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21.1 INTRODUCTION

The Fundamental Purpose of the Generic Design Assessment (GDA) Safety, Security and Environment Case (SSEC) is to demonstrate that the Generic SMR-300 can be constructed, operated, and decommissioned on a generic site in the UK to fulfil the future licensee's legal duties to be safe, secure and protect people and the environment as defined in Holtec SMR GDA Preliminary Safety Report (PSR) Part A Chapter 1 'Introduction' [1].

The Fundamental Purpose is achieved through the Fundamental Objective of the PSR, which is to summarise the safety standards and criteria, safety management and organisation, claims, arguments and intended evidence to demonstrate that the generic SMR-300 design risks to people are likely to be tolerable and As Low as Reasonably Practicable (ALARP).

Part B Chapter 21 of the PSR presents the Claims, Arguments and intended Evidence (CAE) for the External Hazards topic that underpins the design of the generic SMR-300.

External Hazards are defined by the Office for Nuclear Regulation (ONR), 'NS-TAST-GD-013, External Hazards' [2] as:

'…natural or man-made hazards to a site and facilities that originate externally to both the site and its processes, i.e., the duty holder may have very little or no control over the initiating event'.

External Hazards have the potential to be initiating events progressing to faults and causing common cause failures of Structures, Systems and Components (SSCs) which are required to deliver the High Level Functions identified in PSR Part A Chapter 2 'General Design Aspects and Site Characteristics' [3] to ensure safety of the plant.

This chapter should be read in conjunction with the 'Generic Site Envelope Report for SMR-300 UK GDA' (GSER) [4], which defines the generic SMR-300 Great Britain Generic Site Envelope (GB GSE) and the characteristics of the generic site to be used as the basis for the safety analysis. The assumptions made in the development of the GB GSE are populated in Appendix C of the GSER [4].

21.1.1 Purpose and Scope

The Overarching SSEC Claims are presented in PSR Part A Chapter 3 'Claims, Arguments and Evidence' [5].

This chapter (Part B Chapter 21) links to the overarching claim through Claim 2.1:

Claim 2.1: The nuclear safety assessment identifies plant initiating events, specifies the requirements for safety measures such that safety functions are fulfilled, informs operational and emergency arrangements and demonstrates that risk is tolerable and As Low As Reasonably Practicable (ALARP).

As set out in Part A Chapter 3 [5], Claim 2.1 is further decomposed across several safety assessment disciplines which are responsible for the development of the overall nuclear safety assessment. This chapter (Part B Chapter 21) presents Claim 2.1.5 with the objective to demonstrate that risks from External Hazards, and their combinations, have been demonstrated to be tolerable and ALARP.

Claim 2.1.5: Risks from External Hazards and their combinations have been demonstrated to be tolerable and ALARP.

Further explanation of the decomposition of Level 3 claims into Level 4 claims and the substantiation of those Level 4 claims is provided in subchapter 21.3.

The chapter structure is set out to present the following:

- An overview of the approach to External Hazards undertaken within the development of the SMR-300 GDA Reference Design to demonstrate alignment with international regulatory guidance and Relevant Good Practice (RGP) – subchapter 21.2.1.
- An overview of the approach undertaken for the fundamental GDA safety assessment of the generic SMR-300 against the External Hazards identified and characterised in the GSER [4] to demonstrate that risks from those External Hazards, are tolerable and ALARP – subchapter 21.2.2.
- The CAE architecture relevant to the External Hazards topic area – subchapter 21.3.
- The applicable codes and standards, RGP and regulatory guidance used to identify and characterise External Hazards in both the GDA Reference Design and the development of the GB GSE – subchapter 21.4.
- The identification and screening methodology adopted to identify the External Hazards, and their combinations, which are relevant to the deployment of the generic SMR-300 in Great Britain and can be considered on a generic basis – subchapter 21.5.
- The generic SMR-300 SSCs with External Hazards related safety functions – subchapter 21.6.
- An evaluation of each External Hazard including hazard characterisation, the derivation of the GB GSE parameter(s) and a preliminary evaluation of the GDA Reference Design – subchapter 21.7.
- A technical summary of how the overarching claim for External Hazards is substantiated including a summary of the contribution made by this chapter to support the demonstration that risks, specifically relating to External Hazards, are likely to be tolerable and ALARP for the generic SMR-300 design – subchapter 21.8.

A master list of definitions and abbreviations relevant to all PSR Chapters can be found in Part A Chapter 2 [3].

21.1.2 Assumptions

The following assumptions have been made in this revision of the PSR:

- All External Hazards screened as site-specific during the development of the GB GSE [4] are outside the scope of GDA and are to be assessed in detail at the site-specific stage. The output of the hazard identification and screening process is provided in Appendix A of the GSER [4].
- A Site Justification Report or similar, will be produced at the site-specific stage to characterise the prospective site and confirm that the site is bounded by the GB GSE defined in the GSER [4]. This report should review the screening analysis presented in the GSER [4] and undertake a detailed hazard analysis, including those External Hazards screened out of the scope of GDA.
- For the purposes of this GDA, it has been assumed that the 'Generic Site' is 'dry' when subjected to flood levels up to the design basis, as such the site operator will develop

a protection solution to ensure this for their site. Further information on potential protection solutions and RGP is provided in subchapter 21.7.2.1.

21.1.3 Interfaces with other SSEC Chapters

The External Hazards chapter interfaces with the following PSR chapters.

The SMR-300 High Level Functions, which are to be achieved for all plant states except where a postulated condition involves the loss of that function, are presented in PSR Part A Chapter 2 [3]. The definition of the Great Britian Generic Site Envelope (GB GSE), including the generic site characteristics to be used as the basis of the safety assessment, is also presented in PSR Part A Chapter 2 [3].

All identified and screened External Hazards are to be treated as initiating events in the Design Basis Accident Analysis (DBAA). PSR Part B Chapter 14 ‘Design Basis Accident Analysis’ [6] presents the DBAA for reactor faults and at Revision 1, will present a Preliminary Fault Schedule (PFS).

PSR Part B Chapter 15 ‘BDBA, Severe Accidents Analysis and Emergency Preparedness’ [7] is considered as an extension of Part B Chapter 14 [6]. The aim of Part B Chapter 15 [7] is to address the evaluation of Design Extension Conditions (DECs) for the generic SMR-300 and to demonstrate that accidents that have the potential to lead to severe consequences have been systematically analysed with appropriate safety measures beyond those derived from the DBAA identified. PSR Part B Chapter 16 ‘Probabilistic Safety Assessment’ [8] supports the DBAA and Beyond Design Basis Analysis (BDBA) with an objective to demonstrate that the design of the generic SMR-300 is balanced such that risk is tolerable and ALARP.

External Hazards and PSR Part B Chapter 22 ‘Internal Hazards’ [9] interface closely due to their nature. Combinations of hazards is a key consideration in the safety analysis as an Internal Hazard could occur as a consequence of an initiating External Hazard.

Part B Chapter 4 ‘Control and Instrumentation Systems (I&C)’ [10], Part B Chapter 5 ‘Reactor Supporting Facilities’ [11], Part B Chapter 6 ‘Electrical Engineering’ [12], Part B Chapter 19 ‘Mechanical Engineering’ [13], and Part B Chapter 20 ‘Civil Engineering’ [14] identify and present the SSCs relevant to each discipline, which will be qualified against External Hazards.

External Hazards also interfaces with PSR Part B Chapter 17 ‘Human Factors’ [15]. The Human Factors discipline supports the identification, analysis and modelling of human failures related to External Hazards and is responsible for the substantiation of any developed human-based safety claims.

21.2 EXTERNAL HAZARDS APPROACH

This subchapter initially presents the approach to External Hazards undertaken within the development of the SMR-300 GDA Reference Design with the objective to demonstrate alignment with international regulatory guidance and RGP.

The approach to External Hazards for the purposes of the generic SMR-300 GDA is then presented to outline the methodology undertaken to fundamentally assess the deployment of the generic SMR-300 on a generic site bounded by the GB GSE, when subjected to the generic and credible External Hazards identified in the GSER [4].

21.2.1 GDA Reference Design Approach

This subchapter presents the approach to External Hazards undertaken in the GDA Reference Design, and therefore inherent within the generic SMR-300, as detailed in the Holtec 'Design Standard for External Events' [16] and the 'SMR-300 Specification - Environmental Conditions' [17] reports. Further information on the GDA Reference Design is provided in Part A Chapter 2 [3] with the process for managing prospective design changes during GDA captured in 'Holtec SMR-300 GDA Reference Design Process and GDA Prospective Design Change Register' [18].

United States Nuclear Regulatory Commission (US NRC) Title 10 Code of Federal Regulations, Appendix A to Part 50, 'General Design Criteria for Nuclear Power Plants' [19], General Design Criterion 2, states that SSCs important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions.

The overall design objective for the SMR-300 relating to External Hazards states that:

- For design-basis events (DBE), to demonstrate that failure of SSCs or a large release of radioactive material to the environment will not occur.
- For beyond-design-basis events (BDBE), to provide reasonable assurance that core-damage or a large release of radioactive materials to the environment will not or is unlikely to occur.

21.2.1.1 Design Methodology

The general design methodology for the consideration of External Hazards in the GDA Reference Design is provided below. There are several different methods employed, which largely depend on the type of event and its frequency. However, the same general process is employed for all External Hazards.

1. A set of External Hazard events has been developed for the GDA Reference Design through a comprehensive hazard identification process.
2. External Hazards are classified based upon their frequency of occurrence, engineering judgement, prior industry experience, or a combination thereof.
3. External Hazard events which are a consequence of the initiating hazard are defined and considered.
4. Important to safety SSCs are either evaluated for or protected from the effects of the External Hazard event and any consequential hazards through one or more of these approaches (as appropriate for the event classification):

- For DBEs, the plant layout or design provisions may ensure the SSCs are protected, such as by barriers or physical separation.
- For DBEs, the SSC may be designed to withstand the effects of the event(s).
- For BDBEs, SSC designs may be demonstrated as sufficiently robust to remain intact and/or functional so as to still meet safety requirements.
- For BDBEs, important to safety SSCs which may not be demonstrated to remain intact and/or functional after the event are considered as such in the safety analysis.

5. The safety goals of the deterministic or probabilistic safety analysis are demonstrated to be met, with due consideration of the state of important to safety SSCs.

21.2.1.2 Safety Requirements for Design Basis External Hazards

The following are the fundamental derived acceptance criteria which are inherent within the generic SMR-300 design for design basis External Hazards identified in the development of the GDA Reference Design, as detailed in the Holtec 'Design Standard for External Events' [16] and the 'SMR-300 Specification – Environmental Conditions' [17] reports:

a) The fundamental safety functions of the plant shall remain available.
b) There shall be no failure of fuel or the reactor coolant pressure boundary.
c) The containment function shall be maintained.
d) The ability to monitor the state of the plant shall be maintained.

21.2.1.3 Safety Requirements for Beyond Design Basis External Hazards

The following are the fundamental derived acceptance criteria which are inherent within the generic SMR-300 design for beyond design basis External Hazards identified in the development of the GDA Reference Design, as detailed in the Holtec 'Design Standard for External Events' [16] and the 'SMR-300 Specification – Environmental Conditions' [17] reports:

a) The reactor shall remain capable of being shut down and maintained in a safe shutdown state.
b) To the greatest extent practical, the reactor shall remain coolable and confinable.
c) The containment function shall be maintained without significant degradation.
d) The ability to monitor the state of the plant shall be maintained.
e) Cliff-edge effects shall be eliminated such that a small change in accident parameters does not cause a disproportionately large change in accident progression or consequences.
f) On and off-site emergency measures shall be capable of responding to events in an appropriate timeframe.

21.2.1.4 Defence In Depth

The GDA Reference Design approach considers five levels of defence in depth, consistent with International Atomic Energy Authority (IAEA) No. SSG-30, 'Safety Classification of Structures, Systems and Components in Nuclear Power Plants' [20] and IAEA INSAG-10, 'Defence in Depth in Nuclear Safety' [21]. With respect to defence in depth, the following requirements are set in the assessment of External Hazards for the GDA Reference Design:

- For design basis External Hazard events, the event shall not challenge the defence-in-depth beyond Level 3.

- Level 4 and 5 defence-in-depth shall be defined to the extent practical with consideration of the identified beyond design basis External Hazard events.

21.2.1.5 GDA Reference Design Parameters

The design basis of the External Hazards identified in the GDA Reference Design has been established through the application of international regulatory design codes and standards, which are presented in subchapter 21.4.

The Holtec 'Design Standard for External Events' [16] and the Holtec 'SMR-300 Specification – Environmental Conditions' [17] specify the magnitude of the External Hazard DBEs applied in the GDA Reference Design. These design basis parameters are referred to as the 'GDA Reference Design parameters' throughout this chapter.

