|  |  |  |  |
| --- | --- | --- | --- |
| **Assessment Report** | | | |
| **Unique Doc. ID:** | ONR-NR-AR-22-005 | **Issue No.:** | 1 |
| **Record Reference:** | 2022/23939 | | |
| **Project:** | Sizewell C Licensing | | |
| **Site:** | Sizewell C | | |
| **Title:** | External hazards assessment of an application by NNB Generation Company (SZC) Ltd for a nuclear site licence | | |
| **Nuclear Site Licence No.:** | N/A | | |
| **Licence Condition(s):** | LC 6, 10, 12, 14 | | |
| **ONR Assessment Rating:** | Green | | |

Table 1: Step-based document review

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Step | Description | Role | Name | Date | Revision No.[[1]](#footnote-1) |
| 1 | Initial Draft, including identification and mark-up of SNI/CCI | Author |  | 22/04/22 | 1 |
| 2 | Main editorial review | Author |  | 22/04/22 | 1 |
| 3 | Peer Review in accordance with  NS-PER-GD-016 | Peer Reviewer |  | 29/04/22 | 2 |
| 4 | Assessor update / sentencing of comments and return to Peer Reviewer | Author |  | 06/05/22 | 3 |
| 5 | Final editorial / clean draft review | Author |  | 06/05/22 | 4 |
| 6 | Acceptance review in accordance with  NS-PER-GD-016 | Professional Lead |  | 12/05/22 | 5 & 6 |
| 7 | Report Sign-off | Author/  Peer Reviewer/ Professional Lead |  | 26/05/22 | 7 |

Table 2: Document acceptance

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Role | Name | Position | Signature | Date | CM9 reference for review |
| Author |  | Inspector |  | 26/05/22 | N/A |
| Peer Review[[2]](#footnote-2) |  | Principal Inspector |  | 26/05/22 | 2022/28415 |
| Acceptance[[3]](#footnote-3) |  | Superintending Inspector |  | 26/05/22 | 2022/29929 |

Table 3: Revision history

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Issue No.: | Date | Author(s) | Reviewed By | Accepted By | Description of Change |
| 0 | 26/05/2022 |  |  |  | First formal issue |
| 1 | 24/03/2023 |  |  |  | Publication review |

Table 4: Circulation list

|  |  |
| --- | --- |
| Organisation | Name |
| ONR | SZC Team |
| NNB Generation Company (SZC) Ltd | Regulatory Interface Office |

**Sizewell C Licensing**

**External hazards assessment of an application by NNB Generation Company (SZC) Ltd**

**for a nuclear site licence**

Assessment Report Ref.: ONR-NR-AR-22-005

Issue No.: 1

Date: 24 March 2023

# Executive Summary

This report presents the findings of the assessment of the external hazards aspects of the NNB Generation Company (SZC) Ltd (NNB GenCo (SZC)) application for a nuclear site licence to construct and operate two UK EPR™ reactors at Sizewell C.

The scope of the assessment was to consider whether:

* the site is of a sufficient size to accommodate all necessary systems to ensure safe operation;
* there is adequate cooling capability for all normal and fault conditions;
* the environmental conditions would not preclude the use of the site with respect to external hazards;
* the geology of the site will provide a secure long term support to the necessary structures, systems and components; and
* that operations of the site will not adversely affect the safety case for any adjoining nuclear licensed site.

NNB GenCo (SZC)’s documentation, provided to support its nuclear site licence application, was well structured and allowed for the assessment of site-specific external hazards. Through the information sampled, the assessment concludes that each of the above have been adequately addressed.

Whilst the assessment highlighted areas requiring further work, none of these findings preclude the use of the Sizewell C site. The areas requiring further work have, where necessary, been captured as ONR regulatory issues, which have been raised to track their resolution.

I recommend that from an external hazards perspective a nuclear site licence should be granted to NNB GenCo (SZC) to construct and operate a nuclear power station at Sizewell C.

# List of Abbreviations

AFoE Annual Frequency of Exceedance

ALARP As low as reasonably practicable

ASCE American Society of Civil Engineers

BDBA Beyond Design Basis Analysis

BEEMS British Energy Estuarine & Marine Studies

BSI British Standards Institute

BS British Standard

CEFAS Centre for Environment, Fisheries, and Aquatic Science

CFS Capable Faulting Study

CMIP5 Coupled Model Intercomparison Project Phase 5

CWS Cooling Water System

DBE Design Basis Earthquake

DCO Development Consent Order

EVA Extreme Value Analysis

FEH Flood Estimation Handbook

FRS Floor Response Spectra

FSR Flooding Summary Report

GDA Generic Design Assessment

GIC Geomagnetically Induced Current

GMM Ground Motion Model

GMRS Ground Motion Response Spectrum

GSE Generic Site Envelope

HPC Hinkley Point C

Hs Significant wave height

HVAC Heating, Ventilation and Air Conditioning

IAEA International Atomic Energy Agency

JPM Joint Probability Methods

JSSR Justification of Site Suitability Report

LC Licence Condition

LPL Lightning Protection Level

NNB GenCo (SZC) NNB Generation Company (SZC) Ltd.

NRW Natural Resources Wales

NSL Nuclear Site Licence

MHWS Mean High Water Spring

OD Ordnance Datum

ONR Office for Nuclear Regulation

OHL Over Head Line

PAR Project Assessment Report

PCSR Pre-construction Safety Report

PGA Peak Ground Acceleration

PINS Planning Inspectorate

PML Principia Mechanica Ltd.

POLCOMS Proudman Oceanographic Laboratory Coastal Ocean Modelling System

R&D Research and Development

RCP Representative Concentration Pathway

PRT Peer Review Team

PSHA Probabilistic Seismic Hazard Analysis

RC2.0 Reference Configuration 2.0 design

RGP Relevant Good Practice

RHWG Reactor Harmonisation Working Group

RI Regulatory Issue

SAP Safety Assessment Principle(s)

SDSR Site Data Summary Report

SEPA Scottish Environment Protection Agency

SQEP Suitably Qualified and Experienced Personnel

SSC Structure, System and Component

SSHAC Senior Seismic Hazard Analysis Committee

SSJPM Skew Surge Joint Probability Method

SSM Seismic Source Model

STUK Radiation and Nuclear Safety Authority in Finland

SZC Sizewell C

SZB Sizewell B

TAG Technical Assessment Guide(s) (ONR)

TOMAWAC TELEMAC-based Operational Model Addressing Wave Action

Computation

TQ Technical Query

TSC Technical Support Contractor

UKCP09 UK Climate Projections 2009

UKCP18 UK Climate Projections 2018

U.S. NRC U.S. Nuclear Regulatory Commission

UHS Uniform Hazard Spectrum

WENRA Western European Nuclear Regulators’ Association

Table of Contents

[Executive Summary 5](#_Toc129609291)

[List of Abbreviations 6](#_Toc129609292)

[1. Introduction 9](#_Toc129609293)

[1.1. Background 9](#_Toc129609294)

[1.2. Scope of this Report 9](#_Toc129609295)

[1.3. Methodology 9](#_Toc129609296)

[2. Assessment Strategy 11](#_Toc129609297)

[2.1. Assessment Scope 11](#_Toc129609298)

[2.2. Sampling Strategy 13](#_Toc129609299)

[2.3. Out of Scope Items 16](#_Toc129609300)

[2.4. Standards and Criteria 16](#_Toc129609301)

[2.5. Use of Technical Support Contractors 19](#_Toc129609302)

[2.6. Integration with Other Assessment Topics 21](#_Toc129609303)

[2.7. Other Regulatory Interfaces 21](#_Toc129609304)

[3. NNB GenCo (SZC) Submission 23](#_Toc129609305)

[3.1. Justification of Site Suitability Report 23](#_Toc129609306)

[3.2. Key Primary References 24](#_Toc129609307)

[4. ONR Assessment 34](#_Toc129609308)

[4.1. Considerations of the External Hazards Assessment 34](#_Toc129609309)

[4.2. ONR Licensing Questions 65](#_Toc129609310)

[4.3. Licence Condition Compliance 70](#_Toc129609311)

[4.4. Assessment of NNB GenCo (SZC) Organisation and Systems 72](#_Toc129609312)

[4.5. ONR Assessment Rating 73](#_Toc129609313)

[5. Conclusions and Recommendations 74](#_Toc129609314)

[5.1. Conclusions 74](#_Toc129609315)

[5.2. Recommendations 76](#_Toc129609316)

[6. References 77](#_Toc129609317)

[Appendix A – SZC NSL External Hazards Engagements 86](#_Toc129609318)

[Appendix B – Status of ONR Platform Height Observations and NNB GenCo (SZC) responses 88](#_Toc129609319)

[Appendix C – Seismic Hazard Graphs 98](#_Toc129609320)

[Appendix D – Coastal Flood Hazard Technical Queries 101](#_Toc129609321)

1. Introduction
   1. Background

NNB Generation Company (SZC) Ltd (NNB GenCo (SZC)) applied to the Office for Nuclear Regulation (ONR) on 30 June 2020 for a nuclear site licence (NSL) to construct and operate a nuclear power station comprising two UK EPR™ reactors at Sizewell C (SZC) in Suffolk.

To reduce costs and project uncertainty, NNB GenCo (SZC)’s strategy for SZC is to derive value from replicating, wherever possible, the Hinkley Point C (HPC) plant and adopting a systematic approach to capturing, quantifying and applying lessons learned to SZC. It is noted that some aspects of the design will not be replicated due to site-specific features. In principle, ONR is supportive of this approach and has communicated its position on replication to NNB GenCo (SZC) via letter SZC504197N [1].

The outcome of ONR’s activities from the NSL assessment will be a project assessment report (PAR), which will draw together the views of ONR’s specialist assessors on NNB GenCo (SZC)’s readiness to become a nuclear site licensee. This will result in a recommendation to the Chief Nuclear Inspector on granting a licence. This external hazards licensing assessment report is one of a number that will inform the PAR.

ONR’s licensing assessment has followed the guidance in Licensing Nuclear Installations [2]. The approach to this assessment project was elaborated in the ONR SZC assessment strategy [3], with guidance on the production of licensing assessment reports set out in the ONR SZC assessment framework [4].

* 1. Scope of this Report

1. This report presents my findings of the assessment of external hazards for NSL, as presented in the Justification of Site Suitability Report (JSSR) [5], Site Data Summary Report (SDSR) [6] and supporting documentation provided by NNB GenCo (SZC). My assessment was focused on considering whether the NSL application provides adequate justification for site suitability based on the site-specific external hazards.
   1. Methodology
2. The methodology for assessment follows ONR’s guidance on the mechanics of assessment, NS-TAST-GD-096 [7].
3. The assessment was undertaken in accordance with the requirements of the ONR Management System. The ONR Safety Assessment Principles (SAPs) [8], together with supporting Technical Assessment Guides (TAGs) [7], were used as the basis for this assessment. Further details are provided in Section 2.
4. Assessment Strategy

The intended assessment strategy for external hazards is set out in this section. This identifies the scope of the assessment and the standards and criteria that have been applied.

* 1. Assessment Scope

1. ONR developed seven key questions for licensing within the ONR SZC assessment framework [4]. These questions were based on an interpretation of Licensing Nuclear Installations [2], consistent with previous projects. NNB GenCo (SZC) then developed claims in the JSSR to address these questions. In order to ensure full assessment coverage, but to also be targeted and proportionate, the questions were linked to specific topic streams. This assessment therefore addresses only those questions relevant to this topic stream.

Table 5 below shows the questions and their alignment to the relevant topic streams.

Table 5: ONR Nuclear Site Licensing Questions

|  |  |
| --- | --- |
| Licensing Question | Topic Stream |
| The site is of a sufficient size [to accommodate all necessary systems to ensure safe operation]. | * Civil Engineering * External Hazards * Internal Hazards |
| The site can be connected to [electricity] grid supplies. | * Electrical |
| There is adequate cooling capability for all normal and fault conditions. | * Mechanical Engineering * Civil Engineering * Internal Hazards * External Hazards |
| The environmental conditions would not preclude the use of the site with respect to external hazards. | * External Hazards |
| The geology of the site will provide a secure long term support to the necessary structures, systems and components. | * Civil Engineering * External Hazards |
| The [NSL] submission would also need to provide a schedule for submission of further Pre-Construction Safety Report (PCSR) updates or revisions to support subsequent construction milestones. | * Safety Case |
| That operations of the site will not adversely affect the safety case for any adjoining nuclear licensed site. | * Internal Hazards (main) * External Hazards |

In addition to the technical licensing questions, and as outlined in the ONR SZC assessment framework [4], I have also looked into organisational capability, including licence condition (LC) compliance, from an external hazards perspective. Whilst consideration of whether NNB GenCo (SZC) is developing a competent organisation to support delivery of the technical activities is not explicitly a question in my assessment report, I have included an overview of my engagement in this area. My findings have fed into the organisational capability topic stream and the associated assessment report [9].

The ONR SZC assessment framework [4] highlights LC10, 12 and 14 as LCs related to the external hazards NSL assessment. These have been considered through specific interventions and my NSL assessment. In addition to the LCs identified in the ONR SZC assessment framework, I also include consideration of LC6 compliance within my assessment, given my external hazards intervention on geotechnical records.

* + 1. Rationale for External Hazards Assessment

The external hazards assessment for NSL typically considers whether the site-specific external hazards demand is bounded by the design value, defined by the generic site envelope (GSE) within Generic Design Assessment (GDA). For example, for the HPC NSL assessment, the HPC site-specific external hazards demand was assessed against the UK EPRTM GSE values; see [10].

For SZC, NNB GenCo (SZC)’s intention is to replicate the HPC design, as outlined in Section 1. Therefore, the HPC design envelope (Reference Configuration 2.0 (RC2.0) [5]) is used in lieu of the UK EPRTM GSE, with the SZC site-specific external hazards demand compared against the HPC RC2.0 design, as opposed to the UK EPRTM GSE.

