	Site Specific	-Biological Fouling -Animals -Infestation (Biological) -Organic Material in Water (Algae, Seaweed, Fish, Sea Mussels, Jellyfish, Marine Growth) -Crustaceans, Molluscs (Shrimps, Clams, Mussels, Shells)	**Cooling/UHS** Water based Biological Fouling could affect UHS and potentially block the water intake due to organic material in the water (fish, seagrass, seaweeds, mussels, crustaceans, jellyfish etc.). A consequential blockage or failure of RSW systems needs to occur for the hazard to impact the safe shutdown of the reactor.	UHS in PCSR Ch.16 Section 16.3	5-2	UHS SFC 5-2.1 (Refer PCSR Ch.16 for other systems.)	ME SPC5	A Reserve UHS (RUHS) is proposed to maintain the cooling functions.
Water based Biological Fouling								

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
20 Land and Air based Biological Fouling	Site Specific	-Airborne Swarms, -Animals, -Biological Fouling, -Infestation (Biological)	These Land and Air based Biological Fouling may affect HVAC by blocking water intake and I&C (Instrumentation and Control) by attacking cables.	-	-	-	-	

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
21	Site Specific	Collisions of Floating Bodies with Water Intakes and UHS Components Flotsam / Jetsam /Log Jam	Flotsam/ Jetsam/Log jam could affect the UHS and potentially block the water intake. A consequential blockage or failure of RSW systems needs to occur for the hazard to impact the safe shutdown of the reactor.	-	-	-	-	
Flotsam/ Jetsam/Log Jam								

Table A-1: Route Map from External Hazards to Related Safety Functions (cont.)

Hazard Group		Specific External Hazards	Consequence	Mitigating or Safety Feature	HLSF	SFC	SPC	Comment
22 Extra-Terrestrial Objects	Screened Out	-Meteorite -Satellite Impact (including Space Debris)	The effects of a large meteorite or asteroid striking Earth will include seismic, thermal and blast hazards, other significant depending on the mass and nature of the object.					This hazard group is screened out due to low frequency.

Appendix B: Document Map