21.2.2 Generic SMR-300 GDA Approach

The following subchapters outline the approach to External Hazards in the context of carrying out a fundamental assessment on the deployment of the generic SMR-300 on a generic site in Great Britain bounded by the GB GSE.

21.2.2.1 Hazard Identification

The definition of the GB GSE, including the generic site characteristics to be used as the basis for the safety analysis, is provided in Part A Chapter 2 [3] with further information provided in the GSER [4]. This definition includes the credible External Hazards which have been identified as affecting nuclear safety, can be considered on a generic basis and are relevant to the deployment of the generic SMR-300 on a generic site in Great Britain.

A comprehensive hazard identification and screening methodology has been undertaken to identify these credible External Hazards with the methodology presented in subchapter 21.5. The codes and standards applied in this process are presented in subchapter 21.4.

21.2.2.2 Hazard Characterisation

A preliminary evaluation of each of the External Hazards identified and screened-in is provided in subchapter 21.7. The first step of this evaluation is to sufficiently characterise each of the hazards to understand the challenge made to the safety of the generic SMR-300. This challenge is often in the form of an external load applied to Civil SSCs.

External Hazards can be classified in terms of their severity and frequency of occurrence as either discrete or non-discrete hazards, as stated in ONR, 'Safety Assessment Principles for Nuclear Facilities" (SAP) [22].

Paragraph 232 of the ONR SAPs [22] states that discrete External Hazards are those hazards that are realised at a single frequency (or set of discrete frequencies) with an associated hazard magnitude. Typically, these are hazards which do not occur with sufficient frequency to enable a relationship between magnitude and frequency to be established. Additionally, some External Hazards such as aircraft impact are discrete because there are a limited finite number of possible events that could occur.

For some discrete External Hazards, a Maximum Credible Event (MCE) can be established to characterise a worst-case event for the hazard. This is typically employed when characterising discrete human-induced External Hazards.

Paragraph 233 of ONR SAPs [22] states that non-discrete External Hazards are those hazards that can occur across a continuous range of frequencies and can be defined in terms of a hazard curve.

21.2.2.3 Input into Fault Schedule

All External Hazards should be treated as initiating events in the fault studies analysis [22]. A fault schedule is to be produced for all credible External Hazards to ensure the 'golden thread' is maintained through the CAE and that hazard sequences are sufficiently captured in an auditable manner. This fault schedule will aim to provide information on the following:

- Hazard Type.
- Hazard Location.
- Hazard Pathway Progression.
- Potential Consequences.
- Available Safety Measure/s.
- Additional Safety Measure/s (DiD).

As part of the work to be undertaken within Part B Chapter 14 [6], a Preliminary Fault Schedule (PFS) is being developed to act as a vehicle to capture the above bullet points.

The PFS will be a live document that will be developed during design development and throughout the lifecycle of the project.

21.2.2.4 Derivation of GB GSE Parameters

DBEs have been derived for each of the credible External Hazards identified in the GSER [4], which are of a magnitude that is bounding of the sites considered within the development of the GB GSE to establish the GB GSE parameters. A summary of this derivation is presented for each External Hazard in subchapter 21.7 with the codes and standards applied in this derivation presented in subchapter 21.4.

The derivation of DBEs in the development of the GB GSE has been undertaken in alignment with the ONR SAPs [22]. Typically, DBEs have been derived in accordance with the frequency of occurrence thresholds set in Principle FA.5 of [22], which is 1 in 10,000 years for natural External Hazards.

The DBEs derived for the GB GSE are referred to as the 'GB GSE parameters' throughout this chapter. A summary of these GB GSE parameters is provided in Part A Chapter 2 [3].

The UK Climate Projections 2018 (UKCP18) climate analysis tool [23] developed by the Met Office has been used in the derivation of the GB GSE parameters to account for the effects of reasonably foreseeable climate change over the lifetime of the facility. Further explanation on the approach to the UK Climate Projections is provided in Part A Chapter 2 [3], which has been developed to align with the ONR's position statement published in 2022, 'Use of UK Climate Projections 2018 (UKCP18) Position Statement' [24].

A detailed hazard analysis, including the production of hazard curves for the non-discrete External Hazards, has not been undertaken at this stage. This analysis should take place at the site-specific stage to establish a detailed characterisation of each External Hazard that is reflective of the prospective site under consideration.

21.2.2.5 Preliminary Evaluation of GDA Reference Design

A preliminary External Hazards evaluation of the GDA Reference Design has been undertaken prior to the production of the PFS and a fully developed UK specific design basis analysis.

The objective of this preliminary evaluation is to demonstrate the fundamental adequacy of the approach to External Hazards inherent within the generic SMR-300 highlighting the robustness of the design to withstand the External Hazards relevant to the GB GSE. This evaluation also provides an early opportunity to identify whether there are any potential topics to be resolved to enable the development of a fully licensable detailed design suitable for deployment in Great Britain.

At this stage, this preliminary evaluation consists of a high-level comparison study between the identified External Hazards in the GDA Reference Design and the GB GSE.

21.2.2.5.1 Preliminary External Hazards Design Basis Evaluation

The purpose of this exercise is to perform a high-level preliminary evaluation of deploying the GDA Reference Design on a generic site in Great Britain.

In subchapter 21.7, for each External Hazard a comparison of hazard severity and magnitude is made between the GDA Reference Design parameters, which were introduced in subchapter 21.2.1.5, and the GB GSE parameters presented in Part A Chapter 2 [3]. In many cases, significant margin is present between the GDA Reference Design demonstrating the robustness of the design in the context of deploying the generic SMR-300 in Great Britain.

It's important to note that the design of all SSCs will be fully examined following a fully developed UK specific design basis analysis. Further explanation is provided in Part B Chapter 14 [6].

Any gaps initially identified in hazard characterisation and/or design basis magnitude in this initial exercise have been captured and further work has been proposed to examine these topics further.

21.2.2.5.2 Preliminary External Hazards Beyond Design Basis Evaluation

The purpose of this evaluation is to meet the intent of ONR SAPs EHA.18 and EHA.7 [22], which identify the importance of considering 'Beyond Design Basis Events' and 'Cliff Edge Effects' in the evaluation of External Hazards.

Further work has been proposed to outline the methodology to evaluate External Hazard events beyond the design basis and to demonstrate sufficient margins and the absence of 'Cliff Edge Effects'. The initial assessment aims to utilises margin present between the GDA Reference Design and the GB GSE parameters to demonstrate an absence of cliff edge effects. This evaluation is to be applied for each External Hazard with further information provided in Revision 1 of this Chapter.

Further explanation of the overall BDBA methodology for the generic SMR-300 is presented in Part B Chapter 15 [7], which focuses on the analyses of DECs, including considerations relating to the event sequences to be 'practically eliminated'. The aim of Part B Chapter 15 [7] is to demonstrate that the plant is capable of preventing, controlling, and mitigating sequences which are beyond the design basis.

21.2.2.6 Hazard Protection

As the fault studies topic area progresses, protection measures are to be identified for each External Hazard. These protection measures typically include designing Civil SSCs to withstand the impact of the External Hazard. The substantiation of the Civil (and other engineering discipline) SSCs to withstand the design basis hazard is then typically provided by the Civil (and other) Engineering disciplines through analysis.

At Revision 0, no hazard protection measures are provided in subchapter 21.7.

21.3 EXTERNAL HAZARDS CLAIMS, ARGUMENTS, AND EVIDENCE

The primary purpose of a CAE approach is to capture the golden thread of a safety case narrative demonstrating how plant and operational evidence is brought together to justify that a high-level or fundamental claim is true. In the context of the generic SMR-300, that is how the Fundamental Purpose of the SSEC (presented in Part A Chapter 1 [1]) is achieved.

The Fundamental Purpose follows a golden thread throughout the SSEC to CAE via the objectives of the PSR, Preliminary Environmental Report (PER) and Generic Security Report (GSR). The overarching SSEC claims are presented in Part A Chapter 3 [5], and this chapter links to the overarching claims through Claim 2.1:

Claim 2.1: The nuclear safety assessment identifies plant initiating events and specifies the requirements for safety measures such that safety functions are fulfilled, informs operational and emergency arrangements, and demonstrates that risk is tolerable and As Low As Reasonably Practicable (ALARP).

As set out in Part A Chapter 3 [5], Claim 2.1 is further decomposed across several nuclear safety assessment disciplines which are responsible for the development of the nuclear safety assessment. This chapter presents the External Hazards aspects for the generic SMR-300 and therefore directly supports Claim 2.1.5.

Claim 2.1.5 Risks from External Hazards and their combinations have been demonstrated to be tolerable and As Low As Reasonably Practicable (ALARP).

Claim 2.1.5 has been further decomposed within this chapter (Part B Chapter 21) to provide confidence that the relevant requirements on SSCs will be met during all lifecycle phases.

Claim 2.1.5.1 contributes to the hazard identification and characterisation step of the *Safety Analysis* phase by defining the codes and standards used to identify the External Hazards to be considered within the safety analysis. Additionally, the claim contributes to the *Design Phase* by defining the codes and standards used to derive the design basis of each of the identified External Hazards to be used within the design basis engineering analysis.

Claim 2.1.5.2 contributes to the hazard identification step of the *Safety Analysis* phase and provides confidence that all External Hazards relevant to the deployment of the generic SMR-300 on a generic site in Great Britain have been identified and appropriately screened through a comprehensive process aligned with RGP.

Claim 2.1.5.3 contributes to the *Safety Analysis* phase and the *Design* phase, to ensure SSCs are correctly specified in terms of safety functions and classification, derived from the safety analysis (e.g., to withstand impacts), noting that the maturity of evidence for this claim will be limited at a PSR stage.

Claim 2.1.5.4 then ensures that the *Safety Analysis* phase demonstrates that the plant can reach a safe state following an External Hazard, noting that the maturity of evidence for this claim will be limited at a PSR stage as the PFS is developed.

Table 1 presents a summary of the Level 4 sub-claims highlighting in which subchapter these claims are addressed.

Table 1: CAE Chapters

Claim No.	Claim	PSR Chapter
2.1.5	Risks from External Hazards and their combinations have been demonstrated to be tolerable and ALARP.	Chapter B21
2.1.5.1	External Hazards are identified and characterised using appropriate Codes and Standards, taking cognisance of RGP and Operating Experience (OPEX).	Sub-Chapter 21.4
2.1.5.2	A comprehensive set of External Hazards and their combinations are identified and screened for assessment.	Sub-Chapter 21.5
2.1.5.3	Safety functions and safety measures are identified, categorised, and classified based on their importance to nuclear safety for all External Hazards and provide sufficient lines of protection based on the fault frequency and consequence.	Sub-Chapter 21.6
2.1.5.4	Analysis demonstrates that for all External Hazards, the identified safety features, in conjunction with operator actions, enable the plant to reach a safe state.	Sub-Chapter 21.7

21.4 CODES AND STANDARDS

Claim 2.1.5.1: External Hazards are identified and characterised using appropriate Codes and Standards, taking cognisance of RGP and OPEX.

21.4.1 GDA Reference Design

The Holtec 'Design Standard for External Events' [16] and the Holtec 'SMR-300 Specification – Environmental Conditions' [17] specify the guidance, codes, and standards applied in the identification and characterisation of External Hazards in the GDA Reference Design.

21.4.1.1 Hazard Identification

A comprehensive hazard identification has been conducted for the GDA Reference Design, within Holtec 'Design Standard for External Events' [16] and the Holtec 'SMR-300 Specification – Environmental Conditions' [17]. The External Hazards have been considered and defined to envelope anticipated site-specific hazards. Table 2 presents the list of guidance documents examined to develop the External Hazards considered in the GDA Reference Design.

Table 2: Codes and Standards used in the Hazard Identification for the GDA Reference Design

Author	Title
Canadian Nuclear Safety Commission	REGDOC-2.5.2 Design of Reactor Facilities: Nuclear Power Plants, May 2014 [25].
Canadian Nuclear Safety Commission	REGDOC-2.4.1 Deterministic Safety Analysis, May 2014 [26].
Canadian Nuclear Safety Commission	REGDOC-2.4.2 Probabilistic Safety Assessment for Nuclear Power Plants, May 2014 [27].
International Atomic Energy Agency	Safety Guide No. NS-G-1.5 External Events Excluding Earthquakes in the Design of Nuclear Power Plants, 2003 [28].
International Atomic Energy Agency	Safety Guide No. NS-G-3.1 External Human Induced Events in Site Evaluation for Nuclear Power Plants, 2002 [29].
US Nuclear Regulatory Commission	NUREG-0800 Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Plants [30].
US Nuclear Regulatory Commission	10 CFR Part 50 App. A General Design Criteria for Nuclear Power Plants, Domestic Licensing of Production and Utilization Facilities [19].
US Nuclear Regulatory Commission	Regulatory Guide 1.221 Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants, Revision 0 [31].
US Nuclear Regulatory Commission	Regulatory Guide 1.76 Design Basis Tornado and Tornado Missiles for Nuclear Power Plants, Revision 1 [32].
US Nuclear Regulatory Commission	Regulatory Guide 1.102 Flood Protection for Nuclear Power Plants, Revision 1 [33].
US Nuclear Regulatory Commission	Regulatory Guide 1.59 Design Basis Floods for Nuclear Power Plants, Revision 2 [34].