This report provides an external hazards recommendation on whether to grant a nuclear site licence to NNB GenCo (SZC) for the SZC site. This recommendation is informed by my assessment of whether NNB GenCo (SZC) has adequately addressed the ONR licensing questions, as well as consideration of the safety case architecture and organisational capability from an external hazards perspective. The prospective licensee can address the ONR licensing questions and demonstrate that the site is suitable from an external hazards perspective by:

* the intrinsic nature of the site and its geographical location;
* demonstrating that the site-specific external hazards demand is bounded by the HPC design envelope; and
* demonstrating that the site and/or HPC design can be modified to effect adequate levels of protection or mitigation against the site-specific external hazards demand, and providing appropriate formal commitments to do so.

* 1. Sampling Strategy

This assessment has concentrated on those external hazards aspects where the margin between the HPC design envelope and the SZC site-specific demand is relatively small or absent, or where the hazard is considered as a siting issue, which if present and significant, may undermine the viability of the site for new nuclear build.

1. Of the external hazards that have been identified as relevant to the SZC site, most are bounded by the HPC design envelope, see SDSR [6], and are not considered significant from a site licensing point of view. However, some are considered significant, and it is these that are sampled for detailed assessment, based on:

* having the greatest risk contribution and/or nuclear safety significance;
* those that may preclude the use of the site, for example, capable faulting;
* hazards where the HPC design envelope is exceeded by the SZC site‑specific external hazards demand; and
* hazards where work to confirm the HPC design envelope as bounding is not yet complete, or uses old data to characterise the site-specific hazard.

Based on the sampling strategy, the external hazards considered significant are outlined below:

* seismic hazards;
* flooding hazards;
* meteorological hazards – high air temperature, enthalpy and lightning;
* heat sink hazards – high sea temperature and low seawater level; and
* aircraft impact, specifically in relation to plot plan considerations.

Examining the ONR licensing questions independent of the above verifies that these hazards are an appropriate assessment sample. This consideration is articulated in Table 6 below. The hazards that I consider significant for my NSL assessment are addressed under corresponding report headings in Sections 3 and 4.

Table 6: External hazards related nuclear site licensing questions, including external hazards considerations and assessment strategy

|  |  |  |
| --- | --- | --- |
| External Hazards Licensing Question | External Hazards NSL considerations | External Hazards Assessment Strategy |
| The site is of a sufficient size [to accommodate all necessary systems to ensure safe operation] | Predominantly a consideration for the civil engineering and internal hazards assessment.  For external hazards, this question requires consideration of the plot plan for aircraft impact hazard. | The external hazards considerations for the licensing questions are all related to hazard characterisation.  Section 4 of the external hazards NSL assessment, therefore, focuses on NNB GenCo (SZC)’s hazard characterisation for the SZC site, in order to form a judgement against the licensing questions. |
| There is adequate cooling capability for all normal and fault conditions | For external hazards, this question requires adequate hazard characterisation for sea temperature, sea level and air temperature. |
| The environmental conditions would not preclude the use of the site with respect to external hazards. | For external hazards, this question requires adequate hazard characterisation of the site-specific external hazards. |
| The geology of the site will provide a secure long term support to the necessary structures, systems and components. | For external hazards, this question requires adequate hazard characterisation of the geological external hazards, including capable faulting, seismic hazard and groundwater. |
| That operations of the site will not adversely affect the safety case for any adjoining nuclear licensed site. | For external hazards, this question requires adequate hazard characterisation of flooding hazards and turbine disintegration.  Turbine disintegration, and its potential impact on Sizewell B is considered within the internal hazards assessment report [11]. |

* + 1. Engagement Strategy

ONR has engaged with NNB GenCo (SZC), to gain knowledge and insight from the prospective licensee on the SZC NSL application and to pose technical queries for resolution and discussion. Engagement is detailed in Appendix A and has included:

* level 4 meetings – these are routine technical meetings, allowing for technical discussions and query resolution. Where relevant, hazard‑specific Level 4 meetings were convened;
* workshops – these included workshops where ONR acted as an observer, such as the seismic hazard workshops, as well as technical workshops;
* meeting actions/queries/focus areas – these were technical queries, actions or focus areas that were raised during ONR and NNB GenCo (SZC) engagement, typically closed out by level 4 meetings and/or emails;
* regulatory issue (RI) – RI 8992 was raised to focus engagement on the seismic hazards study and design basis earthquake (DBE);
* a Level 3 meeting – this meeting was convened to propose a resolution to RI 8992 [12]; and
* interventions and site visits – these include:

ONR-NR-CR-21-290 – Sizewell C turbine disintegration and pluvial flooding site visit [13].

ONR-NR-CR-21-571 – LC6 intervention – geotechnical records [14].

ONR-NR-CR-21-583 – Sizewell C licensing intelligent customer intervention [15].

ONR-NR-CR-21-641 – Sizewell C training and suitably qualified and experienced personnel (SQEP) intervention [16].

* + 1. Limitations

Limitations to the external hazards assessment include:

* Maturity of site-specific hazard analysis work – the maturity of hazard analysis is lacking for certain hazards. For example, space weather (covered under replication below), or the use of data in studies that is >10 years old. Where relevant, these limitations are discussed in Section 4.
* Replication – given the replication principle being applied by NNB GenCo (SZC), whereby the HPC design will be replicated on the SZC site, some areas of open engagement for HPC mean that NNB GenCo (SZC) is not yet able to provide an advanced position for SZC. In particular, this relates to HPC RI 6754 on high air temperature and RI 6755 on space weather. ONR will engage with NNB GenCo (SZC) on the SZC implications during resolution of the HPC RIs.
* Validation of assumptions – these will be needed as part of future work. For example, the seismic hazards work uses assumptions for the engineered fill; these will need to be validated once the fill characteristics are known.
* Consideration of beyond design basis analysis (BDBA) – NNB GenCo (SZC) has not provided information pertaining to BDBA as part of its NSL application. Consideration of BDBA is not significant to ONR’s NSL assessment. This is because BDBA (SAP EHA.18 and EHA.7) is suited to later analysis, when detailed site-specific design has been carried out. BDBA will be addressed as part of normal business.
* Combined and consequential hazards – whilst NNB GenCo (SZC) has considered some limited combinations of hazards in its hazard characterisation, explicit consideration of combined and consequential hazards is not included as part of its NSL application. Combined and consequential hazards are not significant to ONR’s NSL assessment, as they do not typically govern site suitability. They will be addressed as part of normal business.
* Hazard verification studies – verification that the design will be able to withstand the site-specific external hazards has not yet been undertaken by NNB GenCo (SZC) and these studies will be addressed as part of normal business.
  1. Out of Scope Items

1. The following items are outside the scope of the assessment:

* adequacy of the HPC design envelope for the HPC site, and HPC site suitability;
* detailed design of sea defences – NNB GenCo (SZC) does not yet have a detailed sea defence design. For NSL, ONR has assessed the characterisation of the SZC flood hazards and will consider the detailed sea defence design as part of future submissions post-NSL. The nature and timing of these submissions has not yet been determined by NNB GenCo (SZC). However, I expect the SZC sea defence design and safety case to consider any potential negative impacts on the Sizewell B (SZB) sea defences; and
* turbine disintegration – consideration of the turbine disintegration hazard is included in the internal hazards assessment report [11] and is therefore explicitly excluded from this assessment.
  1. Standards and Criteria

The relevant standards and criteria adopted within this assessment are principally the SAPs [8], internal TAGs [7], Licensing Nuclear Installations [2] relevant national and international standards and relevant good practice (RGP) informed from existing practices adopted on UK nuclear licensed sites. The key SAPs and any relevant TAGs are detailed within this section. National and international standards and guidance have been referenced where appropriate within the assessment report. Where applicable, RGP has also been cited within the body of the assessment.

* + 1. Safety Assessment Principles (SAPs)

The key SAPs applied within the assessment are included within Table 8 of this report.

* + 1. Technical Assessment Guides (TAGs)

The following TAGs have been used as part of this assessment [7]:

* NS-TAST-GD-005, ONR Guidance on the Demonstration of ALARP (Rev 11)
* NS-TAST-GD-013, External Hazards (Rev 8)
* NS-TAST-GD-017, Civil Engineering (Rev 4)
* NS-TAST-GD-051, The Purpose, Scope and Content of Nuclear Safety Cases (Rev 7)
  + 1. National and International Standards and Guidance

The following standards and guidance have been used as part of this assessment:

International Atomic Energy Agency (IAEA)

* Fundamental Safety Principles, Safety Standards Series No. SF-1 [17]
* Safety of Nuclear Power Plants: Design, Specific Safety Requirements Series No. SSR-2/1 [18]
* Site Evaluation for Nuclear Installations, Specific Safety Requirements, Safety Standards Series No. SSR-1 [19]
* External Events Excluding Earthquakes in the Design of Nuclear Power Plants, Safety Guide, Safety Standards Series No. NS-G-1.5 [20]
* Seismic Design and Qualification for Nuclear Power Plants, Safety Guide, Safety Standards Series No. NS-G-1.6 [21]
* External Human Induced Events in Site Evaluation for Nuclear Power Plants, Safety Guide, Safety Standards Series No. NS-G-3.1 [22]
* Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants, Safety Guide, Safety Standards Series Guide No. NS-G‑3.6 [23]
* Seismic Hazards in Site Evaluation for Nuclear Installations, Specific Safety Guide, Safety Standards Series No. SSG-9 [24]
* Seismic Hazards in Site Evaluation for Nuclear Installations, Specific Safety Guide, Safety Standards Series No. SSG-9 (Rev.1) [25]
* Seismic Design for Nuclear Installations Specific Safety Guide Series No. SSG-67 [26]
* Evaluation of Seismic Safety for Existing Nuclear Installations, Safety Guide No. NS-G-2.13 [27]
* Design of Nuclear Installations Against External Events Excluding Earthquake Specific Safety Guide No. SSG-68 [28]
* Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations, Specific Safety Guide, Safety Standards Series No. SSG‑18 [29]
* Safety Aspects of Nuclear Power Plants in Human Induced External Events: General Considerations, Safety Reports Series No. 86 [30]
* Safety Aspects of Nuclear Power Plants in Human Induced External Events: Assessment of Structures, Safety Reports Series No. 87 [31]
* Safety Aspects of Nuclear Power Plants in Human Induced External Events: Margin Assessment, Safety Reports Series No. 88 [32]

Western European Nuclear Regulators Association (WENRA) Reactor Harmonisation Working Group (RHWG)

* Reactor Safety Reference Levels [33]
* Safety Objectives for New Power Reactors [34]
* Statement on Safety Objectives for New Nuclear Power Plants [35, 36]
* Safety of New Nuclear Power Plant Designs [37]
* Guidance Document Issue TU: External Hazards - Head Document: Guidance for the WENRA Safety Reference Levels for External Hazards [38]
* Guidance Document Issue TU: External Hazards - Guidance on Seismic Events [39]
* Guidance Document Issue TU: External Hazards - Guidance on External Flooding [40]
* Guidance Document Issue TU: External Hazards - Guidance on Extreme Weather Conditions [41]

Other National and International Guidance

* British Standards Institute (BSI), Lightning Protection Standard, British Standard (BS) Europäische Norm (EN) / International Electrotechnical Commission (IEC) 62305 [42]
* U.S. NRC, Updated Implementation Guidelines for SSHAC Hazard Studies, NUREG-2213 [43]
* U.S. NRC, Practical implementation guidelines for SSHAC Level 3 & 4 hazard studies, NUREG-2117 Revision 1 [44]
* American Society of Civil Engineers (ASCE), Seismic Analysis of Safety-Related Nuclear Structures and Commentary ASCE/SEI 4-16 [45]
* ASCE, Seismic Design Criteria for Structures, Systems, and Components In Nuclear Facilities ASCE/SEI 43-19 [46]
* ONR, the Environment Agency, Natural Resources Wales (NRW), Scottish Environment Protection Agency (SEPA), Use of UK Climate Projections 2018 (UKCP18), Position Statement [47]
* ONR and the Environment Agency, Principles for Flood and Coastal Erosion Risk Management [48]
  1. Use of Technical Support Contractors

For substantive assessment work such as this it is usual for ONR to use technical support contractors (TSCs) to provide access to independent advice and experience, analysis techniques and models, and to enable ONR inspectors to focus on regulatory decision making.

Section 2.5.1 and 2.5.2 define the areas where I used TSCs to support my assessment. I required this support to provide additional expert advice on specialist aspects of external hazards topics.

1. Whilst the TSCs undertook detailed technical reviews, this was undertaken under my direction and close supervision. The regulatory judgement on the adequacy, or otherwise, of the SZC NSL application in this report has been made exclusively by ONR.
   * 1. Mott MacDonald

Mott MacDonald provided the TSC role for the external hazards assessment. The external hazards TSC work package [49] was divided into:

* Task 1 – Familiarisation and gap analysis of all the site-specific SZC external hazards. The TSC was required to conduct a high-level review of the SZC hazards analysis and identify areas where the approach adopted differs from the expectations in NS-TAST-GD-013, the SAPs and/or other RGP.
* Task 2 – Detailed assessment of selected external hazards – the TSC was required to conduct a deep dive on a number of external hazards, where appropriate, liaising with the ONR Expert Panel on Natural Hazards. The hazards/topics selected for a deep dive were informed by Task 1 and agreed between the TSC and ONR.

The details of the TSC assessment are presented in the TSC reports [50] and [51].

* + 1. ONR Expert Panel on Natural Hazards

The ONR Expert Panel on Natural Hazards is a group of independent academics and specialist consultants who provide expert advice to ONR [52]. The expert advice is considered holistically by ONR and helps to inform ONR’s regulatory judgement. The ONR Expert Panel consists of two sub-panels:

* seismic hazards sub-panel; and
* meteorological and coastal flood hazards sub-panel.

The ONR Expert Panel has considered areas of NNB GenCo (SZC)’s NSL application at the request of ONR. The ONR Expert Panel conducted a review of the SZC probabilistic seismic hazard analysis (PSHA) and the SZC capable faulting study (CFS) [53], as well as a review of the SZC extreme high air temperature case [54]. The former was excluded from the Mott MacDonald TSC review, and the latter provided an in-depth assessment, that informed Mott MacDonald’s focused review for Task 2.