Author	Title
US Nuclear Regulatory Commission	Regulatory Guide 1.78 Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release, Revision 1 [35].
US Nuclear Regulatory Commission	Regulatory Guide 1.91 Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants, Revision 2 [36].
US Nuclear Regulatory Commission	Regulatory Guide 1.217 Guidance for the Assessment of Beyond-Design-Basis Aircraft Impacts, Revision 0 [37].
US Nuclear Regulatory Commission	Regulatory Guide 1.60 Design Response Spectra for Seismic Design of Nuclear Power Plants [38].

21.4.1.2 Derivation of GDA Reference Design Parameters

A comprehensive set of codes and standards have been referenced in the derivation of the GDA Reference Design parameters. Table 3 presents the list of the codes and standards used to derive hazard parameters. These items have been reproduced from reference [16] and [17].

Table 3: Codes and Standards used in the Derivation of GDA Reference Design Parameters

External Hazard	Author	Title
Ambient Conditions (Wet and Dry Bulb Temperatures, Precipitation)	Electric Power Research Institute	Technical Report Advanced Nuclear Technology: Advanced Light Water Reactor Utility Requirements Document, Revision 13 [39].
	Dominion Virginia Power (Dominion)	North Anna, Unit 3, Combined License Application, Part 2: Final Safety Analysis Report, Revision 9 [40].
	American Society of Heating, Refrigerating and Air-Conditioning Engineers	ASHRAE Handbook Climactic Design Conditions, 2021 edition, Weather Monitor Station No. 722343 (South Haven Area Regional Airport), South Haven, MI, USA [41].
Wind Conditions, and Seismic Conditions	American Society of Civil Engineers/Structural Engineering Institute	ASCE/SEI 7/16 Minimum Design Loads for Buildings and Other Structures, 2016 [42].
Hurricane Wind and Hurricane Missiles	US Nuclear Regulatory Commission	Regulatory Guide 1.221 Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants, Revision 0 [31].
Tornado Wind and Tornado Missiles	US Nuclear Regulatory Commission	Regulatory Guide 1.76 Design Basis Tornado and Tornado Missiles for Nuclear Power Plants, Revision 1 [32].
Lightning	US Nuclear Regulatory Commission	Regulatory Guide 1.204 Guidelines for Lightning Protection of Nuclear Power Plants, Revision 0 [43].
EMI	US Nuclear Regulatory Commission	Regulatory Guide 1.180 Guidelines for Evaluating Electromagnetic and Radio Frequency Interference in Safety-Related Instrumentation and Control Systems, Revision 1 [44].
Precipitation Conditions	Entergy Nuclear Operations, Inc.	Palisades Nuclear Plant, Updated Final Safety Analysis Report, Revision 35 [45].

External Hazard	Author	Title
	National Oceanic and Atmospheric Administration	Hydrometeorological Report No.51, Probable Maximum Precipitation Estimates, United States East of the 105th Meridian, 1978 [46].
Michigan Lake Water Conditions	National Oceanic and Atmospheric Administration	Lake Michigan Average Great Lake Surface Environmental Analysis, Average Surface Water Temperature (GLSEA) [47].
Seismic	US Nuclear Regulatory Commission	Regulatory Guide 1.60 Design Response Spectra for Seismic Design of Nuclear Power Plants [38].
Aircraft impact	US Nuclear Regulatory Commission	10 CFR 50.150(a) Aircraft impact assessment [48].
	US Nuclear Regulatory Commission	Regulatory Guide 1.217 Guidance for the Assessment of Beyond-Design-Basis Aircraft Impacts, Revision 0 [37].
	Nuclear Energy Institute	NEI 07-13, Methodology for Performing Aircraft Impact Assessments for New Plant Designs, Revision 7 [49].

21.4.2 Great Britain Generic Site Envelope

21.4.2.1 Hazard Identification

A comprehensive hazard identification process has been conducted in the development of the GB GSE. Table 4 presents the list of guidance documents examined to identify credible External Hazards which can affect nuclear safety, can be considered on a generic basis and are relevant to the deployment of the generic SMR-300 on a generic site in Great Britain.

Table 4: Codes and Standards used in the Hazard Identification of the GB GSE

Author	Title
ONR Safety Assessment Principles	Safety Assessment Principles for Nuclear Facilities, Revision 1 [22].
ONR Technical Assessment Guide (TAG) 13	ONR Technical Assessment Guide: External Hazards, Issue 9, October 2023 [2].
International Atomic Energy Agency	Specific Safety Guide No. SSG-68 Design of Nuclear Installations Against External Events Excluding Earthquakes [50].
Western European Nuclear Regulators' Association	Safety of new Nuclear Power Plants (NPPs) [51].
Western European Nuclear Regulators' Association	Guidance Document Issue TU: External Hazards Head Document [52].
Swedish Nuclear Inspectorate (SKI)	SKI Report 02:27: Guidance for External Events Analysis [53].
Advanced Safety Assessment Methodologies: Extended PSA	List of External Hazards to be considered in ASAMPSA [54].
Organisation for Economic Co-operation and Development, Nuclear Energy Agency	PSA of Other External Events than Earthquake [55].

Author	Title
Organisation for Economic Co-operation and Development, Nuclear Energy Agency	PSA of Natural External Hazards Including Earthquakes [56].
European Utility Requirements	EUR Vol. 2 Chp. 2.4 Generic and Nuclear Island Requirements, Revision E [57].
US Nuclear Regulatory Commission	NUREG-1407 Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities [58].
Holtec International	HI-2200558 PSA Screening of Other External Events [59].
Holtec International	HPP-160-3015 SMR-160 Design Standard for External Events [16].
Holtec International	HI-2240117 SMR-300 Specification - Environmental Conditions [17].
UK EPR	UKEPR-0002-022: UK EPR PCSR - subchapter 2.2 - Site Environmental Characteristics, Issue 4 [60]. UKEPR-0002-131: UK EPR PCSR -subchapter 13.1 - External Hazards Protection [61].
UK AP1000	UKP-GW-GL-025: UK AP1000 Generic Site Report [62]. UKP-GW-GL-793NP: AP1000 Pre-Construction Safety Report, Chapter 12 [63].
UK ABWR	XE-GD-0213:UK ABWR Generic PCSR Chapter 2: Generic Site Envelope [64]. AE-GD-0168: UK ABWR Generic PCSR Chapter 6: External Hazards [65].
UK HPR1000	HPR/GDA/REPO/0015: UK HPR1000 Generic Site Report [66]. HPR/GDA/PCSR/0018: UK HPR1000 Pre-Construction Safety Report Chapter 18 - External Hazards [67].

21.4.2.2 Derivation of GB GSE Parameters

Table 5 presents the list of the codes and standards used to derive the GB GSE parameters which are presented in Part A Chapter 2 [3].

Table 5: Codes and Standards used in Derivation of GB GSE Parameters

External Hazard	Author	Title
UK Climate Projections	Met Office	UK Climate Projections (UKCP) [68].
	Met Office	UKCP18 Derived Projections of Future Climate over the UK, 2018 [69].
	Met Office	UKCP18 Guidance: Representative Concentration Pathways [70].
	Environment Agency	Flood Risk Assessments: Climate Change Allowances, May 2022 [71].
Extreme Ambient Air Temperature	British Standards Institution	BS EN 1991-1-5:2003 Eurocode 1: Actions on Structures - Part 1-5: General Actions - Thermal Actions, 2010 [72].

External Hazard	Author	Title
	British Standards Institution	NA to BS EN 1991-1-5:2003 UK National Annex to Eurocode 1: Actions on Structures - Part 1-5: General Actions - Thermal Actions, 2007 [73].
Humidity	Met Office	UK Climate Averages [Online] [74].
Extreme Cooling Water Temperature	Met Office	UKCP18 Marine Report, 2018 [75].
Extreme Wind	British Standards Institution	BS EN 1991-1-4:2005 + A1:2010 Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions, 2011 [76].
	British Standards Institution	NA to BS EN 1991-1-4:2005 + A1:2010 UK National Annex to Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions, 2011 [77].
Tornadic Wind and Tornado Generated Missiles	US Nuclear Regulatory Commission	Regulatory Guide 1.76 Design Basis Tornado and Tornado Missiles for Nuclear Power Plants, Revision 1 [32].
Icing	British Standards Institution	BS EN 1993-3-1:2006 Eurocode 3 - Design of steel structures - Part 3-1: Towers, masts and chimneys - Tower and masts, 2010 [78].
	British Standards Institution	NA to BS EN 1993-3-1:2006 UK National Annex to Eurocode 3: Design of steel structures - Part 3-1: Towers, masts and chimneys - Towers and masts, 2010 [79].
Snow	British Standards Institution	BS EN 1991-1-3:2003 +A1:2015 Eurocode 1 - Actions on structures - Part 1-3: General actions - Snow Loads, 2015 [80].
	British Standards Institution	NA+A2:2018 to BS EN 1991-1-3:2003+A1:2015 UK National Annex to Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads, 2018 [81].
Lightning	British Standards Institution	BS EN 62305-1:2011 Protection against lightning - Part 1: General Principles," February 2017 [82].
	International Council on Large Electric Systems (CIGRE)	Lightning Parameters for Engineering Applications, August 2013 [83].
	Energy Technologies Institute LLP (ETI)	Enabling Resilient UK Energy Infrastructure: Natural Hazard Characterisation Technical Volumes and Case Studies, Volume 9: Lightning, February 2018 [84].
	British Standards Institution	BS EN 62305-2:2012 Protection against lightning - Part 2: Risk management, May 2012 [85].
	British Standards Institution	PD 62305-2:2014 Flash density map 2014 - Supplement to BS EN 62305-2:2012 - Protection against lightning - Part 2: Risk management, 2014 [86].
Extreme Rainfall	UK Centre for Ecology & Hydrology	Flood Estimation Handbook (FEH) Web Service [87] [88].
	Met Office	UKCP18 Factsheet: Precipitation [89].
	Office for Nuclear Regulation	European Council "Stress Tests" for UK nuclear power plants, National Final Report [90].

External Hazard	Author	Title
Seismic	European Utility Requirements	EUR Vol. 2 Chp. 2.4 Generic and Nuclear Island Requirements, Revision E [57].
	ONR	"Stress Tests" for UK non-Power Generating Nuclear Facilities Final Report [91].
	British Geological Survey	National seismic hazard maps for the UK: 2020 update [92].
	British Standards Institution	BS EN 1998-1:2004+A1:2013 Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings [93].

21.4.3 CAE Summary

The External Hazard identification and characterisation undertaken in the development of both the GDA Reference Design and the GB GSE has been conducted in accordance with codes and standards, RGP, and international regulatory guidance. This guidance includes learning from previous UK GDA submissions and expectations outlined by both the US NRC and ONR.

21.5 EXTERNAL HAZARD IDENTIFICATION

Claim 2.1.5.2: A comprehensive set of External Hazards and their combinations are identified and screened for assessment.

21.5.1 Hazard Identification

Part A Chapter 2 [3] defines the GB GSE and the generic site characteristics to be used as the basis for the safety analysis. A comprehensive identification and screening process has been undertaken to identify the External Hazards relevant to the deployment of the generic SMR-300 on a generic site in Great Britain. This process has been developed in accordance with ONR SAPs EHA.1 and EHA.2 [22], and ENDP13 of the Environment Agency's 'Engineering: generic developed principles' guidance [94].

Figure 1 presents the methodology applied in the GSER [4] to identify credible External Hazards that are relevant to the GB context, can affect nuclear safety and can be considered on a generic basis. The first step of this methodology involved a comprehensive literature review of UK and International Regulatory Guidance documents, RGP, previous GDA submissions and previous work undertaken by Holtec to define a "universe of External Hazards". The codes and standards, and regulatory guidance examined in this process is provided in subchapter 21.4.2.1.

21.5.1.1 Screening of External Hazards

The result of the first step of Figure 1 is an extensive list of External Hazards which have been screened into the scope of the GB GSE. The following criteria have been developed in accordance with RGP to screen the extensive list of External Hazards, such that those remaining represent generic hazards relevant to the GB GSE:

1. The hazard has a frequency of < 10^{-7}/year for a site in GB – events occurring at less than this return frequency are unlikely to occur in the lifetime of the plant and can be screened out (ONR SAPs FA.5 and EHA.19) [22], [2].
2. The hazard does not affect nuclear safety, i.e., low consequence[1] – events that have no significant contribution to overall risks from the facility can be screened out (ONR SAPs EHA.19) [22], [2].
3. The hazard effect is bound by/included within the definition of another External Hazard such that it doesn't need to be assessed specifically. This bounding approach prevents excessive assessments from being undertaken [95].
4. The External Hazard is site specific:
    a. The hazard can only be assessed in detail at the site-specific stage[2]
    b. Commentary and a confidence statement can be provided during GDA; however, in most cases no design basis value can be derived at this stage. Assumptions have been made as to how the generic design should cope when

1 Where a hazard has been screened out on screening criterion 2, this judgement has been made based on common practice in the nuclear industry and is in keeping with other new build nuclear projects in the UK.

2 Where a hazard has been screened out on screening criterion 4a, an assumption has been made with regards to the protection concept implemented at the site-specific stage.

subject to the hazard with these assumptions captured in Table A.2 of the GSER [4].

5. The hazard is screened in, and a value can be derived.

This screening methodology is illustrated in Step 2 of Figure 1.

21.5.1.2 External Hazard Identification Summary

The full output from the External Hazards identification and screening process is presented in Appendix A of the GSER [4]. The following External Hazards have been screened-in with DBEs derived to define the GB GSE parameters, which establish the bounding characteristics of the GB GSE.

- Extreme Ambient Air Temperature.
- Extreme Cooling Water Temperature.
- Extreme Rainfall.
- Humidity.
- Icing.
- Snow.
- Extreme Wind.
- Tornadic Wind.
- Tornado-Generated Missiles.
- Lightning.
- Seismic.

Additionally, the following External Hazards have also been screened-in, but at this stage no DBE has been derived to establish a GB GSE parameter either due to the maturity of the hazard at this stage of the PSR or due to unknown site-specific variables:

- Aircraft Impact.
- Malicious Activity.
- Electromagnetic Interference (EMI).
- Space Weather.
- Loss Of Off-Site Power (LOOP).

Malicious aircraft impact parameters will be defined by the ONR through the threat definition provided in the regulatory expectation letter. However, these parameters will be excluded from this chapter because of the sensitive nature of the hazard.

LOOP is to be treated as a design basis fault in the safety analysis with LOOP events defined in Part A Chapter 2 [3].

An evaluation of each identified and screened-in External Hazard is provided in subchapter 21.7.

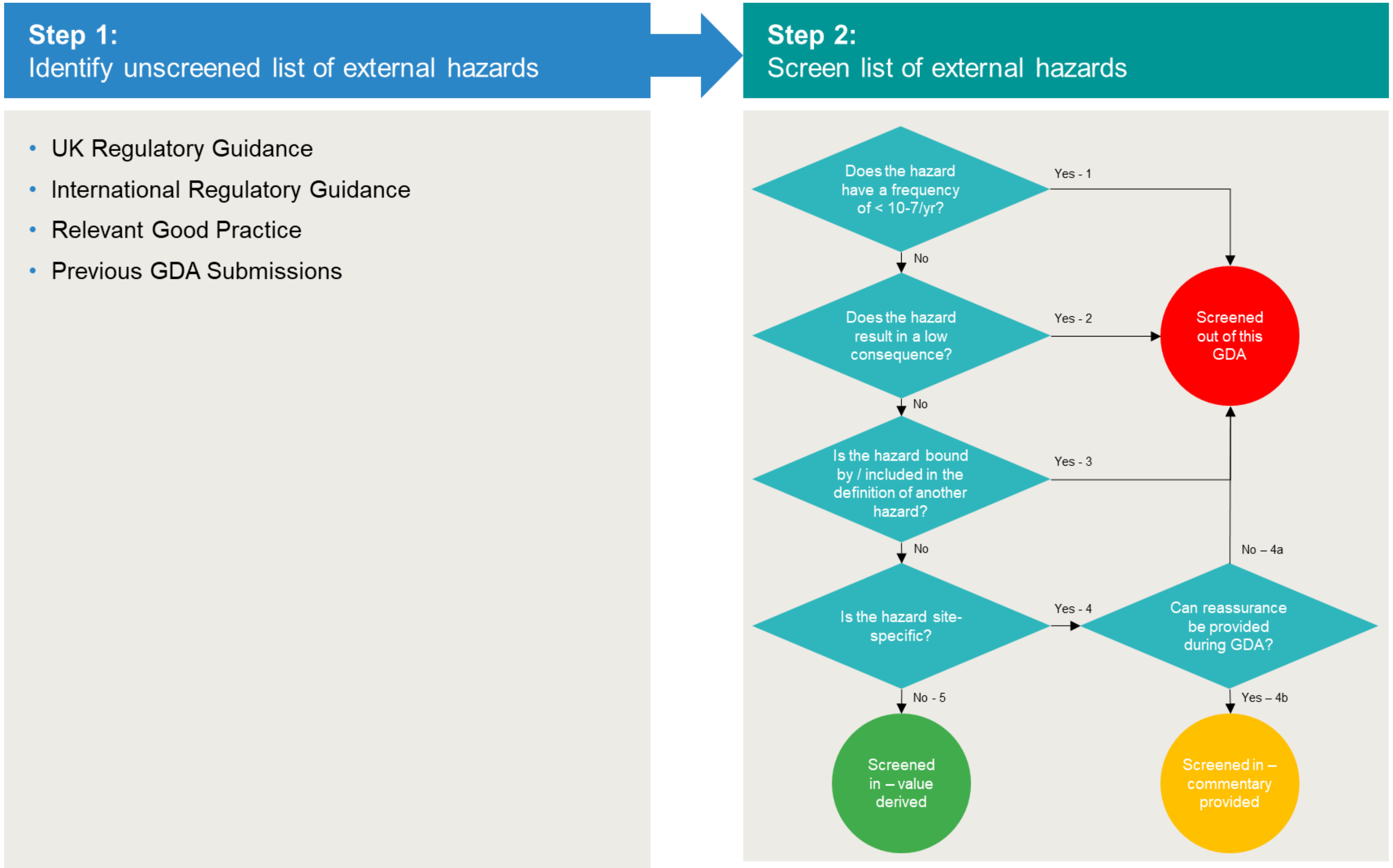

Figure 1: External Hazards Identification and Screening Methodology

21.5.2 Hazard Combinations

In line with ONR SAP [22] EHA.6, hazard combinations should be considered in the analysis of External and Internal Hazards. Hazard combinations are where the occurrence of multiple hazards occur at the same time with a compounding effect such that safety measures could be challenged/defeated. Hazard combinations are not explicitly considered in the US regulatory approach to External Hazards analysis, thus further work has been proposed to address this.

This subchapter presents a high-level methodology proposed for the identification and screening of hazard combinations for the generic SMR-300. It is the intent that this methodology will be reviewed during the production of PSR Revision 1 and, should newly identified RGP be forthcoming, will be amended as needed.

Figure 2 presents the methodology proposed for identifying hazard combinations that are relevant to the GB GSE. The methodology has the following steps:

- Step 1 – Identification of External Hazards and Internal Hazards.
- Step 2 – Identification and Categorisation of Hazard Combinations.
- Step 3 – Screening of Hazard Combinations.

Step 1 of this proposed methodology is to identify an unscreened list of individual External and Internal Hazards.

It is recognised that External Hazards previously screened out on low consequence should be reassessed in the context of combinations on the basis that the hazard combination may exacerbate the consequences.

21.5.2.1 Identification and Categorisation of Hazard Combinations

The identification of potential combinations of External Hazards will be achieved by forming a two-dimensional matrix based on the ASAMPSA_E approach [54].

The identified hazard combinations will then be categorised to demonstrate how the combination is likely to be realised. The following terminology supports the categorisation of the identified hazard combinations:

- Primary hazard: an External Hazard generated directly by a physical process outside the control of the site, for example, a storm event giving rise to wind and precipitation hazards.
- Secondary hazard: an External Hazard that is caused by and dependent on the occurrence of a primary hazard, for example, wind-driven waves occur as a direct result of wind effects on open water.
- Correlated hazard: an External Hazard that can occur simultaneously with the primary hazard because both depend on a common physical process, for example, a storm may give rise to both rain and lightning hazards at the same time.
- Consequential hazard/effects: hazards (internal and external) that are the derived effects of primary, correlated, and secondary hazards and/or their typical effects, leading to a direct challenge to site safety and/or site operations.

- Coincidental hazards: realistic combinations of randomly occurring independent External Hazards affecting the site simultaneously, for example, earthquake and air temperature hazards. These hazards are not correlated through a physical process.

Relevant correlated and consequential combinations will then be identified and extracted from the matrices to form an unscreened list of hazard combinations. Coincidental hazards and hazard combinations of three or more will be determined through a review of RGP and engineering judgement.

21.5.2.2 Screening of Hazard Combinations

The following criteria will then be used to screen the unscreened list of hazard combinations such that those remaining represent reasonably foreseeable generic hazard combinations relevant to GB-context.

1. The hazards are mutually exclusive, i.e., the hazard combination is not credible [54].
2. The hazard combination has a frequency of < 10^{-7}/year for a GB site [22], [2].
3. The hazard combination does not affect nuclear safety, i.e., low consequence [22], [2].
4. The hazard combination effect is bound by/included within the definition of another External Hazard, event, or hazard combination [95].
5. One or more of the hazards are site-specific.
    a. The hazard combination can only be assessed in detail at the site-specific stage[3].
    b. Commentary and a confidence statement can be provided; however, no value can be derived yet.
6. The hazard is screened in, and a value can be derived for the generic design.

3 Where a hazard has been screened out on screening criterion 5a, an assumption can be made with regards to the protection concept implemented at the site-specific stage.

Step 1: Identify unscreened list of external and internal hazards

- UK Regulatory Guidance
- International Regulatory Guidance
- Relevant Good Practice
- Previous GDA Submissions

Step 2: Identify and categorise hazard combinations

- Based on ASAMPSA_E approach, i.e. matrix approach
- Separate matrices used to identify combinations of external hazards with:
  - External hazards
  - Internal hazards
  - Design basis conditions
- Combinations will be categorised by:
  - Consequential hazards
  - Correlated hazards
  - Coincidental hazards

Step 3: Screen list of hazard combinations

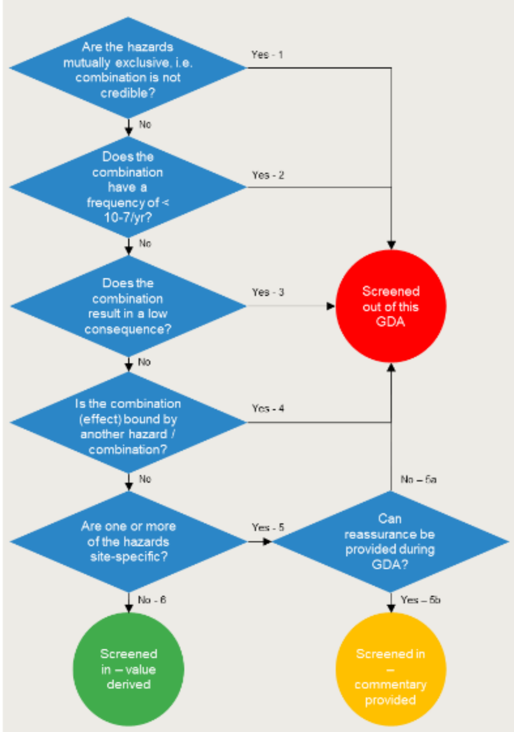

Figure 2: Proposed Methodology for Identification and Screening of Hazard Combinations

21.5.3 CAE Summary

A comprehensive hazard identification and screening methodology has been undertaken in accordance with RGP to identify credible External Hazards which are relevant to the deployment of the generic SMR-300 on a generic site in Great Britain, can affect nuclear safety and can be considered on a generic basis. This work, in addition to the proposed work to be undertaken for hazard combinations, provides a comprehensive set of External Hazards for assessment.

21.6 SSCS WITH EXTERNAL HAZARD SAFETY FUNCTIONS

Claim 2.1.5.3: Safety functions and safety measures are identified, categorised, and classified based on their importance to nuclear safety for all External Hazards and provide sufficient lines of protection based on the fault frequency and consequence.

PSR Part A Chapter 2 [3] introduces the SMR-300 high-level plant functions which have been developed in accordance with IAEA and US NRC guidance. The defined high-level plant functions shall be achieved for all plant states, except where a postulated condition involves the loss of that function, to maintain the physical barriers to the release of radioactivity to the environment.