To ensure appropriate contextualisation of the Expert Panel papers, it should be noted that NNB GenCo (SZC) has subsequently updated its high air temperature data and associated reports, as well as its definition of the design basis earthquake. Therefore, as with any TSC report, the Expert Panel papers represent a review at a given point in time.

* 1. Integration with Other Assessment Topics

1. External Hazards interfaced with several other topic areas as part of the SZC NSL assessment. The topic areas most relevant to the external hazards assessment, and the main interface areas, are:

* civil engineering – I have engaged with the civil engineering inspector in relation to seismic hazards, ground conditions, groundwater, sea defences and aircraft impact. Where relevant, these topics are addressed within the civil engineering assessment report [55];
* mechanical engineering – I have engaged with the mechanical engineering inspector in relation to high air temperature and enthalpy hazards, heat sink hazards and the generation of floor response spectra (FRS). Consideration of FRS and heating, ventilation and air conditioning (HVAC) for NSL are addressed within the mechanical engineering assessment report [56];
* electrical engineering – I have engaged with the electrical engineering inspector in relation to lightning hazard and geomagnetically induced current (GIC). The GIC hazard is addressed within the electrical engineering assessment report [57], given the relevance to electrical engineering equipment and the existing GDA assessment finding AF‑UKEPR‑EE‑026;
* internal hazards – I have engaged with the ONR internal hazards inspector in relation to pluvial flooding and turbine disintegration. Turbine disintegration is addressed within the internal hazards assessment report [11]; and
* organisational capability – I have engaged with the ONR organisational capability inspector in relation to intelligent customer, training and SQEP interventions.
  1. Other Regulatory Interfaces
     1. National
        1. Environment Agency

The prospective licensee’s flood hazard submissions to the Environment Agency and ONR will respond to different regulatory requirements and expectations. However, ONR and the Environment Agency expect that, where they overlap in their predictions of flooding effects on the site, the predictions should be consistent; differences in data, methods used and judgements should be reconcilable and justified between the two analyses. My assessment of NNB GenCo (SZC)’s flood hazard case has utilised the ONR and Environment Agency joint guidance on climate change [47] and flood and coastal erosion management [48]. I have also engaged with the Environment Agency’s SZC Nuclear New Build Project Manager on cross-cutting areas.

* + - 1. Planning Inspectorate

ONR is a statutory consultee in the Planning Inspectorate’s (PINS) planning enquiry, resulting from NNB GenCo (SZC)’s Development Consent Order (DCO) application for the SZC site. I have provided responses to external hazards related PINS queries for ONR. My responses were based on my assessment of NNB GenCo (SZC)’s NSL application and engagement, at that time.

* + 1. International

ONR maintains links and collaborates with international nuclear safety regulators through the IAEA and other fora. In addition to these fora, I have specifically engaged with the United States Nuclear Regulatory Commission (U.S. NRC) and the Radiation and Nuclear Safety Authority in Finland (STUK). For example, [58] [59], in order to better understand their regulatory position in relation to seismic hazards, in particular low seismic hazard sites. This engagement helped to inform my regulatory judgement outlined in Section 4.1.3.3.

1. NNB GenCo (SZC) Submission
2. NNB GenCo (SZC)’s NSL application consists of the JSSR and a number of supporting references. The JSSR is intended to fulfil the role of a site justification report for NSL, as outlined in ONR’s Licensing Nuclear Installations [2]. The structure and intention of the documents relevant to the external hazards case are set out in the subsequent sections.
   1. Justification of Site Suitability Report

The purpose of the JSSR is to provide the overall justification for the suitability of the site. It is a top tier report that intends to summarise and consolidate the arguments and evidence to provide the required confidence that the SZC site is suitable to host a twin UK-EPRTM nuclear power station.

1. As outlined in Section 2, ONR has developed seven key questions based on an interpretation of Licensing Nuclear Installations [2] and ONR’s SAPs [8]. NNB GenCo (SZC) has addressed these questions in the JSSR [5] as specific claims.
2. Previous versions of the JSSR were shared with ONR in order to facilitate early engagement, but for licensing, Revision 3 was submitted which captured the latest work that had been undertaken.

The JSSR is split into sections, each addressing a specific claim and pointing to further supporting ‘primary references’. The sections are as follows:

* Section 2 – Claim 1: The site is of sufficient size to accommodate all necessary systems to ensure safe operation;
* Section 3 – Claim 2: The site can be connected to electricity grid supplies;
* Section 4 – Claim 3: Adequate cooling capability can be provided for all normal and fault conditions;
* Section 5 – Claim 4: There are no external hazards that would preclude the use of the site (including the external hazards presented by SZB to SZC);
* Section 6 – Claim 5: The geology of the site provides secure long term support to the necessary structures, systems, components; and
* Section 7 – Claim 6: Operations on the SZC site will not adversely affect the ability to maintain an adequate Safety Case for the adjoining Nuclear Licensed Site (SZB).

The diagram below is taken from the JSSR which shows the layout of the claims and the key primary references.

Claims 1, 3, 4, 5 and 6 are relevant for the external hazards assessment, with Claim 4 being of particular significance. The primary references for the external hazards related claims are identified in the JSSR (Figure 1).

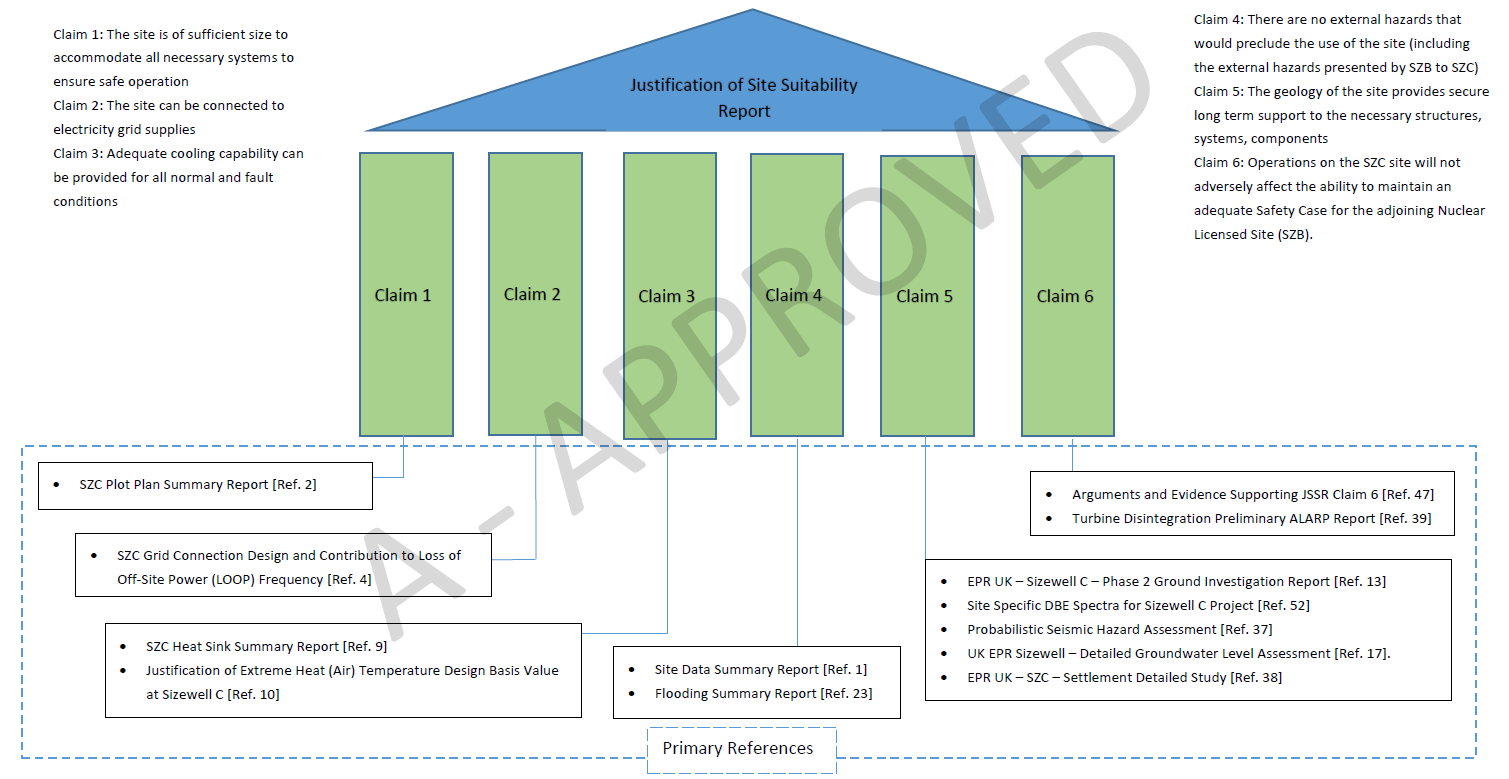


Figure : Diagram taken from JSSR summarising the claims, and the primary references

* 1. Key Primary References

This section focuses on the supporting references for those hazards outlined by my sampling strategy in Section 2.2, effectively the ‘golden thread’ for external hazards.

The SDSR Rev.4 [6] is the key primary reference for my assessment report. In the following sections, I set out the purpose of the SDSR and its supporting references, which provide arguments and evidence intended to support the JSSR claims.

In addition to the SDSR and its supporting references, there are a number of JSSR references that, whilst not directly related to SZC hazard characterisation, provide further context to the external hazards case. These reports are included in my assessment in Section 4, where relevant to the external hazards outlined in my sampling strategy in Section 2.2. The relevant JSSR references include:

* SZC Plot Plan Summary Report [60] – this 2021 report outlines the plot plan for SZC, including any changes from the HPC plot plan. The report aims to demonstrate that, in principle, the site is of sufficient size to accommodate all necessary systems and to ensure safe operation. For external hazards it provides context of the aircraft impact case for SZC and concludes that, although detailed analysis is yet to be performed as part of the SZC PCSR, it is not expected that there will be any significant change in the risk of aircraft impact at SZC as a result of plot plan changes versus that assessed at HPC.
* SZC Heat Sink Summary Report [61] – the aim of this 2021 report is to demonstrate that the currently identified heat sink design changes for SZC, relative to HPC, would not have a material impact on the ability to demonstrate that adequate cooling exists. This includes normal conditions, fault conditions and consequential hazards, as the SZC heat sink design and associated safety case is developed further.
* Arguments and Evidence Supporting JSSR Claim 6 [62] – this 2021 report aims to provide supporting arguments and evidence to the claim that operations on the SZC site will not adversely affect the ability to maintain an adequate safety case for the adjoining nuclear licensed site (SZB). For external hazards, it considers changes potentially affecting external man-made and natural hazards, including pluvial flooding, coastal flood defences and groundwater levels.
  + 1. Site Data Summary Report

The purpose of the SDSR [6] is to summarise the site-specific external hazards characterisation (in terms of magnitude and associated return periods / frequency of each external hazard), and to identify a suitable design basis for each external hazard applicable to the SZC site.

The SDSR aims to justify the use of the HPC design basis values for the SZC site. NNB GenCo (SZC) states that the HPC design basis values are typically conservatively derived and there is consequently substantial ‘head room’ in the HPC design basis compared to the SZC ‘site challenge’.

Where the site characterisation work indicates that a SZC ‘site challenge’ external hazard value is not necessarily bounded by the equivalent HPC design basis value or that the margin between the SZC site challenge and the HPC design basis is significantly reduced (compared to the margin between HPC site challenge and HPC design basis), NNB GenCo (SZC) aims to provide justification for the adoption of the HPC design basis value. SDSR Appendix B provides a summary of whether NNB GenCo (SZC) considers the SZC and HPC hazard design basis to be aligned.

Section 3.1 of the SDSR outlines NNB GenCo (SZC)’s requirements for its approach for the characterisation of external hazards and selection of design basis events, as well as the methodology for characterisation of the external hazards.

Supporting references to the SDSR requirements and methodology include:

* Sizewell C Hazard Listing Report [63] – the list of external hazards covered by the SDSR was derived from this 2015 report, which presents the hazard identification and screening methodology for SZC and the hazard lists to be input to the SZC deterministic and probabilistic hazard assessments.
* Use of United Kingdom Climate Projections 2018 (UKCP18) to Define Reasonably Foreseeable Climate Change [64] – the purpose of this 2021 report is to justify and record how the SZC project defines reasonably foreseeable climate change using UKCP18, taking into account necessary and relevant factors and constraints needed to characterise a hazard magnitude for 10-4/yr annual frequency of exceedance (AFoE) at the location in question.

Sections 3.2 – 3.9 of the SDSR cover the site-specific hazard ‘site challenge’ and the SZC design values for the identified SZC external hazards. The supporting references to the external hazards identified in my sampling strategy are outlined in the following sections.

* + 1. Seismic Hazards

Section 3.2 of the SDSR covers seismic hazards. Whilst the hazard characterisation work is extant, the DBE defined in the SDSR has been superseded. The documents relating to the hazard characterisation are summarised below, with Section 3.2.2.2 providing an overview of the updated DBE and related documentation.

* + - 1. Strong Ground Motion (Probabilistic Seismic Hazard Analysis), Capable Faulting Study and Site Response

NNB GenCo (SZC) contracted Jacobs, formerly CH2M HILL International Nuclear Services Ltd (CH2M2), to undertake the SZC PSHA and CFS. The technical delivery team and independent peer review team (PRT), used by Jacobs, were predominantly the same as that used in the HPC project. The approach for SZC followed an enhanced senior seismic hazard analysis committee (SSHAC) level 2 study and was broadly similar to the HPC approach. The reporting framework for the implementation of the PSHA and CFS is outlined in Figure 2.

The level 1 report presents the high-level overview of the CFS and PSHA study methodology and provides an overview of all the lower-level reports. The level 2 reports summarise the CFS and PSHA process, and the key technical findings and conclusions relating to the capable faulting hazard assessment and seismic hazard calculations. The level 3 reports integrate the outputs of the level 4 and 5 reports and present the findings of the final seismic hazard results and the site response analysis. The development, verification and validation of the seismicity model and ground motion model (GMM) is presented in the two level 4 reports. The review and assessment of data is included in the level 5 reports. The level 6 reports document the data collected.