All SSCs identified as within the scope of this GDA are provided in Appendix B of PSR Part A Chapter 2 [3]. In the case of External Hazards, typically the SSCs that are related to most of the External Hazards are the Civil SSCs, which are designed to have sufficient capacity to withstand applied external loads resulting from hazards such as extreme wind or snow. This engineering design requirement ensures that the high-level plant functions of the Civil SSCs, containment integrity and environmental protection, are maintained during a DBE. Further information on the Civil SSCs is provided in PSR Part B Chapter 20 [14].

The Holtec SMR Class is introduced in PSR Part A Chapter 2 [3] and includes the quality group, seismic category, and electrical category in accordance with US NRC Regulatory Guide 1.26, ‘Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste Containing Components of Nuclear Power Plants’ [96]. The most relevant category to the topic of External Hazards is the seismic category, since the dynamic loading induced by this hazard propagates through the civil nuclear structures challenging systems and components.

The seismic classification methodology used within the SMR Class system complies with US NRC Regulatory Guide 1.29 ‘Seismic Design Classification for Nuclear Power Plants’ [97]. Appendix S to 10 CFR Part 50, ‘Earthquake Engineering Criteria for Nuclear Power Plants,’ [98] contains the criteria to which the plant design bases demonstrate the capability to function during and after vibratory ground motion associated with the Safe Shutdown Earthquake (SSE) conditions.

SSCs with SMR Class A-C are designated as seismic category C-I, SSCs with SMR Class D are designated with seismic category C-II, and SSCs with SMR Class E-F are designated as non-seismic. SSCs that are designated as C-I are designed to withstand the effects of the SSE and remain functional. C-I applies to both functionality and integrity, and C-II applies only to integrity.

A review of Appendix B of PSR Part A Chapter 2 [3] shows that all SSCs in scope of GDA have been assigned SMR Classes A-D, and as a result are either seismic category C-I or C-II. Therefore, all in-scope SSCs identified in Appendix B are considered as SSCs with External Hazard safety functions.

As the fault studies topic area progresses, protection measures are to be identified for each External Hazard.

21.6.1 Categorisation and Classification

The safety categorisation and classification methodology currently defined for SMR-300 by Holtec International utilises the US NRC Regulatory Guide 1.26, Revision 6 [96] and related guidance documents.

Holtec acknowledge the existence of differences in the approach to safety categorisation and classification between the NRC regulatory guides and other international standards. The differences in the approach to safety categorisation and classification have been identified in ‘UK GDA Gap Analysis Report’ [99] and the ‘US/UK Regulatory Framework and Principles Report’ [100].

The methodology for safety categorisation and classification is outside the scope of this chapter and is to be undertaken within Part A Chapter 14 [6].

21.6.2 CAE Summary

The key requirement of the SMR-300 is to protect the reactor and its support systems from all credible identified External Hazards, including their combinations, and to provide containment and shielding to protect people and the environment.

A provisional strategy for categorisation and classification is provided within Part A Chapter [6] and its supporting deliverables. At this stage, the application of the US NRC guidance and US-based RGP provides confidence that safety functions and safety measures have been identified, categorised, and classified based on their importance to nuclear safety for all External Hazards.

21.7 EXTERNAL HAZARD EVALUATION

Claim 2.1.5.4: Analysis demonstrates that for all External Hazards, the identified safety features, in conjunction with operator actions, enable the plant to reach a safe state.

At Revision 0, this subchapter presents a preliminary evaluation of the External Hazards identified in subchapter 21.5 following the approach outlined in subchapter 21.2.2.

This subchapter will be further developed to address Claim 2.1.5.4 as the fault studies topics area progresses with hazard protection measures defined.

21.7.1 Meteorological External Hazards

21.7.1.1 Extreme Ambient Air Temperature

21.7.1.1.1 Hazard Characterisation

Extreme ambient air temperatures can be a hazard to safety related SSCs and their respective safety functions if the SSCs cannot be insulated and adequately protected.

Extreme high and low ambient air temperatures can affect safety related SSCs through the application of thermal loads to structural components and temperature gradients to safety systems typically associated with water. Typically, mitigation measures for such systems challenged by extreme low temperatures include insulation provided either by a designed weather envelope or the application of sufficiently insulating materials.

Extreme ambient air temperature is also a key design parameter in the design of HVAC systems which may be providing cooling to a safety related SSC.

The challenge made to the safety of the generic SMR-300 is to be further investigated in tandem with the progression of the fault studies topic area and the production of the PFS.

21.7.1.1.2 Derivation of GB GSE Parameter

Present-day peak hourly maximum and minimum dry bulb temperatures have been calculated to Eurocode BS EN 1991-1-5 [72] and the associated UK National Annex [73].

Maximum ambient air temperatures are projected to increase with climate change through the lifecycle of the generic SMR-300. The UKCP18 25 km probabilistic land projection models have been used to determine this projected increase in temperature to ensure the derived GB GSE parameters account for reasonably foreseeable climate change.

The GB GSE parameters for maximum and minimum dry bulb temperatures, and maximum wet bulb temperatures are presented in Table 6 below. Further explanation on the derivation of the maximum, minimum and wet bulb temperatures is provided in the GSER [4].

Table 6: GB GSE Parameters for Extreme Ambient Air Temperature

Parameter	GB GSE Parameter	
	Present Day	**Year 2100**
Maximum Peak Hourly Dry Bulb Temperature	(REDACTED)	(REDACTED)
Minimum Peak Hourly Dry Bulb Temperature	(REDACTED)	(REDACTED)
Maximum Peak Hourly Wet Bulb Temperature	(REDACTED)	(REDACTED)

21.7.1.1.3 Preliminary Evaluation of GDA Reference Design

In the GDA Reference Design an environmental envelope of ambient conditions has been specified following the guidance of EPRI Technical Report 'Advanced Nuclear Technology: Advanced Light Water Reactor Utility Requirements Document' [39].

A preliminary evaluation of the GDA Reference Design has found that the minimum dry bulb temperature applied in the GDA Reference Design bounds the GB GSE parameter. However, it was found that the derived maximum dry bulb and wet bulb air temperature GB GSE parameters exceed the GDA Reference Design parameters.

In this preliminary evaluation it's recognised that the temperatures derived for the GB GSE parameters are based on a 'peak hourly' measurement from the Eurocode [72] and it is likely conservative to assume these peak temperatures last for long duration events in the design of SSCs. At this stage, the External Hazard of extreme ambient air temperature has been identified as a topic requiring further investigation, and further work has been planned to address this at PSR Revision 1.

21.7.1.2 Humidity

21.7.1.2.1 Hazard Characterisation

Extreme humidity is typically grouped with extreme ambient air temperature as an External Hazard in terms of characterising the impact of the hazard on safety related SSCs. Humidity, along with extreme ambient air temperatures and enthalpy, is a key design parameter in the design of HVAC systems, which may be providing cooling to safety related SSCs. Extreme humidity can also adversely impact the functionality of I&C equipment.

The challenge made to the safety of the generic SMR-300 is to be further investigated in tandem with the progression of the fault studies topic area and the production of the PFS.

21.7.1.2.2 Derivation of GB GSE Parameter

The GB GSE parameters for maximum, minimum, and average relative humidity are presented in Table 7 below. These values have been adopted based upon Met Office Annual Average Relative Humidity Map for the temporal period of 1991-2020 [74]. Further explanation of the derivation can be found in the GSER [4].

Table 7: GB GSE Parameters for Humidity

Parameter	GB GSE Parameter
Maximum Relative Humidity	(REDACTED)

Parameter	GB GSE Parameter
Minimum Relative Humidity	(REDACTED)
Average Relative Humidity	(REDACTED)

21.7.1.2.3 Preliminary Evaluation of GDA Reference Design

In the GDA Reference Design an environmental envelope of ambient conditions has been specified following the guidance of Electric Power Research Institute (EPRI) Technical Report 'Advanced Nuclear Technology: Advanced Light Water Reactor Utility Requirements Document' [39].

At Revision 0, an evaluation of the humidity hazard for the GDA Reference Design is not possible due to the maturity of the PSR and available design documentation. However, US NRC Regulatory Guide 1.206 'Revision 0 - Combined License Applications for Nuclear Power Plants' [101] outlines the guidance for the consideration of regional meteorological conditions for design and operating bases, which includes the consideration of ambient temperatures and humidity statistics for design of plant heat sinks and HVAC systems. At this stage, the External Hazard of humidity has been identified as a topic requiring further investigation, and further work has been planned to address this at PSR Revision 1.

21.7.1.3 Extreme Cooling Water Temperature

21.7.1.3.1 Hazard Characterisation

Extreme cooling water temperature is typically a key design parameter for cooling systems which rely on a large body of water for cooling.

The hazard is typically highly correlated with the External Hazard of extreme ambient air temperature. However, this correlated relationship is complex and largely site-specific as it depends on the body of water subject to the extreme ambient air temperatures. For example, closed bodies of water such as lakes and reservoirs, may be more susceptible to warming and cooling than the sea because of the shallower depth of water and limited volume.

The challenge made to the safety of the generic SMR-300 is to be further investigated in tandem with the progression of the fault studies topic area and the production of the PFS.

21.7.1.3.2 Derivation of GB GSE Parameters

A review of sea water temperatures has been used to derive the GB GSE parameters for the External Hazard of extreme cooling water temperature [75]. It's acknowledged that these temperatures may not be representative of a prospective site which intends to utilise a closed body of water or lake for cooling purposes.

The present-day maximum sea water temperature adopted for the GB GSE is (REDACTED). Maximum Sea water temperatures are projected to increase with climate change through the lifecycle of the generic SMR-300. The 50th percentile of the RCP8.5 scenario projects an increase in temperature of approximately (REDACTED) [70]. Applying this factor to the present-day maximum Sea water temperature results in a temperature of (REDACTED).

The Met Office webpage states that typically seawater with a salinity of 35 parts per thousand will have a freezing point of approximately -1.8°C [75]. A minimum water temperature of (REDACTED) has been adopted for GB GSE.

The GB GSE parameters for maximum, minimum, and average Sea water temperatures are presented in Table 8.

Table 8: GB GSE Parameters for Extreme Cooling Water Temperature

Parameter	GB GSE Parameter
Maximum Sea Water Temperature (Present Day Value)	(REDACTED)
Maximum Sea Water Temperature (Climate Change Adjusted Value)	(REDACTED)
Minimum Sea Water Temperature	(REDACTED)
Average Sea Water Temperature	(REDACTED)

21.7.1.3.3 Preliminary Evaluation of GDA Reference Design

In the GDA Reference Design, systems utilising Lake Michigan as a source of water have been designed for the maximum postulated elevated temperature of Lake Michigan, which has been derived from analysis published by the National Oceanic and Atmospheric Administration (NOAA) 'Lake Michigan Average Great Lake Surface Environmental Analysis' [47].

A preliminary evaluation of the GDA Reference Design has found that the present-day maximum Sea water temperature derived for the GB GSE is bounded by GDA Reference Design parameter. However, the climate change adjusted maximum Sea water temperature derived for the GB GSE exceeds the GDA Reference Design parameter. At this stage, the External Hazard of extreme cooling water temperature has been identified as a topic requiring further investigation, and further work has been planned to address this at PSR Revision 1.

21.7.1.4 Extreme Wind

21.7.1.4.1 Hazard Characterisation

Extreme wind concerns the damage to the plant by the direct impact of strong wind pressure. The presence of extreme wind results in loading applied to Civil SSCs, in addition, the associated pressure can impact upon HVAC systems as well such that any required pressure cascades can be maintained. The provision of SSCs that can withstand the expected extreme wind conditions is the primary protection from this hazard.

In addition to wind, the presence of wind-generated missiles can also occur during a period of extreme wind. The primary protection from such hazards is by ensuring sources of potential missiles are eliminated to the extent possible.

The challenge made to the safety of the generic SMR-300 is to be further investigated in tandem with the progression of the fault studies topic area and the production of the PFS.

21.7.1.4.2 Derivation of GB GSE Parameter

A maximum ten-minute mean extreme wind speed of (REDACTED) has been derived for the GB GSE in accordance with the method outlined in Eurocode BS EN 1991-1-4 [76] and the associated UK National Annex [77].

The GB GSE parameters for extreme wind are presented in Table 9 below. Further explanation on the derivation of the extreme wind GB GSE parameters is provided in the GSER [4].

21.7.1.4.3 Preliminary Evaluation of GDA Reference Design

The extreme wind speed for the GDA Reference Design was derived to ASCE/SEI 7-16 [42] and envelopes the continental US.

All structures and systems with exterior elements important to safety, consider extreme wind loading in the design [17].

A comparison of the extreme wind parameters is provided in Table 9 to demonstrate that the GDA Reference Design parameter bounds the GB GSE parameter with significant margin present.

Table 9: Comparison of Extreme Wind Parameters

Parameter	GB GSE Parameter	GDA Reference Design Parameter[4]
Wind Speed (ten-minute mean)	(REDACTED)	(REDACTED)
Wind Speed (three-second gust)	(REDACTED)	(REDACTED)

21.7.1.5 Tornadic Wind

21.7.1.5.1 Hazard Characterisation

Tornadic wind concerns the damage to the plant by the direct impact of direct impact of strong tornadic wind pressure, including the effects of pressure differences and rotating wind. This hazard differs from other extreme wind hazards due to the special characteristics of duration, wind speed, and occurrence frequency.

Similar to extreme wind covered within subchapter 21.7.1.4, the primary protection against tornadoes, is through the provision of weather envelopes that can withstand the required wind speeds and overpressures. Tornado generated missiles are covered within subchapter 21.7.1.6.

The challenge made to the safety of the generic SMR-300 is to be further investigated in tandem with the progression of the fault studies topic area and the production of the PFS.

[4] ASCE/SEI 7-16 [42] adopts a three second gust measurement of wind speed whereas Eurocode BS EN 1991-1-4 [76] and the associated UK National Annex [77] adopts a ten-minute mean wind speed. Figure C26.5-1 of ASCE/SEI 7-16 provides a method to convert between the two measurements.

21.7.1.5.2 Derivation of GB GSE Parameter

The design basis tornado for the GB GSE has been derived from US NRC Regulatory Guide 1.76 [32]. 'Region III' has been adopted for the GB GSE, which presents a design basis tornado equivalent to a T5 tornado on the International Tornado Intensity Scale. A tornado of this intensity is considered very conservative in the GB context.

The influence of climate change on tornado intensity and frequency is currently unknown. Holtec are confident that the design basis tornado assumed for the GB GSE is sufficiently conservative to account for any future projections.

The GB GSE parameters for tornadic wind are presented in Table 10 below. Further explanation on the derivation of the tornadic wind GB GSE parameters is provided in the GSER [4].

21.7.1.5.3 Preliminary Evaluation of GDA Reference Design

The design basis tornado for the GDA Reference Design has been derived from US NRC Regulatory Guide 1.76 [32]. 'Region I' has been adopted for the design basis tornado for the GDA Reference Design, which is the geographical region of the US with the most severe tornadoes. This is equivalent to a T8 tornado on the International Tornado Intensity Scale and therefore is conservatively bounding of the GB GSE.

All structures and systems with exterior elements important to safety, consider tornadic wind loading in the design. Additionally, all structures and systems with exterior elements important to safety, consider hurricane wind loading in the design [17].

A comparison of the tornadic wind parameters is provided in Table 10 to demonstrate that the GDA Reference Design parameters are bounding of the GB GSE parameters.

Table 10: Comparison of Tornadic Wind Parameters

Parameter	GB GSE Parameter	GDA Reference Design Parameter
Rotational Wind Speed	(REDACTED)	(REDACTED)
Maximum Wind Speed	(REDACTED)	(REDACTED)
Translational Speed	(REDACTED)	(REDACTED)
Radius of Maximum Rotation Speed	(REDACTED)	(REDACTED)
Atmospheric Pressure Drop	(REDACTED)	(REDACTED)
Rate of Pressure Drop	(REDACTED)	(REDACTED)

21.7.1.6 Tornado Generated Missiles

21.7.1.6.1 Hazard Characterisation

Tornado generated missiles hazard is defined by the damage to the plant due to the impact of tornadic-wind-blown missiles. The primary protection against tornado-generated missiles, is through the design of structures to provide sufficient protection to SSCs important to safety.

The challenge made to the safety of the generic SMR-300 is to be further investigated in tandem with the progression of the fault studies topic area and the production of the PFS.

21.7.1.6.2 Derivation of GB GSE Parameters

Tornado generated missiles for the GB GSE have been derived from US NRC Regulatory Guide 1.76 [32]. 'Region III' has been adopted for the GB GSE to align with the approach undertaken for tornadic wind.

21.7.1.6.3 Preliminary Evaluation of GDA Reference Design

Tornado generated missiles for the GDA Reference Design have been derived from US NRC Regulatory Guide 1.76 [32]. 'Region I' has been adopted for the GDA Reference Design to align with the approach undertaken for tornadic wind.

All structures and systems with exterior elements important to safety, are analysed and designed for the defined missiles hazards [17].

A comparison of the tornado generated missile parameters is provided in Table 11 to demonstrate that the GDA Reference Design parameters are bounding of the GB GSE parameters.

Table 11: Comparison of Tornado Generated Missile Parameters

Parameter	Mass	GB GSE Parameter	GDA Reference Design Parameter
Schedule 40 Pipe: 0.168 m diameter x 4.58 m long	130 kg	(REDACTED)	(REDACTED)
Automobile: 4.5 m x 1.7 m x 1.5 m	1178 kg	(REDACTED)	(REDACTED)
Solid Steel Sphere: 2.54 cm diameter	0.0669 kg	(REDACTED)	(REDACTED)

21.7.1.7 Icing

21.7.1.7.1 Hazard Characterisation

There are many types of ice to be considered in the assessment of NPPs such as frazil ice, rime ice, clear ice, and glaze ice.

Frazil ice is the formation of loose needle-shaped ice crystals within a turbulent body of water. The resulting slush has been attributed to several issues at NPPs, such as blocking the screening system within the water intake. Frazil ice has been screened as site-specific in the GSER [4] as the formation of Frazil ice is dependent on the salinity of the water source and any solution developed should be tailored to the site.

The ASCE journal publication, "Prevention of Water Intake Blockage by Ice during Supercooling Events" [102] is a state-of-the-art review on preventing water intake blockage by ice. Typical solutions include:

- Avoidance (i.e., locating the intake such that it is never exposed to a supercooling event).

- Prevention (i.e., stopping supercooled water entering the intakes).
- Mitigation (i.e., modifying the intake such that the degree of blockage is minimised).
- Remediation (i.e., removing blockage once it has formed).

Rime, clear and glaze ice all form on surfaces and need to be accounted for in the design of lightweight external structures. The formation of ice on the surface of structures applies an additional load to the structure whilst also increasing the total applied wind load because of the increased surface area.

The challenge made to the safety of the generic SMR-300 is to be further investigated in tandem with the progression of the fault studies topic area and the production of the PFS.

21.7.1.7.2 Derivation of GB GSE Parameters

Eurocode BS EN 1993-3-1 [78] and the respective UK National Annex [79] has been used to derive the GB GSE icing parameters. Further explanation on the derivation is provided in the GSER [4].

A summary of the GB GSE icing parameters is provided in Table 12. In Table 12, an unfavourable action refers to the case where the unit weight of ice increases the resultant stress in a structural element. Whereas a favourable action refers to the case where the unit weight of the ice acts to reduce the resultant stress in a structural element.

Table 12: GB GSE Parameters for Icing

Parameter	GB GSE Parameter
Radial Ice Thickness, r_o (without wind)	(REDACTED)
Radial Ice Thickness, r_w (with wind)	(REDACTED)
Unit Weight of Ice (without wind)	(REDACTED)
Unit Weight of Ice (unfavourable action with wind)	(REDACTED)
Unit Weight of Ice (favourable action with wind)	(REDACTED)

21.7.1.7.3 Preliminary Evaluation of GDA Reference Design

At Revision 0, an evaluation of the GDA Reference Design, with respect to the icing hazard, has not been undertaken due to the maturity of the design documentation available.

In the US, ASCE 7-10, ‘Minimum Design Loads for Buildings and Other Structures’ [103] is typically used in the design of ice-sensitive structures and covers the atmospheric ice loads caused by freezing rain, snow, and in-cloud icing. This code of practice is considered RGP and is aligned with the approach outlined in Eurocode BS EN 1993-3-1 [78].

21.7.1.8 Snow

21.7.1.8.1 Hazard Characterisation

Extreme snow loading can lead to damage of safety related SSCs, particularly the roofs of structures, due to overloading and potential disruption of power delivery systems (e.g., due to the build-up of snow and ice pack on power lines). In addition to ‘normal’ snow, snow drift is an important consideration especially where one building abuts another. Snow drifts have the potential to apply greater snow loading than 'normal' snow and can result in the burying/clogging of SSCs, e.g., substations, HVAC intakes.

Where SSCs do not have sufficient capacity to withstand snow loading, or the formation of snow drift, there is a risk of collapse or blockage. Typically, SSCs are substantiated to withstand the design basis snow loading plus additional margin to accommodate credible beyond design basis occurrences. Protection from snow drifting is typically site specific such that barriers/wind breaks can be installed away from SSCs in the orientation of the prevailing wind to prevent snow build up on key SSCs.

The challenge made to the safety of the generic SMR-300 is to be further investigated in tandem with the progression of the fault studies topic area and the production of the PFS.

21.7.1.8.2 Derivation of GB GSE Parameter

An extreme snow load has been derived for the GB GSE in accordance with the methods outlined in Eurocode BS EN 1991-1-3 [80] and the respective UK National Annex [81].

The design basis ground snow load for the GB GSE has been determined as (REDACTED) kN/m^2. Further explanation on the derivation is provided in the GSER [4].

21.7.1.8.3 Preliminary Evaluation of GDA Reference Design

A design basis 'normal' snow load has been derived for the GDA Reference Design following the guidance provided in EPRI Technical Report, 'Advanced Nuclear Technology: Advanced Light Water Reactor Utility Requirements Document,' [39].

An extreme snow load has been derived following a recent US NRC observation on the North Anna 3 Licence Application [40]. This extreme snow load considers the combination of a 100 year snowpack and weight of probable maximum winter precipitation accumulation.

All structures for which by design snowpack cannot practically accumulate with concurrent rainfall, the normal snow load is applied for defining snow load in lieu of the extreme load [17].

A comparison of the snow parameters is provided in Table 13 to demonstrate that the GDA Reference Design parameter is bounding of the GB GSE parameter. This margin also provides confidence that the GDA Reference Design has the capacity to account for any potential increases in UK snow load due to climate change which have not been accounted for within the derivation of the GB GSE parameter.

Table 13: Comparison of Snow Parameters

Parameter	GB GSE Parameter	GDA Reference Design Parameter
Snow Loading	(REDACTED)	(REDACTED)
Extreme Snow Loading	(REDACTED)	(REDACTED)

21.7.1.9 Lightning

21.7.1.9.1 Hazard Characterisation

The Met Office defines thunderstorms as a series of sudden electrical discharges resulting from atmospheric conditions [104] with frequency and intensity varying regionally across the UK.

Lightning can impact the plant directly, causing structural damage, or resulting in a LOOP through the production of EMI, or indirectly through fire started by lightning.

The typical protection measure for lighting strikes is a robust lighting protection system to arc primary strikes to the ground. For secondary strikes, surge protection and suitable grounding is the typical form of protection to prevent the overloading of electrical devices. Additionally, reinforced concrete structures can be designed to act as a Faraday Cage in the event of a lightning strike providing that the reinforcement is adequately connected and earthed.

The challenge made to the safety of the generic SMR-300 is to be further investigated in tandem with the progression of the fault studies topic area and the production of the PFS.

21.7.1.9.2 Derivation of GB GSE Parameters

The GB GSE parameters for lightning are presented in Table 14. Further explanation on the derivation is provided in the GSER [4].

BS EN 62305-1 [82] proposes a peak lightning current of 200 kA. EUR guidance [57] also proposes a design basis lightning current of 200 kA for a first stroke and 50kA for a second stroke.

However, both the CIGRE report [83] and Volume 9 of ETI [84] suggest a maximum credible peak current of 300 kA. Therefore, a value of (REDACTED) has been adopted for the GB GSE.

The UK committee (GEL/81 – protection against lightning) undertook a review of BS EN 62305-2 [86] and provided a UK interpretation of the standard in Annex NF of [85]. Annex NF presents a global map of the number of thunderstorm days per year based on record information from the World Meteorological Organization for the year 1955. The data shows that the UK is positioned between the five thunderstorm days a year contour and the 20 thunderstorm days per year contour, with the South-East of England shown to experience approximately 15 thunderstorm days per year.

The supplementary Flash Density Map 2014 [85] to [86] shows a maximum flash density of 1.4 flashes per km^2 per year for the UK. This value has been adopted for the GB GSE to conservatively bound all of the sites considered.

Table 14: GB GSE Parameters for Lightning

Lightning Parameter	GB GSE Parameter
Peak Lightning Current	(REDACTED)
Thunderstorm Days	(REDACTED)
Mean Flash Frequency	(REDACTED)

21.7.1.9.3 Preliminary Evaluation of GDA Reference Design

In the GDA Reference Design, grounded and lightning protection systems are incorporated to protect SSCs from potential lightning strikes, as per US NRC Regulatory Guide 1.204 [43].