The suite of CFS and PSHA reports were reviewed by the Jacobs PRT, with the PRT’s review comments included as appendices to the reports.

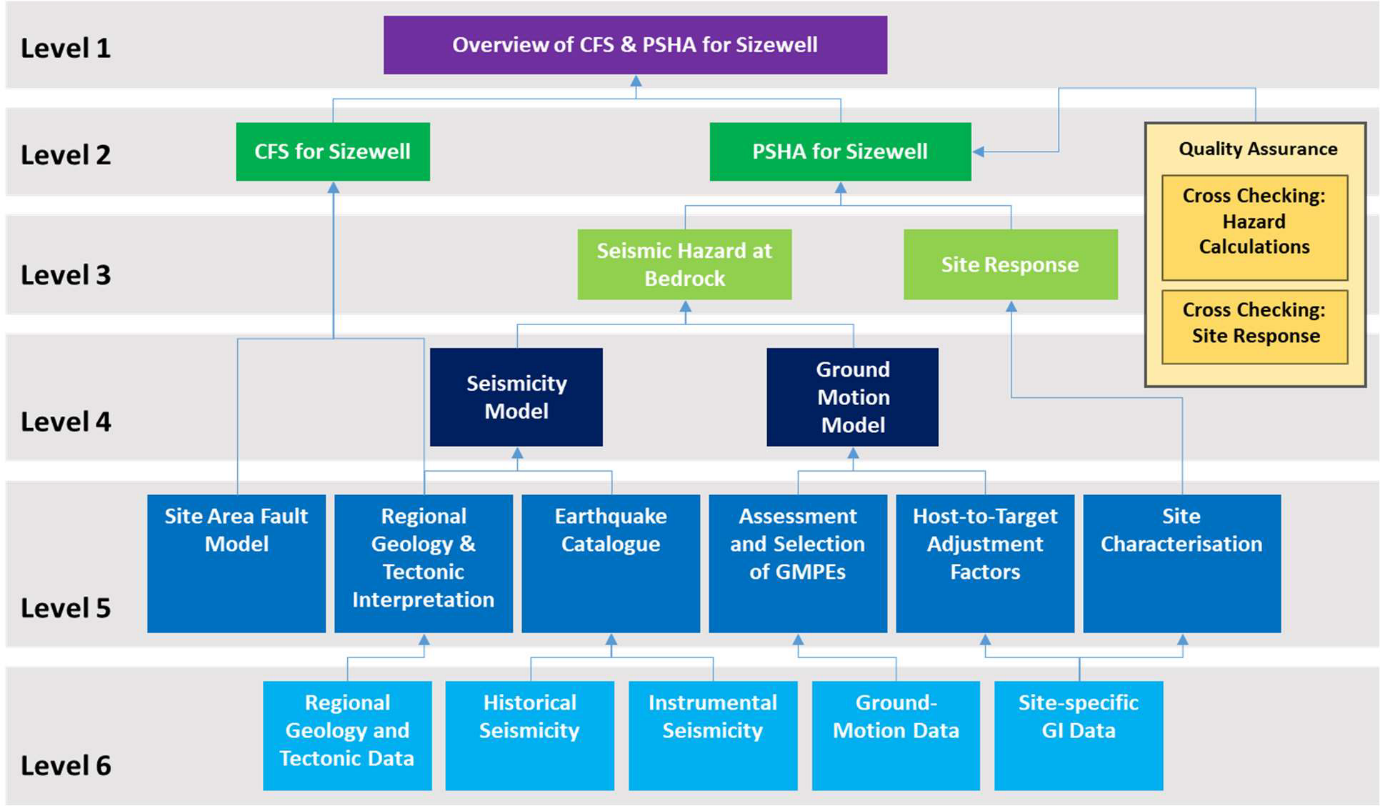


Figure : CFS and PSHA Reporting Structure

NNB GenCo (SZC) produced the following report to support its own decisions that inputted into the Jacobs studies:

* Sizewell C CFS & PSHA – NNB Position on Minimum Magnitude Value for PSHA Studies [65] – the purpose of this report is for NNB GenCo (SZC) to set out its position on the use of a minimum magnitude limit of 5 being adopted in the PSHA calculations.
  + - 1. Design Basis Earthquake

Section 3.2 of the SDSR covers earthquakes, including the site-specific DBE. ONR engaged with NNB GenCo (SZC) on its SZC DBE and NNB GenCo (SZC) has since updated its DBE definition from that referenced in the SDSR.

The following letters outline NNB GenCo (SZC)’s commitment to revise the SZC DBE:

* letter ONR-SZC-21655N – 10 February 2022 [66] – this letter outlines NNB GenCo (SZC)’s commitment to revise the (onshore) horizontal DBE; and
* letter ONR-SZC-21568N – 12 April 2022 [67] – this letter outlines NNB GenCo (SZC)’s commitment to revise the (onshore) vertical DBE and includes a commitment for NNB GenCo (SZC) to revise the offshore DBE to align with ONR’s expectations, in relation to RGP.

The supporting reference to ONR-SZC-21568N, is the Project Deliverable Sizewell C DBE Definition document [68], which outlines the revised onshore horizontal and vertical DBE. The revised DBE supersedes the DBE definition provided in the SDSR.

The revised onshore DBE is a standardised (piecewise linear) design spectrum, inspired by EUR soft, fixed to a target level of +7.3 m ordnance datum (OD) [68], specified as geometric mean, using generic fill assumptions and profiles [69].

In addition to the DBE definition, NNB GenCo (SZC) has provided a document titled ‘Generation of 3 Sets of Free-Field Time-Histories for the Sizewell-C Site Interim DBE for the Replication/Design Studies’[70]. This document provides a methodology for producing time histories for the interim DBE. Whilst this document relates to the interim DBE, rather than the revised DBE, NNB GenCo (SZC) has informed ONR that it intends to use the same approach, of producing synthetic time histories, for the revised DBE [69].

* + 1. Flooding Hazards

Section 3.5 of the SDSR covers external flooding, including coastal flooding, tsunami and surface run-off (pluvial flooding) hazard characterisation.

The SDSR states that the SZC platform height is set at +7.3 mOD, which provides a margin of 1.35 m above the design basis extreme still water level in 2110 and 0.43 m in 2140. The sea defence will protect against waves, with crest levels of +12.6 mOD (for reasonably foreseeable climate change) and +16.4 mOD (for maximum credible climate change).

Supporting references to the SDSR flooding section include:

* Flooding Summary Report (FSR) [71] – the purpose of this 2021 document is to feed into the SDSR by characterising the flooding hazard (in terms of magnitude and associated return periods / frequency), identifying the site challenge, setting and justifying the design basis and identifying margins, for each external flooding hazard applicable to the SZC site, as well providing arguments and evidence intended to support JSSR claim 4. The FSR includes coastal flooding, pluvial flooding, fluvial flooding and high groundwater level.
* Update to estimation of extreme high-water levels at SZC [72] – this report from 2021 is the most recent report on calculating extreme still water levels at SZC. The report provides sea level projections for Sizewell, including extreme high still water at different return periods, years, uncertainty percentiles and the potential impact of climate change.
* HR Wallingford Sizewell Power Station Extreme Sea Level Studies, Joint Probability of Waves and Sea Levels and Structure Response [73] – this report from 2010 is where the SZC present day wave conditions were initially derived. The report considers offshore and nearshore waves and sea levels at Sizewell. It also derives the joint probability of waves and sea levels offshore, their equivalent transformed values nearshore, and demonstration of overtopping rates and crest levels for specimen defence structures at the shoreline.
* British Energy Estuarine & Marine Studies (BEEMS) Technical Report TR319: Derivation of extreme wave and surge events at Sizewell with results of the coastal wave modelling, climate change and geomorphic scenario runs [74] – this report from 2017 develops the work from [73], using data to 2012. It explains the methodology used to generate the extreme wave and water level combinations which could occur under high tides and storm surges to use as boundary conditions for a TELEMAC-based Operational Model Addressing Wave Action Computation (TOMAWAC) wave model of the Sizewell area. This includes consideration of geomorphological change scenarios. The methodology used to derive the input boundary conditions is the publicly available JOIN-SEA method.
* Main Development Site Flood Risk Assessment Appendices 1-7 [75] – these appendices from 2020 are predominately DCO related; however, they are referenced in the SDSR and provide detail on the climate change allowances used in the wave characterisation.
* Sizewell C Safety Case – Coastal Flood Risk Modelling [76] – this technical note from 2020 provides details on the coastal overtopping model of the proposed SZC development to determine flood risk to the site during an extreme surge and nearshore waves event.
* Sizewell C – Tsunami Hazard Assessment Report [77] – the purpose of this report from 2016 is to review the tsunami hazard at the Sizewell C site in order to provide confidence in the adequacy of the coastal flooding protection which is being designed for extreme high seawater levels (tides and surge) and wind waves. Credible forms of tsunami initiation are considered, that is, seismic, landslide (submarine / sub-aerial) and meteorite impact. A second objective is to assess the potential for exposure of the offshore cooling water intakes due to the drawdown in water level associated with the arrival of tsunami wave troughs.
* SZC Platform Height: ALARP Analysis Decision Paper, Version 3 [78] – this report from 2017 is limited to the selection of an as low as reasonably practicable (ALARP) platform height when considering the external flooding hazard. This report was assessed by ONR in 2018 [79] and the platform height was set as +7.3 mOD. As part of ONR’s assessment, a number of platform height observations were raised; see Appendix B for their status.
* EW0601 Sea Defences Calculation Report [80] – this report from 2020 presents the calculations undertaken for the sea defences and includes, where appropriate, the methodology used and the inputs and outputs.
* Extreme Rainfall at SZC [81] – this 2019 report estimates 10-4/yr AFoE levels of extreme rainfall for several time resolutions (5-minute, 10‑minute, 12-minute, 15-minute, hourly and daily resolution) for SZC. Extreme value analysis (EVA) is applied to precipitation data from several observation gauges near Sizewell for the present climate and defined climate change adjustment factor using the representative concentration pathway (RCP) 8.5 scenario from UKCP18 daily 12 km x 12 km resolution climate change data.

An additional report of relevance, referenced in the FSR [71] is:

* Sizewell C Safety Case – Fluvial Flood Risk Modelling [82] – this 2020 technical note provides details on the fluvial hydraulic model of River Minsmere and Leiston Drain catchment developed for the fluvial flood risk study.
  + 1. Meteorological Hazards
       1. High Air Temperature and Enthalpy

Section 3.6.5 of the SDSR covers high air temperature, which includes dry bulb air temperature and enthalpy. Whilst the SZC study results show that the SZC site-specific enthalpy value is bounded by the HPC design values, the SZC site-specific high air temperature values are not. For example, the SZC instantaneous temperature site challenge is reported as 45.7°C, whilst the design value is 44°C. NNB GenCo (SZC) outlines its position that the analysis concludes that the adoption of the HPC design basis air temperatures at SZC will result in a design for which an adequate safety demonstration will be made in the SZC PCSR.

The supporting references to the SDSR high air temperature section include:

* Justification of Extreme Heat (Air) Temperature Design Basis Value at Sizewell C [83] – this 2021 report was updated to include data from April 2017 to April 2020 and aims to justify the HPC design basis value of high air temperature hazard for SZC.
* Extreme air temperatures at Sizewell C [84] – this 2021 report was updated to include data from April 2017 to April 2020 and its aim is to estimate extreme high dry-bulb and wet-bulb temperatures and enthalpy that could occur at SZC, under both the present climate and future climate change conditions. This report uses data from 1961 to April 2020, predominately using data recorded since 1980.
* Advanced heatwave profile for SZC [85] – this report from 2019 provides a heatwave profile for SZC using observed daily maximum and minimum dry-bulb air temperature data taken from the Wattisham gauge over the period 1980-2017. The heatwave profile is constructed using multivariate EVA and is intended to supplement the return levels estimated in [84] for SZC using univariate EVA.
  + - 1. Lightning

Section 3.7.1 of the SDSR covers lightning. The SDSR uses a joint study for SZC and HPC as the basis of its hazard characterisation. The SZC hazard characterisation considers the EPRTM power plant block target area, the number of lightning strikes in the lightning survey area (circle of radius 20 km) over the course of the survey (11 years) and the distribution of strike currents (to give the lightning peak current exceedance probability). NNB GenCo (SZC) concludes in the SDSR that an appropriate lightning site challenge is 200 kA, which aligns with the HPC site challenge and design basis values.

The supporting references to the SDSR lightning section include:

* Lightning Data Analysis for Hinkley Point and Sizewell Power Station Sites [86] – this report from 2011 provides analysis of lightning activity for proposed power station sites at Hinkley Point and Sizewell. Data from 1999-2010 is used in the analysis. The report does not propose a 10-4/yr AFoE event for either SZC or HPC. However, it does conclude in Section 4 that “the existence of a few strikes with significantly larger currents indicates however that the strike current distribution has a very long tail in the high-current region, which needs to be taken into account when assessing the risk posed by low-probability events”.
* Analysis Of Impacts In The Case Of Strikes On The OHL With Or Without A Failure From The Surge Protection [87] – the aim of this report from 2020 is to summarise the study about the analysis of impacts in the case of strikes on the over head line (OHL).

ONR TSC reports refer to other lightning hazard documents; these were either references provided in an earlier revision of the SDSR, or were provided by NNB GenCo (SZC) to support technical queries, outlined in the Task 2 technical note [51].

* + 1. Heat Sink Hazards

Section 3.9 of the SDSR outlines the heat sink specific hazards. Given the sampling approach outlined in Section 2.2, the high sea temperature and low seawater level case are outlined below.

* + - 1. High Sea Temperature

Section 3.9.1 of the SDSR covers high sea temperature. The site challenge value, including climate change, is given as 27.2°C, with the design input set at 28.5°C. The initial site evaluation studies for SZC were carried out by the following Centre for Environment, Fisheries, and Aquatic Science (CEFAS) and EDF research and development (R&D) reports:

* TR489 Sizewell extremes for maximum sea temperature and combined sea levels and waves at the Sizewell C intakes [88] – this 2019 report by CEFAS covers an assessment of heat sink related hazards, including extreme low seawater events at the SZC intake locations, the temperature of cooling water (sea temperature) and salinity.
* Reproducing CEFAS analysis on extreme sea temperature and salinity for SZC [89] – this 2020 report aimed to replicate the analysis undertaken in TR489. Its conclusions suggest additional studies should be conducted.