At Revision 0, a preliminary evaluation of the GDA Reference Design against the defined GB GSE peak lightning current has not been undertaken due to the maturity of the PSR and available design documentation. At this stage, lightning has been identified as a topic requiring further investigation, and further work has been proposed to address this topic at PSR Revision 1.

21.7.2 Flooding and Hydrological External Hazards

21.7.2.1 Flooding

Flooding is a site-specific External Hazard, and all types of associated flooding hazards will be assessed at the site-specific stage; no GB GSE parameters are derived.

In the development of the GB GSE, it has been assumed that the 'Generic Site' is 'dry' when subjected to flood levels up to the design basis, as such the site operator will develop a protection solution to ensure this for their site. The 'Dry Site Concept' defined in IAEA, No. SSG-18, 'Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations' [105] and promoted in ONR and Environment Agency (EA) guidance document, 'Principles for Flood and Coastal Erosion Risk Management Revision 2' [106] is considered RGP, but it will be up to a future site operator to determine whether to pursue this or a hybrid solution including flood protection barriers.

At the site-specific stage, a detailed assessment will be required to understand the effect of all types of associated flooding hazards relevant to a specific prospective site. Further work has been proposed to outline the methodology and strategy for the consideration of beyond design basis flooding.

21.7.2.2 Extreme Rainfall

21.7.2.2.1 Hazard Characterisation

Extreme rainfall can be a hazard to safety related SSCs and their safety functions if the SSCs cannot either withstand the force from standing water or withstand the rainfall (e.g., failure of electrical equipment exposed to rainfall). Typically, mitigation measures for such systems challenged by extreme rainfall include the provision of adequate drainage to prevent the build-up of water, sufficient design load margins for structural SSCs, and suitable Ingress Protection Ratings for any exposed electrical equipment that cannot be housed inside.

The challenge made to the safety of the generic SMR-300 is to be further investigated in tandem with the progression of the fault studies topic area and the production of the PFS.

21.7.2.2.2 Derivation of GB GSE Parameters

Extreme rainfall events for the GB GSE have been derived using the Flood Estimation Handbook Depth-Duration-Frequency (FEH DDF) models [87], [88] for a 1 in 10,000 year event with an applied factor from the UKCP18 projections to account for reasonably foreseeable climate change over the lifetime of the facility.

The GB GSE parameters for extreme rainfall are presented in Table 15 below. Further explanation on the derivation of the extreme rainfall GB GSE parameters is provided in the GSER [4].

21.7.2.2.3 Preliminary Evaluation of GDA Reference Design

Extreme rainfall events applied in the GDA Reference Design have been derived in accordance with US RGP. A five-minute rainfall event and a one-hour rainfall event have been derived in accordance with EPRI Technical Report 'Advanced Nuclear Technology: Advanced Light Water Reactor Utility Requirements Document' [39]. A six-hour rainfall event has been derived from the Final Safety Analysis Report for the North Anna 3 Combined Licence Application [40]. A 24-hour rainfall event has been derived from NOAA National Weather Service Hydrometeorological Design Studies Centre [46].

A comparison of the extreme rainfall parameters is provided in Table 15 to demonstrate that the GDA Reference Design parameters are clearly bounding of the GB GSE parameters.

Table 15: Comparison of Extreme Rainfall Parameters

Parameter	GB GSE Parameter	GDA Reference Design Parameter
5 minute	(REDACTED)	(REDACTED)
1 hour	(REDACTED)	(REDACTED)
6 hour	(REDACTED)	(REDACTED)
24 hour	(REDACTED)	(REDACTED)

21.7.3 Seismic

21.7.3.1 Hazard Characterisation

Seismic events are considered site-specific in nature with probabilistic seismic hazard assessments typically undertaken to characterise the hazard for a specific site. At GDA, to the extent possible, a generic seismic hazard can be defined on a "best-estimate" basis utilising regional hazard maps and widely adopted Seismic Design Response Spectra (SDRS).

There are several External Hazards associated with seismic activity, such as liquefaction and capable faulting, that can only be assessed at the site-specific stage and therefore are screened out of the scope. Further information on the screening process can be found in subchapter 21.5.1.1 of this PSR chapter and in Appendix A of the GSER [4].

The External Hazard of seismic induced vibration presents a significant challenge to nuclear safety because all SSCs may be simultaneously subjected to dynamic loading. A seismic classification system is typically implemented across a nuclear power plant to define the performance requirements on SSCs when subjected to a seismic event.

21.7.3.2 Derivation of GB GSE Parameters

Design basis earthquakes are often defined in terms of a design response spectrum anchored to a Peak Ground Acceleration (PGA) value. The PGA is a function of the geological characteristics of the ground present and the distance of the site from the epicentre of the earthquake.

A representative seismic design response spectrum applicable to a GB site and adopted by other generic designs subjected to the GDA process is the EUR spectra [57]. These spectra have been used to define the seismic hazard for the GB GSE with the EUR Hard spectrum anchored at a PGA of (REDACTED) g, and the Medium and Soft spectra anchored at a PGA of (REDACTED) g. Further information on the derivation of the PGA values and the justification behind adopting the EUR spectra is provided in the GSER [4].

Paragraph 254 of the ONR SAPs [22] states that an Operating Basis Earthquake (OBE) should be defined where no SSC should be impaired by ground motions at the OBE level.

The EUR code [57] states that the Designer shall provide information on the maximum level of earthquake under which no specific inspection would be required to continue with operation, equivalent to the OBE defined above. The EUR code [57] suggests typical values of horizontal PGA in the range of (REDACTED) g to (REDACTED) g. Thus, an OBE of (REDACTED) g has conservatively been adopted for the GB GSE.

21.7.3.3 Preliminary Evaluation of GDA Reference Design

The SDRS used for the GDA Reference Design is based on a modified version of the NRC Reg. Guide 1.60 spectra [38] anchored at a PGA of (REDACTED) g in each orthogonal direction. Notably, the SDRS are anchored below grade at the base of the Containment Enclosure Structure (CES).

A PGA of (REDACTED) g can be considered very conservative for the UK resulting in a conservative seismic design in the context of the GB GSE. The GDA Reference Design defines an OBE of (REDACTED) g in all directions, which is 1/3 of the design basis earthquake. Further information on the seismic analysis methodology is provided in Part B Chapter 20 [14].

A comparison of the seismic parameters is provided in Table 16 to demonstrate that the GDA Reference Design parameters are bounding of the GB GSE parameters.

Table 16: Comparison of Seismic Parameters

Parameter	GB GSE Parameter	GDA Reference Design Parameter
Design Basis Earthquake, PGA	(REDACTED)	(REDACTED)
	(REDACTED)	
Operating Basis Earthquake, PGA	(REDACTED)	(REDACTED)

Figure 3 further demonstrates that the SDRS adopted in the GDA Reference Design is suitably bounding of the EUR spectra [57] anchored at a PGA representative of the sites considered within the GB GSE. Further discussion is provided in the GSER [4].

REDACTED

Figure 3: (REDACTED)

21.7.4 Human-Induced External Hazards

21.7.4.1 Aircraft Impact

21.7.4.1.1 Hazard Characterisation

Aircraft impact is a human induced External Hazard to be considered in the safety assessment of any NPP. This safety assessment considers the damage made to the plant including dynamic impact loads applied to structures and any consequential effects such as aircraft impact induced vibrations and fire.

There are two categories of aircraft impact: accidental and malicious. Accidental aircraft impact has been screened as a site-specific External Hazard. At the site-specific stage it should be determined whether the accidental aircraft impact hazard has a total initiating frequency that is demonstrably below once in 10 million years. A method for determining the total initiating frequency of an accidental aircraft impact for a range of aircraft types is provided in the GSER [4].

Malicious, or “malevolent” as known in the US, aircraft impact is within the scope of GDA. The assessment of malicious aircraft impact is to be addressed in detail outside of this chapter due to the sensitive and classified nature of the hazard.

21.7.4.1.2 Derivation of GB GSE Parameters

No GB GSE parameter has been derived for accidental aircraft impact due to the site-specific nature of the hazard. It’s also expected that the malicious case will likely govern the design for aircraft impact at the site-specific stage.

The UK threat definition for malicious aircraft impact is defined by the ONR. Holtec understand that the ONR will issue an expectation letter providing this threat definition and outlining the regulatory expectations for the consideration of malicious aircraft impact on a UK nuclear site.

21.7.4.1.3 Preliminary Evaluation of GDA Reference Design

The details of the malicious aircraft used in the GDA Reference Design including maximum take-off weight, impact velocity, and angle of impact are security classified and therefore, no information is provided within this report. An evaluation of the GDA Reference Design, with respect to malicious aircraft impact, will be undertaken upon the receipt of the ONR regulatory expectation letter.

The GDA Reference Design considers aircraft impact in accordance with US NRC guidance and 10 CFR 50.150(a) [48], which states that any new reactor designed after July 13, 2009, requires a design-specific assessment of the effects on the facility from the beyond-design-basis impact of a large, commercial aircraft used for long distance flights in the United States.

To satisfy the requirements of 10 CFR 50.150(a) [48] an aircraft impact safety assessment is performed in accordance with the following standards:

- Realistic analyses per NEI 07-13, 'Methodology for Performing Aircraft Impact Assessments for New Plant Designs' [49].
- US NRC Regulatory Guidance 1.217, 'Guidance for the Assessment of Beyond Design Basis Aircraft Impacts' [37].

The following general requirements apply for the generic SMR-300 design following aircraft impact:

a) The reactor core shall remain coolable.
b) The containment shall remain intact.
c) Spent Fuel Pool (SFP) cooling and SFP integrity is maintained.
d) The following structures shall be demonstrated that they are able to continue to perform their safety functions following the External Hazard event:
    i. CES and Containment Structure (CS).
    ii. Main Control Room (MCR) and Remote Shutdown Facility (RSF) areas of the Reactor Auxiliary Building (RAB).
e) Missile effects on important to safety SSC shall be considered.
f) Safety functions of safety systems shall not be degraded, such as due to the effects of the External Hazard event on nearby SSC or consequential missile hazards.
g) Support systems integrity shall be maintained such that there is no degradation of the availability of fundamental safety functions following the External Hazard event.

Further work has been planned to address the aircraft impact hazard at Revision 1 of the PSR.

21.7.4.2 Malicious Activity

Malicious activity will be addressed separately via a Threat Interpretation Report due to the sensitive and classified nature of the hazard.

21.7.5 Electromagnetic Interference

21.7.5.1 Hazard Characterisation

Electromagnetic Interference is defined in ONR TAG 13 Annex 5, 'Other External Hazards' [107] as "a disturbance that affects an electrical circuit due to electromagnetic radiation emitted from an external source". This disturbance has the potential to interrupt, obstruct or limit the performance of safety related I&C, and electrical equipment.

EMI can be a result of a variety of natural external sources including lightning strikes, electrical storms, and extra-terrestrial events such as solar flares. Other external sources of EMI include human-induced sources such as communication systems and electrical circuits.

EMI sources that originate from within the site are considered as Internal Hazards, which are the subject of Part B Chapter 22 'Internal Hazards' [9].

The challenge made to the safety of the generic SMR-300 is to be further investigated in tandem with the progression of the fault studies topic area and the production of the PFS.

21.7.5.2 Derivation of GB GSE Parameter

EMI, arising from sources external to the site and its processes, has been screened as a site-specific hazard in the GSER [4]. At the site-specific stage, all local sources of EMI should be identified and characterised.

The hazard is still within the scope of GDA but at this stage no DBE has been derived to establish a GB GSE parameter. A design basis peak lightning current has been defined for the GB GSE with the derivation presented in subchapter 21.7.1.9.

21.7.5.3 Preliminary Evaluation of GDA Reference Design

The GDA Reference Design follows the guidance provided in US NRC Regulatory Guide 1.180, 'Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems' [44]. This is an established code of practice used in the design of NPPs in the US and provides guidance for evaluating EMI in I&C systems. This includes guidance on testing procedures to determine whether EMI presents a significant hazard to the plant.

21.7.6 Space Weather

21.7.6.1 Hazard Characterisation

Space weather is a collective term to describe the effects at or close to the Earth's surface of variations in the Sun, solar wind, magnetosphere, ionosphere, and upper atmosphere [108]. There are a variety of associated External Hazards that need to be considered within the design of NPPs.