The SDSR uses a new EDF R&D report, produced following [89], for its high sea temperature hazard characterisation and states that the new report uses an updated analysis and the latest data from a wider variety of sources, when compared to the TR489 report [88]. An overview of the new EDF R&D report is below:

* Sizewell C Extreme High Sea Water Temperatures [90] – this report from 2021 aims to support the design of a safe and efficient cooling water system for the Sizewell C nuclear power station, by assessing the extremes of seawater temperature based on both present climate and projected climate change in the region. For the present climate, hourly sea surface water temperature measurements are analysed from five different temperature sensors in the SZB cooling water system between 1994‑2020. This data was cross-referenced against sea temperature measurements from the Sizewell Waverider buoy, part of CEFAS’s WaveNet network of buoys for ocean wave characterisation around the UK, between 2008 and 2020. For the climate change addition, daily sea surface temperature projections from the Proudman Oceanographic Laboratory Coastal Ocean Modelling System (POLCOMS) were analysed. These were available from 2006-2099 and were driven by one global climate model under the RCP 8.5 emissions scenario.
  + - 1. Low Seawater Level

Section 3.9.9 and 3.9.10 of the SDSR cover extreme low seawater level and extreme low seawater level (tsunami) respectively. The extreme low seawater level is given as ‑3.4 mOD, with a design input value of ‑3.7 mOD. No site challenge is defined for tsunami, as the SDSR states that the maximum level of draw down during a 10-4/yr AFoE tsunami does not challenge nuclear safety. The supporting references are:

* TR489 Sizewell extremes for maximum sea temperature and combined sea levels and waves at the Sizewell C intakes [88] – this report is outlined in Section 3.2.5.1.
* TR139 Sizewell Extremes Report [91] – this 2011 report, signed off by NNB GenCo (SZC) in 2014, is referenced in the SDSR as where discussion of statistical methods and tools is reported. The report was commissioned to provide an expert assessment of ‘extreme events’ in the Sizewell region, where ‘extreme events’ refers to past and ongoing changes in coastal configuration and bathymetry, and to the frequency and magnitude of various oceanographic events.
* Sizewell C – Tsunami Hazard Assessment Report [77] – this report is outlined in Section 3.2.3.
  + 1. Aircraft Impact

Section 3.3 of the SDSR covers accidental aircraft impact and states that malicious aircraft impact will be covered by the SZC security case. Emails from NNB GenCo (SZC) confirm that SZC malicious aircraft impact is a replication of the HPC case [92].

Further to the SDSR, the JSSR contains a statement on aircraft impact risk with respect to SZC plot plan versus HPC, under Section 2.2.4, as does Section 3.3.6.6 of the SZC plot plan summary report [60]. These statements outline that NNB GenCo (SZC) does not expect there to be any significant change in the risk of aircraft impact at SZC as a result of the plot plan changes, compared to HPC.

1. ONR Assessment
   1. Considerations of the External Hazards Assessment

The scope of my assessment uses the external hazards considerations in Table 6 and focuses on NNB GenCo (SZC)’s hazard characterisation for the SZC site, in order to form a judgement against the ONR licensing questions.

The structure of my assessment initially considers the broad methodologies applied by NNB GenCo (SZC) to identify, screen and analyse external hazards, followed by consideration of the hazards identified in Section 2.2. I then consider the safety case architecture, before I form a judgement for external hazards on the ONR licensing questions, as well as considering LC compliance and NNB GenCo (SZC)’s organisation and systems.

I have used the standards, guidance and RGP, outlined in Section 2.4, to inform my assessment.

* + 1. Identification, Screening and Analysis of External Hazards

ONR’s expectations for identification and screening are set out in SAPs EHA.1 and EHA.19, and NS-TAST-GD-013 [7]. NNB GenCo (SZC)’s methodology for hazard identification and screening is outlined in Section 2 and Figure 1 of [63]. I consider that the methodology appears to follow a systematic process for identifying the hazards significant to the SZC site. Whilst I recognise that NNB GenCo (SZC) does not identify combinations of hazards for the SZC site, as per SAP EHA.1 paragraph 234, this is not a requirement for NSL and I consider that it can be addressed as part of normal business. Hazards are assessed in more detail in subsequent sections. However, for the purposes of NSL, I am content that NNB GenCo (SZC)’s identification and screening of external hazards meets the intent of SAP EHA.1 and EHA.19.

Detailed consideration of the analysis of the effects of external hazards and the behaviour of the facility in response to the hazard (SAP EHA.5 & 6), taking into account hazard combinations etc., is a limitation within this NSL assessment. Where applicable, this will be followed up as normal business as part of future external hazard assessments.

* + 1. Definition of Site Challenge

Section 3.1.3 and 3.1.4 of the SDSR outlines the requirements for the definition of the external hazards site challenge. The SZC site challenge requirements are for the derivation of the 84th percentile, site-specific hazard level with an AFoE of 10-4/yr (or 10-5/yr for man-made hazards), including an allowance for reasonably foreseeable climate change where appropriate. NNB GenCo (SZC) clarifies that a more conservative site challenge may be defined by aligning it with a higher confidence interval, for the most safety significant hazards. I am content that NNB GenCo (SZC)’s definition of the site challenge aligns with SAPs EHA.3 and EHA.4.

With respect to data sources, Section 3.1.4 of the SDSR outlines that the methodology uses site-specific, or if this is not appropriate, best available relevant data for each hazard incorporated within the design basis, to determine the relationship between event magnitudes and their frequencies. I am satisfied that this overarching philosophy adequately aligns with the intent of SAP EHA.2, noting that the application of the methodology is considered further in the hazard-specific sections of my assessment.

* + - 1. Climate Change

ONR’s expectation is that the reasonably foreseeable effects of climate change over the lifetime of the facility are taken into account (SAP EHA.11, paragraph 259, NS-TAST-GD-013). I have assessed NNB GenCo (SZC)’s approach to define climate change allowances against ONR’s expectations.

ONR considers UKCP18 to be RGP for determining climate change allowances at existing or proposed sites [47]. UKCP18 uses scenarios called representative concentration pathways that specify the radiative forcing at the top of the atmosphere by 2100, relative to pre-industrial levels. Four forcing levels have been defined: 2.6 W/m2, 4.5 W/m2, 6.0 W/m2 and 8.5 W/m2, which give the four RCPs used in UKCP18: RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5. Each RCP results in a different range of global mean temperature. UKCP18 superseded UK Climate Projections 2009 (UKCP09) and, whilst ONR does not prescribe the use of a certain RCP, ONR expects that there should not be a reduction in the level of conservatism with the use of UKCP18 compared with previous approaches that ONR has accepted for UKCP09 [47]. For example, the UKCP09 medium emissions scenario at the 84th percentile.

NNB GenCo (SZC)’s definition of reasonably foreseeable climate change is given in Section 3.1.3 of the SDSR [6] as the UKCP18 scenario RCP 8.5 incorporating *at least* 50% of the uncertainty (50th percentile), for the full lifetime of the plant. NNB GenCo (SZC) provides justification for its approach in the use of UKCP18 to define reasonably foreseeable climate change report[64]. Whilst I recognise that UKCP18 RCPs do not directly align with the UKCP09 emissions scenarios (those provided in the Special Report on Emissions Scenarios), RCP 8.5 provides higher temperature projections than the medium emissions scenario for UKCP09, with RCP 6.0 lying between the UKCP09 low and medium scenarios. Given that RCP 8.5 represents the greatest warming scenario currently provided by UKCP18, I judge that RCP 8.5 at the 50% percentile is an adequate definition of reasonably foreseeable climate change and aligns with SAP EHA.11 paragraph 259.

Where UKCP18 does not currently provide data for particular hazards (for example seawater temperature) NNB GenCo (SZC) has adopted a different approach, which is discussed in more detail for relevant hazards in the following sections and sub-sections of this report. For hazard minima (for example low air temperature) NNB GenCo (SZC)’s approach is to not include a climate change allowance. I am content that this approach is conservative, as extreme minima are expected to become less frequent in a warming climate.

* + 1. Seismic Hazards
       1. Strong Ground Motion (Probabilistic Seismic Hazard Analysis)

The SZC PSHA was carried out by Jacobs, at the request of NNB GenCo (SZC). Given the in-depth technical nature of PSHA, I utilised the expertise and experience of the seismic hazards sub-panel of the ONR Expert Panel on Natural Hazards. Along with ONR external hazards inspectors, the ONR Expert Panel acted as observers during the PSHA and CFS workshops run by Jacobs. Dates of the workshops are provided in Appendix A. Observing these workshops allowed for an understanding of the processes and methodologies used, as well as an insight into the interactions between the Jacobs Technical Delivery Team and the independent PRT.

The SZC-SH-EP-2022-1 paper [53] provides an in-depth review of the PSHA, conducted by the ONR Expert Panel. Due to the limited margins between the original SZC DBE and the PSHA output, the ONR Expert Panel conducted a rigorous and detailed technical review, in line with the intent of paragraph 69 NS-TAST-GD-013 Annex 1 [7]. The enhanced level of rigour applied is due to small margins requiring greater confidence that the site demand has fully captured all major sources of uncertainty. SZC‑SH‑EP‑2022‑1 provides an extensive discussion and review against RGP for the PSHA, covering the seismic source model (SSM), the GMM and site response. For brevity, I have summarised the Expert Panel’s findings, and how these have been considered, in my assessment below.

Peer Review Team

A robust peer review function is considered RGP when undertaking a PSHA [25] and provides ONR with confidence in the overall quality of the PSHA. The PRT carried out the peer review function for the SZC study, similar to the independent participatory peer review feature of a SSHAC study. The Jacobs study recognises SSHAC guidelines. For example [43] [44], and can be considered aligned to an enhanced SSHAC level 2 study, meeting RGP for new nuclear build projects, as outlined in NS-TAST-GD-013 Annex 1 [7].

The overview of CFS & PSHA report [93] provides a summary of the three PRT members, as well as the PRT close-out report included as Appendix B. As recognised by the ONR Expert Panel [53], the evidence in the PSHA and CFS reports suggest that the PRT has made a significant contribution to ensuring an adequate quality of work. A technical meeting specifically convened with the PRT [94] provided me with additional confidence in its role. Whilst the ONR Expert Panel highlight the critical role of the PRT, it also notes that the size of the PRT means that it likely provides the minimum acceptable level of challenge; see Section 2.1 of [53]. Therefore, it is unsurprising that the ONR Expert Panel, as another group of qualified individuals, raise findings not covered by the PRT; see Section 7 of [53].

Seismic Source Model

Section 4.1 of the ONR Expert Panel review outlines expectations in relation to the SSM. The review against these expectations in SZC‑SH‑EP‑2022‑1 identified a number of key findings that may impact the computed hazard, see Section 4 and 7 of [53]. Those areas likely to have the greatest impact upon the computed hazard relate to whether or not the Gutenberg-Richter parameters (associated with earthquake magnitude and frequency distribution) are biased, and whether their coupling with the maximum magnitude has been accounted for.

Ground Motion Model and Site Response

1. Section 5.1 of the ONR Expert Panel review outlines expectations in relation to the GMM and site response, with the review against these criteria covered in Section 5 of [53]. As detailed in Section 7 of [53], the most important GMM and site response finding identified within SZC‑SH‑EP‑2022‑1 is likely to be the uncontrolled variation of epistemic uncertainty in the median predicted spectral accelerations for the reference horizon predicted by the multi‑GMM. This is reported as having a direct influence upon the location of the 84th percentile hazard values. The ONR Expert Panel review also highlights that the improper treatment of depth effects is likely to have a non-trivial impact and will likely increase predicted ground-motions if corrected.

ONR Expert Panel Summary

Whilst the ONR Expert Panel review concluded that the majority of work performed within the SZC PSHA has been conducted to a high standard, it did identify a number of findings that, if addressed, may increase the hazard; see Section 7 of [53]. In addition to the findings, Section 7 also refers to the limit to the precision that can be achieved within any given PSHA. Two papers by McGuire are referenced [95] [96], which, in summary, suggest that it is very challenging to estimate the mean hazard to a precision greater than 25-30%. Therefore, to ensure the design basis is robust for the lifetime of the plant, the ONR Expert Panel advised that a design basis should consider a margin in the region of 30% on the ground motion response spectrum (GMRS) or the 10-4/yr uniform hazard spectrum (UHS) at the 84th percentile.

ONR Summary

Given the PRT endorsement of the PSHA, and taking the ONR Expert Panel review findings into account, I consider the PSHA to be adequate, provided that its outputs are used with the appropriate sensitivity and understanding. For example, by factoring the 30% margin into its use. The consideration of the 30% margin and the revised DBE is covered by my assessment in Section 4.1.3.3.

* + - 1. Capable Faulting Study

A capable fault is a geological fault that has a significant potential for any displacement at, or near, the ground surface. Jacobs produced the CFS [97] on behalf of NNB GenCo (SZC). As with the PSHA, the PRT performed an independent peer review function for the CFS and attended the CFS workshops (see Appendix A for workshop dates), with the CFS also being considered aligned to an enhanced SSHAC level 2 study. Given the significance of the hazard, the ONR Expert Panel conducted an independent review of the CFS; this is reported within SZC-SH-EP-2022-1 [53].

The Jacobs study concludes that there are no capable faults within the SZC site area. The ONR Expert Panel considered the supporting data and methodology in detail and summarised that “the ultimate conclusion of the CFS study has been reached through an appropriate conduct of due diligence”[53]*.* Whilst the ONR Expert Panel considers that the CFS has included and evaluated all of the issues relevant to the likelihood of capable faulting in the vicinity of SZC, it raises a number of recommendations for further clarity [53]. As part of letter ONR-SZC-21568N [67], NNB GenCo (SZC) has committed to resolve the CFS comments.

I have reviewed the findings of the ONR Expert Panel and assessed the data gathered for the CFS, its appropriateness, the use of subject matter experts and the diverse range of analytical methods and techniques used. From my assessment, I consider that the CFS is adequate, with the resolution of the CFS comments tracked as part of regulatory issue RI-10805.

1. In summary, from my assessment of the CFS, I am content that capable faulting hazard can be screened out as not a credible hazard at SZC, as per the intent of SAP EHA.19.
   * + 1. Design Basis Earthquake

From my assessment of the DBE presented in the SDSR [6], I was aware that international expectations with regards to the minimum DBE were potentially more onerous than the site challenge calculated via the PSHA. ONR NS-TAST-GD-013 Annex 1 paragraphs 70 and 71 [8], refer to the previous revision of IAEA SSG-9 [24] that suggests a DBE should meet a minimum of a horizontal free-field standardised response spectrum anchored to a peak ground acceleration (PGA) value of 0.1 g. Furthermore, ONR NS‑TAST‑GD‑013 Annex 1 recognises that the Principia Mechanica Ltd (PML) spectra from 1981 have historically been used in the UK as the standardised response spectrum to meet the minimum DBE. I identified that the SZC DBE presented in [6] did not meet this ONR NS-TAST-GD-013 Annex 1 check of PML (soft) 0.1 g, given that SZC is a soft site. However, I was also aware of the updated IAEA SSG-9 [25], revised post-issue of ONR NS-TAST-GD-013 Annex 1, as well as IAEA SSG‑67 [26] and WENRA guidance on seismic events [39], where use of a standardised response spectrum is not specified.

Given that RGP for the minimum DBE anchor point remains 0.1 g PGA, I engaged with international regulators on their application of the minimum DBE. I was advised that U.S. NRC and STUK both use the site-specific spectral shape scaled to 0.1 g at 100 Hz, as opposed to a standardised response spectrum [58] [59]. This site-specific spectral shape is the PSHA 10-4/yr and/or 10-5/yr mean UHS results. When applied to the SZC PSHA results, it is evident that this shape is more representative of the SZC site challenge than the PML (soft) spectrum anchored at 0.1 g; see Appendix C figures.

From my review of RGP, I consider the following criteria to be appropriate for judging the adequacy of NNB GenCo (SZC)’s DBE against the minimum DBE:

* A PGA value of 0.1 g at 100 Hz has widely accepted provenance internationally as an appropriate value to anchor a minimum spectral shape to for the horizontal components.
* The most accurate characterisation of the spectral shape for the SZC site is derived by the PSHA study described above. These results can be used to define a spectral shape by obtaining the mean UHS for the 0.1 g (PGA at 100 Hz) anchor point. Alternatively, PSHA UHS results could be scaled to provide a spectral shape, for example, scaling the 10-4/yr and/or 10-5/yr mean UHS to 0.1 g at 100 Hz.
* For the corresponding vertical component, appropriate vertical/horizontal ratios can be applied to the horizontal spectrum above to define the vertical spectrum.
* The control point for application of this minimum DBE should be consistent with the DBE definition for the site, that is, +7.3 mOD.

Given the relatively low seismic hazard in the Sizewell C area, the original SZC DBE did not meet the criteria outlined above, the site-specific UHS mean (10-4 or 10-5/yr) scaled to 0.1 g at 100 Hz. It also did not meet standardised response spectra, such as the PML (soft) spectrum anchored to 0.1 g, or EUR (soft) anchored to 0.1 g. Furthermore, the original DBE did not meet the additional margin of 30% that the ONR Expert Panel considered should be added to the GMRS or 10-4/yr UHS 84th percentile [98] [53]; see Appendix C figures.

Following engagement with ONR, NNB GenCo (SZC) committed to revise its onshore DBE, for both the vertical and horizontal, to that outlined in the project deliverable Sizewell C DBE definition document [68]; see Appendix C figures. This revised DBE includes the 30% additional margin, advised by the ONR Expert Panel. From my assessment of the PSHA, the minimum DBE expectations, and the dynamic characteristics of the site including the important soil-structure interaction frequencies and/or structural response modes (i.e., an important SZC frequency of engineering interest is ~1Hz; see [99]), I consider the revised onshore DBE to be adequate, meeting the intent of SAP EHA.4 and EHA.9, given that it:

* bounds the site-specific hazard, with the additional margin of 30% that the ONR Expert Panel consider should be added to the SZC PSHA output;
* broadly meets the SZC site-specific 10-4/yr mean UHS and 10-5/yr mean UHS scaled to 0.1 g PGA at 100 Hz. I recognise this approach of determining a minimum DBE better represents the site-specific hazard, than the PML soft (0.1 g). Also, it provides greater levels of margin at frequencies of engineering interest (for example ~1Hz for the horizontal), than use of a standardised response spectrum; and
* the downstream civil engineering process, based on the principles of replication, builds in further margin (paragraph 51, NS-TAST-GD-013 Annex 1 [8]).

By contrast, the offshore DBE does not currently meet minimum DBE RGP, and I do not consider it to be adequate as it does not meet the intent of SAP EHA.4 and EHA.9. As part of letter ONR-SZC-21568N [67], NNB GenCo (SZC) has committed to revise the offshore DBE to align with ONR’s expectations. For my NSL assessment, I consider the offshore DBE commitment made by NNB GenCo (SZC) to be adequate, given that the offshore structures have yet to be designed in detail. I have captured this in regulatory issue RI-10805 to track NNB GenCo (SZC)’s offshore DBE commitment post-licensing.

**Seismic Hazards RI-10805**: In relation to seismic hazards, NNB GenCo (SZC) should:

* Define an offshore design basis earthquake for both the horizontal and vertical that meets relevant good practice for the minimum design basis earthquake, in line with the onshore design basis earthquake.
* Formally include the revised design basis earthquake definitions within the Sizewell C safety case.
* Adequately address all of the Capable Faulting Study comments raised within ONR Expert Panel Paper, SZC-SH-EP-2022-1.
  + - 1. Other Seismic Considerations

Time Histories

Paragraph 87 to 90 of NS-TAST-GD-013 Annex 1 [8] provides guidance to inspectors on the production of time histories. Whilst time histories have not yet been generated to match the revised SZC DBE, I am aware of NNB GenCo (SZC)’s intention to replicate the approach used for HPC [69], where time histories were artificially generated. I do not consider the use of artificially generated time histories to align with RGP, for example, ASCE 4‑16 [45], ASCE 43‑19 [46], NS‑TAST‑GD‑013 Expert Panel Paper – Seismic Hazards [8]. Instead, the use of modified records of real earthquakes is considered RGP. However, I consider that the proposed approach can be tolerated based on the linear elastic structural response, predicted by the structural analysis. This means that, in practice, the approach taken to produce time histories will not have a significant impact in analyses. In addition, I have made the ONR civil engineering inspector aware of the approach taken to generate time histories.

Seismic Monitoring

NNB GenCo (SZC) installed a seismic monitor at the SZC site in spring 2021 [100]. This seismic monitor consists of a 3-instrument Guralp Radian borehole seismometer array. Whilst the seismic monitor was installed after much of the PSHA work had completed, it will provide valuable data for future hazard analyses. I consider that the installation of a free-field seismic monitor meets RGP, for example IAEA SSG‑67 [26] and IAEA NS‑G‑2.13 [27].

* + - 1. Interface with Civil Engineering

There is a strong interface between external hazards and civil engineering for seismic and geological hazards. I have worked closely with the civil engineering inspector and consideration of the following is included within the civil engineering assessment report [55]: Ground investigations, for example the ground investigation report [101], ground model, geotechnical parameters and groundwater. I have also engaged with the civil engineering inspector on the soil-structure interaction, structure-soil-structure interaction and engineered fill. Future ONR civil engineering and external hazards engagement in relation to seismic hazards will be needed to confirm the offshore DBE and to ensure that the engineered fill assumptions used in the seismic hazards analyses are validated once the fill characteristics are known.

* + 1. Flooding Hazards
       1. Coastal Flooding

The SZC platform height of +7.3 mOD has previously been assessed by ONR [79]. Whilst the platform height is intended to protect the SZC site against the extreme still water level, a sea defence is intended to provide protection against waves and erosion. The SDSR [6] reports that the sea defence will have crest levels of +12.6 mOD (for reasonably foreseeable climate change) and +16.4 mOD (for maximum credible climate change). ONR will consider the detailed sea defence design, when available, to ensure that it can withstand the SZC coastal flood hazard.

The ONR assessment of the SZC platform height raised a number of observations [79]; NNB GenCo (SZC) provide a progress update on these in Appendix A of the flooding summary report [71]. The observations cover further work that should be undertaken by NNB GenCo (SZC), or further evidence for assumptions, for example, in relation to erosion. The status of these observations is detailed in Appendix B of this assessment report. The majority of the observations are not licensing specific and are considered open; resolution of these will be tracked as part of regulatory issueRI-10806.

For my NSL assessment, I have considered the different components of coastal flood hazard. Data, methodology, climate change and the selected design values are considered for extreme still water level, waves and tsunami hazard. My findings for coastal flood hazards are summarised in Section 4.1.4.1.4.

* + - * 1. Extreme Still Water Level

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Hazard | SZC site challenge | | | SZC design value | |
| Present day | 2110 | 2140 | 2110 | 2140 |
| Extreme Still Water Level | +4.34mOD | +5.57mOD | +6.09mOD | +5.95mOD | +6.88mOD |

Data

As reported in [72], in order to characterise extreme still water level, data from Lowestoft was taken from the UK National Tide Gauge Network. A conversion factor, based on the Environment Agency’s coastal flood boundary report, was applied to account for the SZC locality. Data used was from 1964-2019, with hourly observations available for 1964-1992 and 15-minute intervals from 1993-2019. I consider that the use of data from a UK Class A tide gauge aligns with RGP, for example, NS-TAST-GD-013 Annex 3 [7]. However, as highlighted by [51], SZC is approximately equidistant from Lowestoft and Felixstowe. I recognise that data is available from Felixstowe’s tide gauge, also providing a long and reliable dataset, however, no justification as to its exclusion is provided. Further, the Environment Agency’s coastal flood boundary model estimates higher water levels for Felixstowe than Lowestoft (0.46 m higher for the median 10-4/yr event [102]). Therefore, it is not clear to me that the best available relevant data has been used, as per the intent of SAP EHA.2, and I have raised a technical query with NNB GenCo (SZC) (TQ1, Appendix D), which will be tracked as part of regulatory issue RI-10806. However, I am cognisant that, should Felixstowe data be included and the site challenge increases, there is additional margin between the SZC design value of +6.88 mOD (2140) and the platform height of +7.3 mOD.

Methodology

Joint probability methods (JPM) produce a probability distribution of extreme sea levels for a given location by combining statistically the separate distributions of tides and storm surges. Whilst [72] acknowledges that JPMs are the simplest approach to modelling extremes, the report highlights statistical modelling issues with the approach and instead opts for a skew surge joint probability method (SSJPM). As reported in NS-TAST-GD-013 Annex 3 [7], the best dataset of extreme levels is obtained by calculating the probabilities of (deterministic) tide and skew surge. Skew surge is the difference between the height of the predicted astronomical high tide and the observed high water within a given tidal cycle; it accounts for weather and storm surge effects over a full tidal cycle. The SSJPM models the joint probability of skew surge and predicted high tide. I consider the use of SSJPM meets RGP, given its use in the Environment Agency’s coastal flood boundary model [103] and its recognition in NS-TAST-GD-013 Annex 3 reference paper [7].

However, as raised in [51] and reported above, the Environment Agency’s coastal flooding boundary model shows that from Lowestoft to Felixstowe, i.e. north to south along that stetch of the coastline, the water levels increase [103]. This suggests that the SZC site, which lies in-between Lowestoft and Felixstowe, would have higher water levels than at Lowestoft. The SSJPM results, detailed in [72], closely align with the Environment Agency’s coastal flooding boundary model estimates for Lowestoft but show a 0.4 m drop in water levels from Lowestoft to the SZC site. Therefore, I have a raised a technical query with NNB GenCo (SZC) (TQ2, Appendix D), as it is not clear that the methodology will result in a conservatively derived site challenge, in line with EHA.4. TQ2 will be tracked as part of regulatory issue RI-10806. As with TQ1, given the platform height of +7.3 mOD, I do not consider that resolution of the TQ will impact my judgement for NSL.

The EVA threshold exceedance approach is used in deriving the extreme sea levels. Whilst I recognise that this is a valid method, there is limited justification provided as to why it is selected over the block maxima approach, which [51] suggests may result in higher values. Therefore, I have raised a technical query with NNB GenCo (SZC) (TQ3, Appendix D). TQ3 will be tracked as part of regulatory issue RI-10806.

Climate Change

NNB GenCo (SZC) uses a climate change adjustment of RCP 8.5 at the 95th percentile when characterising the extreme sea level site challenge [71]. The site challenge is defined at 2110 and 2140; accounting for end of operation (60-year operational lifetime plus a 20-year extension) and proposed end of life of the interim spent fuel store, respectively. This adjustment using the 95th percentile exceeds NNB GenCo (SZC)’s requirement for the 50th percentile. Therefore, I judge that the use of RCP 8.5 at the 95th percentile meets the intent of SAP EHA.11 paragraph 259.

Design Value

The extreme still water design value for 2110 is +5.95 mOD, which is 0.38 m above the 2110 site challenge; for 2140 it is +6.88 mOD which is 0.79m above the 2140 site challenge. Furthermore, the SZC platform height is set at +7.3 mOD, providing a margin of 1.35 m above the design value extreme still water level in 2110 and 0.42 m in 2140.

NNB GenCo (SZC) has informed me of new and ongoing work to update the extreme still water level characterisation and address technical queries TQ1, 2 and 3 (Appendix D) [104]. I have raised regulatory issueRI-10806 to track resolution of the TQs and other items identified in my assessment of the coastal flood hazard.