Large Geomagnetically Induced Currents (GICs) can be produced from solar flares and Coronal Mass Ejections (CMEs). Solar flares are defined as the sudden release of electromagnetic radiation from the Sun. A CME is the ejection of magnetized plasma from the Sun, which can drive geomagnetic storms if their magnetic orientation opposes the geomagnetic field. GICs can lead to transformer damage, voltage instability and harmonics triggering protective relays, which could all result in a LOOP event. Infrastructure typically affected by GIC events includes electrical power transmission systems, pipelines, and railways [107].

GIC is a site-specific hazard and is related to the UK power network topology, the geomagnetic latitude of the site, the ground conductivity profile and the proximity to the coast.

Solar Energetic Particle (SEP) events consist of the ejection of protons, electrons, and ions from the Sun. SEPs can cause a Ground Level Enhancement event which can disrupt the performance of I&C and electrical equipment.

The challenge made to the safety of the generic SMR-300 is to be further investigated in tandem with the progression of the fault studies topic area and the production of the PFS.

21.7.6.2 Derivation of GB GSE Parameter

Space weather has been screened as a site-specific hazard in the GSER [4]. The hazard is still within the scope of GDA but at this stage no national or regional DBE has been derived to establish a GB GSE parameter.

21.7.6.3 Preliminary Evaluation of GDA Reference Design

At Revision 0, a preliminary evaluation of the space weather hazard for the GDA Reference Design has not been undertaken due to the maturity of the PSR and available design documentation.

21.7.7 CAE Summary

The key requirement of the SMR-300 is to protect the reactor and its support systems from all credible External Hazards identified, including their combinations, and to provide containment and shielding to protect people and the environment.

The maturity of this claim will develop as the GDA progresses with the PFS planned to act as the vehicle to capture all of the credible External Hazards, along with their fault progressions, to ensure that sufficient safety measures and lines of protection are in place. Substantiation and validation of these safety measures will be provided by their corresponding disciplines, e.g., Civil Engineering, Mechanical Engineering etc.

At this stage, the application of the US NRC guidance and US-based RGP provides confidence that safety measures in conjunction with operator actions, enable the plant to reach a safe state. The preliminary evaluation of each External Hazard has demonstrated that in many cases significant margin is present between the GDA Reference Design, and the requirements of a generic site in Great Britain bounded by the GB GSE. Further work is planned to address External Hazards where the preliminary evaluation has identified a difference in hazard characterisation and/or design basis magnitude between the GDA Reference Design and the GB GSE.

21.8 CHAPTER SUMMARY AND CONTRIBUTION TO ALARP

This subchapter provides an overall summary and conclusion of the External Hazards Chapter and how this chapter contributes to the overall demonstration of ALARP for the generic SMR-300. PSR Part A Chapter 5 ‘Summary of ALARP’ [109] sets out the overall approach for demonstration of ALARP and how contributions from individual chapters are consolidated.

This subchapter therefore consists of the following elements:

- Technical Summary.
- ALARP Summary.
    - Review against Relevant RGP.
    - Demonstration Against Risk Targets.
        - Evaluation of Risk.
    - Risk Reduction Options.
    - GDA Commitments and Forward Actions.
- Conclusion.

A review against these elements is presented below under the corresponding headings.

21.8.1 Technical Summary

PSR Part B Chapter 21, Revision 0 aims to provide confidence that the in-scope SSCs with External Hazard related safety functions will meet the high-level claims of the SSEC and that the SSCs can be substantiated at Pre-Construction Safety Report (PCSR) stage. This is to be demonstrated through the following claim:

Claim 2.1.5: Risks from External Hazards and their combinations have been demonstrated to be tolerable and As Low As Reasonably Practicable (ALARP).

A key requirement of the SMR-300 is to protect the reactor and its support systems from all credible identified External Hazards, including their combinations, and to provide containment and shielding to protect people and the environment. Substantiation and validation of these safety measures will be provided by their corresponding disciplines, e.g., Civil Engineering, Mechanical Engineering etc.

A comprehensive hazard identification and screening methodology has been undertaken in accordance with RGP to identify credible External Hazards which are relevant to the deployment of the generic SMR-300 on a generic site in Great Britain, can affect nuclear safety and can be considered on a generic basis. The identified External Hazards have then been characterised following appropriate codes and standards, taking cognisance of RGP and OPEX, to establish the GB GSE parameters.

All the identified External Hazards are to be treated as initiating events in the fault studies analysis with suitable withstand capacity and sufficient safety measures identified for each hazard. This exercise is to be undertaken in conjunction with the development of PSR Part B Chapter 14 [6], and the production of the PFS.

At Revision 0 of the PSR, where possible, a preliminary evaluation of the GDA Reference Design has been undertaken for each of the identified External Hazards. This preliminary evaluation has demonstrated that for many of the identified External Hazards there is significant margin present between the GDA Reference Design parameters and the GB GSE parameters providing confidence in the robustness of the generic SMR-300 in the context of a UK deployment. This evaluation has also identified hazards which require further investigation to address initial gaps in hazard characterisation and/or design basis magnitude. In some cases, a preliminary evaluation had not been undertaken at this stage due to the maturity of the design documentation available.

For Revision 0 it is deemed that the maturity of the safety justification presented in this chapter (Part B Chapter 21) is appropriate for a PSR. The comprehensive hazard identification process and the preliminary evaluation of the GDA Reference Design provide confidence that Claim 2.1.5, will be substantiated in future safety submissions and risks evaluated as tolerable and ALARP.

21.8.2 ALARP Summary

21.8.2.1 Demonstration of Relevant Good Practice

The approach to External Hazards inherent within the generic SMR-300 design complies with RGP and US NRC requirements applicable in the US. The design adopts nuclear-specific codes and standards endorsed by the US NRC and internationally recognised bodies such as the IAEA. The codes, standards and international regulatory guidance applied to identify and characterise External Hazards in the GDA Reference Design are presented in subchapter 21.4.

The GB GSE has been established in accordance with RGP and international regulatory guidance. The hazard identification process undertaken in the GSER [4] consisted of a comprehensive literature review of UK and International Regulatory Guidance documents, RGP, previous GDA submissions and previous work undertaken by Holtec International to define a “universe of External Hazards”, which consisted of an extensive unscreened list of External Hazards. This included guidance from the ONR [2], [22], IAEA [50], Western European Nuclear Regulators' Association (WENRA) [51], [52], SKI [53], ASAMPSA [54], the OECD [55], [56] and the US NRC [58] to name a few. This extensive list of External Hazards has then been screened applying a criteria developed in accordance with RGP from the ONR [2], [22] and the IAEA [95].

Any gaps in hazard identification and characterisation between the GDA Reference Design and the GB GSE, and UK RGP, have been identified with further work planned. Forward actions will form the basis for setting out the process to justify any gaps from UK RGP.

Forward Actions have been collated and are managed via the process described in PSR Part A Chapter 4 ‘Lifecycle Management of Safety and Quality Assurance’ [110].

21.8.2.2 Demonstration Against Risk Targets

The numerical targets against which the demonstration of ALARP is considered can be found in PSR Part A Chapter 2 [3]. SSCs, through the defined safety functions, will contribute to the demonstration of ALARP by comparison against the risk targets in the following ways:

- By ensuring the cumulative risk from the identified External Hazard fault progressions are below the required Targets 4-9, along with the identification of a list of contributors

(basic events, system failures, human errors, etc.) ranked according to risk importance measures.
  - There are a number of importance measures routinely used in PSA studies but the two identified within PSR Part B Chapter 16 [8] that are most useful in ALARP assessments are Fussell-Vesely (FV) Importance and Risk Achievement Worth (RAW), full details of the insights available through PSA are subject to PSR Part B Chapter 16 [8].
- By achieving their safety classification as a duty system or a protection system, where claimed, they will contribute to the achievement of accident risk, Targets 4-9.

Risks below the Basic Safety Objectives (BSOs) are considered broadly acceptable, however, the RP is still required to identify further risk reduction measures in line with the ALARP approach. Risks between the BSOs and Basic Safety Levels (BSLs) require a consideration of risk reduction options. Risks above the BSLs are not acceptable for new plants.

21.8.2.2.1 Evaluation of Risk

For External Hazards the evaluation of the normal operations and accident risks against Targets 1-9 has not been provided at this stage of design, however, this information will be presented in the following chapters:

- PSR Part B Chapter 10 ‘Radiological Protection’ [111] for normal operations.
- PSR Part B Chapter 14 ‘Design Basis Accident Analysis’ [6], Part B Chapter 15 ‘Beyond Design Basis and Severe Accident Analysis, and Emergency Preparedness’ [7] and Part B Chapter 16 ‘Probabilistic Safety Analysis’ [8] for accident conditions.

21.8.2.3 Risk Reduction Options

This is a placeholder to identify and review relevant Position Papers and Design Decision Papers with a view to demonstrate which option(s) is/are ALARP.

In Revision 1 it will summarise those option evaluations, and it will briefly explore if other risk reduction options have or could be considered and either:

- Present the ALARP argument for why those options have not been implemented.
- Present the ALARP argument for why those options will be implemented in future.
- Create a Forward Action to consider the option(s) at some future point (noting this still must be a point where a meaningful design improvement could be made).

The process for the assessment of risk reduction options is presented in Holtec SMR-300 ‘GDA Reference Design Process and GDA Prospective Design Change Register’ [18]. Part A Chapter 5 ‘ALARP Summary’ [109] considers the holistic risk-reduction process for the generic SMR-300.

21.8.2.4 GDA Commitments and Forward Action

At Revision 0, no GDA commitments have been identified for Part B Chapter 21, ‘External Hazards’.

Forward Actions have been collated and presented in Part A Chapter 4, ‘Lifecycle Management of Safety and Quality Assurance’ [110].

21.8.3 Conclusion

The conclusion of Chapter B21 is that:

- The Chapter Claims identified have been met to a maturity aligned with a PSR at this stage of GDA. Further claims, arguments, and evidence will be presented in due course as the design develops.
- The approach to External Hazards inherent to the generic SMR-300 design complies with RGP and US NRC requirements applicable in the US.
- All credible External Hazards that can affect nuclear safety, are relevant to the deployment of the generic SMR-300 on a generic site in the Great Britain and can be considered on a generic basis, have been identified and characterised in accordance with RGP.
- An appropriate methodology is proposed for the identification, screening, and categorisation of hazard combinations, to a level of maturity aligned with a PSR.
- Ongoing input of External Hazards into the draft PFS being produced as part of Part B Chapter 14 'Design Basis Accident Assessment' [6] will ensure safety functions and identified safety measures are categorised and classified to provide suitable and sufficient lines of protection.
- All in-scope SSCs identified in Appendix B of PSR Part A Chapter 2 [3] are considered as SSCs with External Hazard safety functions as all have been seismically classified as C-I or C-II. As the fault studies topic area progresses, protection measures are to be identified for each External Hazard. A provisional strategy for categorisation and classification is provided within Part B Chapter 14 'Design Basis Accident Assessment' [6] and its supporting deliverables.
- The preliminary evaluation of the GDA Reference Design has demonstrated that for many of the External Hazards, significant margin is present between the GDA Reference Design parameters and the GB GSE parameters providing confidence in the robustness of the design in the context of a UK deployment.
- The preliminary evaluation of the GDA Reference Design has also identified where there may be a gap in hazard characterisation and/or design basis magnitude between the GDA Reference Design and the GB GSE with further work planned to address these topics.

Part A Chapter 5 of this PSR 'ALARP Summary' [109] concludes that it can be demonstrated that the generic SMR-300 reduces risks to ALARP and provides confidence that the Fundamental Purpose of the SSEC can be fulfilled at PCSR stage.

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21.10 LIST OF APPENDICES

Appendix A External Hazards CAE Route Map

Table 17: Chapter B21 CAE Route Map

Overarching SSEC Claim	Chapter Claim	Chapter Sub-claim/s	Chapter Section
Claim 2.1 – Nuclear Safety The nuclear safety assessment identifies plant initiating events and specifies the requirements for safety measures such that safety functions are fulfilled, informs operational and emergency arrangements, and demonstrates that risk is tolerable and ALARP.	**Claim 2.1.5** Risks from External Hazards and their combinations have been demonstrated to be tolerable and ALARP.	**Claim 2.1.5.1** External Hazards are identified and characterised using appropriate Codes and Standards, taking cognisance of RGP and OPEX.	Sub-Chapter 21.4
		Claim 2.1.5.2 A comprehensive set of External Hazards and their combinations are identified and screened for assessment.	Sub-Chapter 21.5
		Claim 2.1.5.3 Safety functions and safety measures are identified, categorised, and classified based on their importance to nuclear safety for all External Hazards and provide sufficient lines of protection based on the fault frequency and consequence.	Sub-Chapter 21.6
		Claim 2.1.5.4 Analysis demonstrates that for all External Hazards, the identified safety features, in conjunction with operator actions, enable the plant to reach a safe state.	Sub-Chapter 21.7