Notwithstanding RI-10806, and the potential for the site challenge to evolve based on the ongoing hazard characterisation work, I consider that the extreme sea level design value is adequate as it bounds the site challenge by 0.38 m (2110) and 0.79 m (2140). Furthermore, there is margin between the SZC design values and the platform height of +7.3 mOD. However, I recognise that extreme sea level cannot be reviewed in isolation and should be considered in conjunction with wave and tsunami hazard, assessed below.

* + - * 1. Offshore Waves

|  |  |  |
| --- | --- | --- |
| Hazard | Significant wave height (Hs) (baseline) | Hs (10% climate change allowance) |
| Offshore waves (A1 Scenario) | 8.14 m | 8.95 m |

Data

Present day wave conditions were initially derived in [73]; this work was developed by CEFAS in [74]. [74] uses extreme sea level hazard studies which predate those discussed in Section 4.1.4.1.1.

As reported in [74], the wave climate was divided into four sectors, Sector 1: 330-40⁰N, Sector 2: 41-75⁰N, Sector 3: 76-135⁰N and Sector: 4 136-210°N, with 8 separate cases of wave height and water level developed for each sector. The results demonstrated that only Sector 1 and 4 produce large wave and surge conditions. In each Sector case, 33-year (1980 to 2012) 1 and 3-hourly time series were considered and the waves from directions outside the sector were filtered out. Sector 1 data was taken from the Met Office European wave model prediction point 1069, with Sector 4 using data from the prediction point 950. The Lowestoft tide gauge, modified for use at Sizewell, was used to obtain the water level time series using data from 1990-2009 [73]. [74] states that the wave and water level datasets were combined for each sector to create simultaneous and independent records of wave height, period and water level.

Given that recent data is not utilised in the offshore wave hazard characterisation and the extreme still water values have been superseded, I do not consider that best available relevant data source has been used and, therefore, I do not consider that the intent of SAP EHA.2 has been met. This finding is captured as part of regulatory issue RI-10806.

Methodology

JOIN-SEA methodology is used for developing the shape of the extreme profiles of wave height and water level combination at Sizewell in both [73] and [74]. Whilst the JOIN-SEA software has been available since 2000, NS‑TAST‑GD‑013 Annex 3 reference paper [7] reports that this method tends to underestimate flood hazards unless correction factors are applied. This view is supported by [51], which suggests that results derived using JOIN‑SEA often do not reflect the reality for rare events. Therefore, I consider that the joint probability analysis of extreme sea level and significant wave heights should be reviewed and updated, using a different method if appropriate, to ensure that it is aligned with RGP. This review should use recent data and the latest extreme sea level hazard site challenge and is captured in regulatory issue RI-10806.

The TOMAWAC wave transformation model, developed by CEFAS, was used to model nearshore waves. However, I have not considered its use in detail as part of my assessment, given that nearshore wave characterisation will need to be updated following the updates to the offshore wave hazard characterisation. Therefore, I expect NNB GenCo (SZC) to update its nearshore wave analysis, ensuring it aligns with RGP and, where relevant, taking into account updates to the offshore wave hazard and the sea defence design, this is captured in regulatory issue RI-10806.

Geomorphology and Bathymetry

The evolution of the coast and offshore sediment has the potential to impact on the coastal flood hazard for SZC. TR319 [74] provides details on the geomorphology and sandbank scenarios considered, including assumptions made, with details of the different scenarios provided in TR319 Section 2.1. The only scenario that results in nearshore wave increases is the lowered sandbank scenario. For return periods of 2-100 years, TR319 reports an increase in wave energy in the nearshore (within 1000 m of the shore), suggesting the present-day sandbank morphology reduces this wave energy. However, there is little wave energy difference in the very near shore (<200 m from shore) for this scenario. Further, TR319 reports that for the 10-4/yr AFoE, where sea levels are also higher, there is little difference in the nearshore when compared to the present day. TR319 demonstrates that different offshore morphological scenarios have been considered for SZC and suggests that there is limited impact on the wave hazard. However, given that NNB GenCo (SZC) has committed to further coastal flood hazard studies [104], I would expect the impacts of changing geomorphology and bathymetry to be taken into account accordingly in these studies, which is captured in regulatory issue RI-10806.

Climate Change

NNB GenCo (SZC) uses a 10% increase in wave heights to account for climate change. This 10% increase takes Environment Agency guidance into account [105]. Further, the UKCP18 marine report [106] states that “simulations suggest an overall decrease in mean SWH [significant wave height] around most of the UK coastline of 10-20% over the 21st century, but the sign of the change differs among models and coastal location”.Figure 3.3.1 of [106] shows that model outputs for the Lowestoft and Felixstowe locations, in the vicinity of SZC, predominantly show a decrease in mean significant wave height, and no models produce outputs >10% increase for the mean significant wave height or annual maximum wave height.Therefore, I judge that the offshore wave site challenge climate change allowance of 10% increase is adequate and aligns with RGP (that is UKCP18).

Design Value

The site challenge for waves is defined for offshore conditions; the SDSR [6] states that this is to allow nearshore wave conditions to be modelled using appropriate software. The SDSR cites the offshore wave site challenge as the SZC design values.

I am aware of further work by NNB GenCo (SZC) to characterise offshore waves and wave transformations to shore [104]. The SDSR also recognises that work is ongoing to ensure that the site challenge and design value wave heights are adequate and in line with latest RGP. Protection of the SZC site against the combination of extreme still water level and significant wave height will be provided by a sea defence, with a planned crest level of +12.6 mOD (for reasonably foreseeable climate change) and +16.4 mOD (for maximum credible climate change) [71]. The increase to a +16.4 mOD crest height will be implemented should climate change predictions exceed those considered to be reasonably foreseeable by NNB GenCo (SZC). Platform height observation 14 was raised to ensure that ‘trigger points’ are identified to make sure that construction of the additional height occurs far enough in advance of the climate change effects, so that the site remains protected; see Appendix B.

Overall, I do not consider the current offshore wave design values to be adequate. However, the deficiencies are recognised in my assessment and these will be resolved through NNB GenCo (SZC)’s commitments to update the wave modelling for SZC [104], which will be tracked via regulatory issue RI-10806.

* + - * 1. Tsunami

Data and Methodology

Given that the tsunami hazard study [77] is based on a literature review of the tsunami threat to the UK, along with consideration of tsunami propagation towards the SZC site, I consider data and methodology in conjunction.

Within [77], NNB GenCo (SZC) covers tsunami types and sources with the potential to affect SZC, the SZC setting in relation to tsunami wave propagation (for example bathymetry), and tsunami wave run-up factors and wave amplitudes. I consider the approach taken to identify tsunami sources is reasonable, with site-specific considerations taken into account. For example, the SZC site is located on the Suffolk coast and is, therefore, shielded from tsunami waves originating from the west, including north-west and south-west.

When framing tsunami hazard in the context of overall coastal flood hazard, I acknowledge that tsunami hazard can be considered independent of meteorological hazards and, therefore, independent of storm surge, that is, they are coincidental hazards. This means that, as per NS-TAST-GD-013 Annex 3 paragraph 117 [7], it would be overly conservative to consider tsunami hazard in conjunction with significant storm surge, which is included in the SZC extreme still water level site challenge.

Instead of combining tsunami hazard with extreme still water level, NNB GenCo (SZC) use the mean high water spring (MHWS) [6]. MHWS is the average, across the year, of two successive high waters (i.e. spring tides – when tidal range is greatest) within a 24-hour period in each month. NNB GenCo (SZC) reports that this accounts for >90% of tidal levels [6]. Assuming that MHWS accounts for 90% of high tidal levels, this would mean that in a given year 10% of high tides exceed this level. NS-TAST-GD-013 paragraph 157 [7] reports that for coincidental hazards “inspectors should ensure that a pragmatic and reasonably conservative approach has been taken”. NS-TAST-GD-013 suggests that a 2x10-2/yr (1/50 yr) event, may be an appropriate return period for a coincidental hazard to be considered in conjunction with the 10-4/yr event of the hazard in question. Given that 10% of high tides exceed the MHWS in a year, I do not consider this to align with the expectation of NS-TAST-GD-013 detailed above. Therefore, I do not consider the still water level used (MHWS of +2.13 mOD (2110) and +2.50 mOD (2140)) in conjunction with tsunami hazard (1.5 m wave amplitude) to be adequate. Paragraph 137 provides further detail on my consideration of MHWS and implication for the adequacy of the design value.

Climate Change

The tsunami hazard assessment report [77] and the FSR [71] acknowledge that initiation of landslide tsunamis may be affected by climate change. For example, due to sediment instability as a result of temperature changes. Further, climate change is explicitly taken into account for rising sea levels in conjunction with tsunami hazard. Whilst paragraph 135 details my judgement for the use of MHWS, I consider the inclusion of climate using RCP 8.5 at the 70th percentile to be in line with RGP, for example, SAP EHA.11 paragraph 259. Further, the use of the 70th percentile exceeds NNB GenCo (SZC)’s own requirement for climate change (RCP 8.5 at 50th percentile).

Design Value

As reported in paragraph 135, I do not consider the use of MHWS in combination with tsunami hazard to be aligned with RGP. However, I recognise that a 1.5 m tsunami wave combined with the 10-2/yr extreme still water level for 2110 (84th percentile) of +4.16 mOD [72] is bounded by the sea defence crest height of +12.6 mOD [6]. Further, tsunami hazard combined with the SZC extreme still water level site challenge for 2110 (+5.57 mOD) and 2140 (+6.09 mOD) [6] are also bounded by the sea defence crest. Therefore, the still water level return frequency is unlikely to pose a problem for the sea defence design. However, I recognise that these comparisons do not account for tsunami run-up height. As part of regulatory issue RI-10806, I expect NNB GenCo (SZC) to review its approach to using the MHWS in combination with tsunami hazard, to ensure that it aligns with RGP, providing the rationale for its selected approach.

* + - * 1. Coastal Flooding Summary

As part of my NSL assessment, I have identified a number of items related to coastal flood hazard characterisation that should be resolved prior to detailed design and/or construction of the sea defences, to ensure that the intent of SAP EHA.2, EHA.4 and EHA.12 is met. These items can be resolved, should the derivation of the 10-4/yr AFoE event, for all components of the coastal flood hazard:

* use the best available relevant data source(s); and
* use methodologies that align with relevant good practice.

For the purposes of my NSL assessment, I am content that the outstanding items can be addressed post-licensing, in conjunction with detailed design of the sea defences. This judgement is based on the detailed design of the sea defences being conducted post ONR’s licensing assessment, allowing the outstanding items to be addressed prior to the construction of the sea defences. Therefore, I have raised regulatory issue RI-10806 to track these items, in addition to the platform height observations. Further, the external hazards inspector will consider the detailed sea defence design, when available, to ensure that it adequately accounts for any updates to the SZC coastal flood site challenge. The detailed sea defence design itself will be considered by the civil engineering inspector.

**Coastal Flood Hazards RI-10806**: In relation to coastal flood hazards, NNB GenCo (SZC) should:

* For all components of the coastal flood hazard, ensure that derivation of the 10-4/yr annual frequency of exceedance event uses:
  + the best available relevant data source(s)
  + methodologies that align with relevant good practice
* Ensure resolution of all the ONR Platform Height Observations.
  + - 1. Fluvial Flooding

The FSR [71] concludes that there is minimal fluvial flooding risk to the SZC main development site, since the 10-4/yr AFoE flood levels, including a climate change allowance, in the area around the SZC site (3.0-3.5 m) remain below the design levels of the site platform (+7.3 mOD). This fluvial flood hazard value is taken from the Sizewell C fluvial flood risk modelling report[82]; see Plate 5.1 and 5.2 in [82]. Further the 10‑5/yr AFoE fluvial flood hazard event has a flood level range of 4.7-5.0 m. Given the significant margin between the site platform and the 10‑4/yr AFoE fluvial flood event, and the 10‑5/yr AFoE event, I consider the intent of SAP EHA.12 to be met for fluvial flood. Therefore, for my NSL assessment, based on the ~4 m margin between the site challenge and platform height, and that the fluvial flood challenge is bounded by extreme still water level, I judge that the fluvial flood withstand is adequate. Therefore, I have not sampled the fluvial flood hazard in further detail.

* + - 1. Pluvial Flooding

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Hazard | | | SZC site challenge | | SZC design value |
| Present day | Including climate change |
| Rainfall | Storm Duration | 10 minutes | 48.5 mm | 59.6 mm | 59.6 mm |
| 1 hour | 126 mm | 147.8 mm | 147.8 mm |

Pluvial flooding typically results from rain falling on saturated ground. For the SZC site, extreme rainfall has the potential to impact site drainage, causing flooding on the platform. Therefore, it also has the potential to affect the SZB site, should water flow from the SZC site to SZB. Pluvial flooding was discussed with NNB GenCo (SZC) as part of a site visit, see [13].

Data

Data used in the SZC extreme rainfall study is detailed in [81] and includes hourly observations from Mildenhall (01/01/1960-31/12/1968), Honington (01/01/1970-31/12/1981) and Wattisham 1 (01/01/1982-31/12/2018), and daily observations from Westleton (01/05/1988-31/03/2015) and Thorpeness (01/04/2015-31/12/2018). Data from different weather stations was utilised, whilst [81] acknowledges that this is not ideal for use in EVA which requires a homogeneous dataset, it was done to allow for a longer time series and to reduce uncertainties in data. I consider that the approach taken meets the intent of SAP EHA.2, using the best available relevant data.

Methodology

Rainfall hazard studies often use the flood estimation handbook (FEH). However, the FEH only provides best estimate hazard values. Instead, NNB GenCo (SZC) use threshold exceedance EVA on the different datasets identified, to produce results for different resolutions. The 84th percentile is used to define the site challenge [71]. From the information sampled, the approach appears to allow for the site challenge to be conservatively defined, in line with SAP EHA.4. Therefore, I consider the use of EVA, as opposed to the FEH, to be appropriate.

Climate Change

The extreme rainfall study [81] reports that for climate change, due to several limitations and uncertainties of the modelling, use of RCP 8.5 at the 84th percentile is recommended. Additionally, the report highlights new hourly climate change data with 2.2 km x 2.2 km resolution from UKCP18, released in September 2019, which would allow a more robust climate change adjustment factor to be determined. Whilst I consider the climate change adjustment factor meets the intent of EHA.11 paragraph 259, I have advised NNB GenCo (SZC) to consider reviewing the 2.2 km x 2.2 km resolution data, in order to understand the impact on the climate adjustment factor.

**Pluvial Flooding ONR Advice**: NNB GenCo (SZC) should review the UK Climate Projections 2018 rainfall 2.2km x 2.2km resolution data and determine whether its rainfall climate change adjustment factor should be updated. Should the review result in an increase to the climate change adjustment factor, the Sizewell C rainfall site challenge and design value should be updated accordingly.

Design Value

The rainfall site challenge is taken as the design value. Provided that beyond design basis and hazard combinations are adequately addressed as part of future studies and submissions, then I consider the use of the site challenge for design to be aligned with SAP EHA.3 and 4. However, should the review of the UKCP18 2.2 km x 2.2 km resolution data result in an increase to the site challenge, I would expect the design value to be updated to reflect this.

Further, Appendix B of the FSR [71] presents the pluvial and overtopping inundation study results. NNB GenCo (SZC) discussed its ongoing work on pluvial flooding during a SZC site visit [13]. NNB GenCo (SZC) is working to confirm mitigation measures for SZC to avoid unwanted water accumulating on the SZC platform; these include gradually profiling the SZC platform to the north-west corner to direct water off the platform and away from SZB, as well as culverts and channels with gradient flow directing water away from SZC and SZB, including a channel between SZC and SZB. I consider that work carried out to date helps to provide confidence that design of the SZC platform and culverts/channels is feasible to mitigate the effects of rainfall and overtopping, minimising the impact on SZB. The pluvial and overtopping inundation study will undergo future iterations to account for plot plan alterations and sea defence design; I consider that this can be tracked by ONR as part of closure of the ONR platform height observation 11 (Appendix B) and, therefore, via regulatory issue RI-10806.

Summary

Based on the information sampled as part of my NSL assessment, I consider that the rainfall site challenge meets the intent of SAP EHA.2, EHA.4 and EHA.11 paragraph 259.

* + 1. Meteorological Hazards
       1. High Air Temperature and Enthalpy

|  |  |  |  |
| --- | --- | --- | --- |
| Hazard | | SZC site  challenge (2110) | SZC design value |
| High air temperature | Daily maximum | 45.7°C | 44°C |
| 12-hour average | 40.2°C | 40°C |
| Enthalpy | Daily maximum | 78.9 kJ/kg | 83 kJ/kg |
| 12-hour average | 70.2 kJ/kg | 78.5 kJ/kg |

As the SZC site challenge exceeds the SZC design values for high air temperature, my assessment focuses on high air temperature, with some limited discussion on enthalpy.

Data

Data used in the original characterisation of the SZC high air temperature site challenge was predominately from 1980-2017. This data was taken from the Wattisham weather station, ~46 km from the SZC site and 89 m above sea level.

Informed by [54], I observed that Met Office Wattisham data from 2019 suggested that there had been exceedances of the SZC site challenge, excluding the climate change allowance, for different averaging periods (2‑day, 3‑day and 4‑day), as detailed in Table 2 from the justification of extreme high (air) temperature design basis value at Sizewell CreportRev.2 [107]. It is important to conservatively define the site-specific hazard, in line with SAP EHA.4, in order to understand the margin that exists between the hazard and design. Given this, I requested clarification from NNB GenCo (SZC) as to whether there have been exceedances of the SZC site challenge. Following engagement, NNB GenCo (SZC) updated the justification of extreme high (air) temperature design basis value at Sizewell Creport to Rev.4[83]based on the latest extreme air temperatures at Sizewell Creport Rev. 5 [84], which was revised to include data from 2017-2020. The inclusion of the more recent data resulted in an increase in the SZC high air temperature site challenge, meaning that it exceeds the HPC design value which is being replicated for SZC. I consider that the use of more recent data for defining the site challenge meets the intent of SAP EHA.2. Discussion of the SZC site challenge exceedances over the SZC design value are covered by paragraphs 159 and 160.

NNB GenCo (SZC) uses data from Wattisham to calculate the SZC site challenge for high air temperature and enthalpy. NNB GenCo (SZC) justifies the choice of Wattisham and its data given the data availability, length of record, time resolution, data quality and location. NNB GenCo (SZC)’s choice of weather station is further supported by a limited cross-check with SZB data using data from summer 2019 reported in Section 3.3.1 of [107]. Maximum Wattisham air temperature values were reported in summer 2019 and the SZB air temperature data recorded is ~1-3°C lower than that recorded at Wattisham. This provides confidence, albeit based on a limited study, that Wattisham is conservative for the SZC site. ONR’s Expert Panel [54] reported that the choice of weather station is considered suitable for high air temperature characterisation. On this basis, I consider that the use of Wattisham data meets the intent of SAP EHA.2.

In relation to enthalpy, I queried whether Wattisham is conservative for the SZC site, given that it is an inland location. NNB GenCo (SZC) included its response in Section 3.1.4 of [83]. NNB GenCo (SZC) report that Wattisham is the closest weather station for which all of the data parameters required to estimate enthalpy are available. Further, a review of available literature did not identify any adequate and recognised methods for estimating localised spatial variability in enthalpy between coastal and inland sites. NNB GenCo (SZC) concludes that data from Wattisham represents the best approach of estimating enthalpy for the SZC site. Given that Wattisham is a reliable Met Office weather station in the vicinity of the SZC site and the 10-4/yr AFoE at the 85th percentile is used, I consider that NNB GenCo (SZC)’s use of Wattisham data meets the intent of SAP EHA.2 and can be considered adequate for the SZC site. I recognise that enthalpy is a topic of ongoing research and I expect future periodic safety reviews to consider advances in the understanding of variability in enthalpy between coastal and inland sites.

Methodology

EVA is the methodology used to calculate the SZC high air temperature site challenge, utilising the threshold exceedances approach. As recognised by [54], EVA is a well tried and tested statistical procedure that faces challenges if the mean base state is varying. This can impact derivation of a conservative high air temperature site challenge, as climate change means that the base state for high air temperature varies over years and decades. I asked the ONR TSC to review the EVA methodology in detail [51]. Whilst the TSC considers NNB GenCo (SZC)’s approach to be reasonable, the TSC highlighted further work that could be undertaken to provide additional confidence (page 28 [51]):

“Detrending the 40 years of data to present day (using the climate change analysis from 1980-2020) may help reduce some uncertainty and account for potentially higher temperatures in the coming years.”

“Whilst the GPD [Generalised Pareto Distribution] may be the most appropriate fit to the extreme temperature data, there is no comparison against other statistical distributions or mention of the ‘goodness of fit’ statistics relating to this. Similarly, visual plots of the extreme temperature data plotted against the statistical distribution (and confidence limits) will help to understand how good the representation of the GPD is to the underlying data.”

I note that NNB GenCo (SZC) already use the upper confidence limit (84th percentile) for the 10-4/yr AFoE temperatures, as suggested by [51], meeting the intent of SAP EHA.4.

Overall, I consider that NNB GenCo (SZC)’s use of EVA and approach to defining the high air temperature site challenge is in line with RGP. However, I recognise that there are challenges with EVA as the result of climate change. I consider that NNB GenCo (SZC) should regularly review the high air temperature data and analysis for SZC, taking into account the limitations of EVA. This is in line with reviewing data as part of periodic safety reviews, LC15 [108]. Further, should NNB GenCo (SZC)’s substantiation of the SZC HVAC equipment place significant reliance on the SZC site challenge, I advised NNB GenCo (SZC) to undertake further sensitivity studies, as suggested by [51], such as detrending the data used in the analysis and demonstrating the ‘goodness of fit’ of data against GPD, to account for the uncertainties in the EVA. This relates to mechanical engineering regulatory issue RI-10802.

Climate Change

The high air temperature site challenge includes climate change to 2110, which is intended to account for 10 years to operation, 60 years of operation and 20 years decommissioning. The climate change adjustment factor used by NNB GenCo is derived using UKCP18 RCP 8.5, in line with NNB GenCo’s definition of reasonably foreseeable climate change [64]. As I consider NNB GenCo’s definition of reasonably foreseeable climate change meets the intent of EHA.11 paragraph 259 (see paragraph 88) I am content with its application for high air temperature. A climate change adjustment factor to 2110 is reasonable, given that the hazard impacts HVAC equipment, which is predominantly used in operation.

Given the uncertainty of the impact of climate change on enthalpy, no adjustment is made by NNB GenCo (SZC) [6]. I consider this to be reasonable. However, should developments in climate projections allow for a clearer understanding of changes to enthalpy, then I would expect NNB GenCo (SZC) to take account of these in its derivation of the SZC enthalpy site challenge, as part of normal business. For example, periodic safety reviews, LC15 [108].

ONR Expert Panel Considerations

The main areas for consideration, raised by [54], have been addressed for NSL, as outlined in Table 7.

Table 7: ONR Expert Panel considerations for high air temperature and their resolution for NSL

|  |  |
| --- | --- |
| ONR Expert Panel Consideration | Resolution / Forward Work |
| The absence of data from 2017-2020 may be affecting the SZC site challenge value. | NNB GenCo (SZC) included data from 2017-2020 in its updated reports [83] [84]. The updated reports now define a SZC site challenge that is greater than the HPC site challenge. |
| The SZC locality, on the east coast, is likely to be warmer than the HPC locality, on the west coast. |
| Examination of the climate change offset between the present day and future (2110) high air temperature values. | NNB GenCo (SZC) has provided further justification for its use of UKCP18 RCP 8.5 in [64]. UKCP18 still represents RGP for the UK, and I would expect NNB GenCo (SZC) to take account of future advances in climate change projections. |
| The SZC heat wave profile should be over a longer duration and not fixed at 44°C. | NNB GenCo (SZC) confirmed that the heat wave profile [85] is not being updated using the 2017-2020 data and is not planned for use in future safety cases [109]. |
| Whether 44°C is a suitable design value for SZC. | NNB GenCo (SZC) recognises that the SZC site challenge exceeds the SZC design value of 44°C maximum temperature and for PCSR are aiming to demonstrate that the HVAC design can withstand the SZC site challenge. |

Design Value

Due to the replication strategy being adopted for SZC, NNB GenCo (SZC) is taking forward the HPC design values as the SZC design values and will aim to demonstrate in the future (via the PCSR) that the HVAC design can withstand the SZC site challenge, for high air temperature and enthalpy. I note that, if the SZC design cannot be adequately substantiated against the SZC high air temperature and enthalpy site challenge, a design change may be necessary. Such a design change may take account of the managed adaptive approach, where flexibility is built into options selected and decisions made now, so they can be adjusted in response to what happens in future. For example, greater than anticipated climate change increases, to ensure that sites remain safe.

Summary

In relation to my NSL assessment, I consider that the high air temperature and enthalpy site challenge meets the intent of SAPs EHA.2, EHA.4 and EHA.11 paragraph 259. Whilst the SZC site challenge for enthalpy is bounded by the SZC design value, the SZC high air temperature site challenge exceeds the SZC design value. I recognise this as a topic for engagement post-NSL as I do not consider that the SZC site challenge will preclude the use of the SZC site. Rather, NNB GenCo (SZC) is proceeding with the risk that HVAC redesign will be required, should an adequate demonstration of HVAC withstand against the SZC site challenge not be possible. I have discussed this issue with the mechanical engineering inspector and consideration of the HVAC design is included in the mechanical engineering assessment report [56] and substantiation of the SZC HVAC equipment will be tracked via a mechanical engineering regulatory issue RI-10802.

**High Air Temperature Hazard ONR Advice** (related to RI-10802): Should NNB GenCo (SZC)’s substantiation of the Sizewell C Heating Ventilation and Air Conditioning equipment place significant reliance on the Sizewell C high air temperature site challenge, NNB GenCo (SZC) should undertake further sensitivity studies, to account for the uncertainties in the extreme value analysis.

* + - 1. Lightning

|  |  |  |  |
| --- | --- | --- | --- |
| Hazard | | SZC site challenge | SZC design value |
| Lightning | Peak current | 200 kA | 200 kA |

Data

Data used in the lightning hazard characterisation is from 1999-2010 and provides lightning intensity data within a 20 km and 10 km radius of the SZC site. Given that only 11 years of data is used in the hazard analysis and that the most recent data is from 2010, I do not consider NNB GenCo (SZC)’s position aligns with SAP EHA.2.

Focusing on the data used in the lightning hazard characterisation for the SZC site, the SDSR states that 300 kA was the largest strike intensity observed during the 11-year survey, recorded in 2005, 27.87 km from the SZC site. In total there were four strikes ≥200 kA within 20 km of the SZC site (see Table 6 [86]), noting that radius uncertainties of ~10 km exist for some strikes. The SDSR reports that 300 kA is estimated as the upper bound of lightning strike intensity for a temperate climate. This data and discussion do not appear to align with NNB GenCo (SZC)’s site challenge definition of 200 kA. However, it does appear commensurate with RGP for a 10-4/yr AFoE UK lightning strike being in the region of 300 kA, as reported by [51] and recent GDAs, for example, [110].

Further to the above, the EDF EU stress test report for Sizewell B [111] states “The bounding design basis hazard for lightning is defined as being a current of 290 kA and a rate of current rise of 340 kA/μs at a frequency of 10‑4p.a. The assessment is judged to be conservative”. I have highlighted this in engagements with NNB GenCo (SZC) and I do not consider that NNB GenCo (SZC) has provided sufficient justification as to why the SZC site’s defined 10-4/yr AFoE event is 90 kA less than that defined for the adjacent SZB site.

Methodology

The methodology for defining the site challenge is outlined in the SDSR, with the report on lightning data analysis for Hinkley Point and Sizewell power station sites[86] limited to analysis of data. The hazard is characterised using an area defined as the EPRTM ‘power plant block’, which includes a single EPRTM unit and is given by length 145 m, width 80 m, and height 47 m (a collection area of 0.1375 km2). The SDSR does not provide full details of the application of the methodology and justification for its suitability, nor is a supporting reference included. Additionally, the approach does not appear to include consideration of strikes to structures, systems and components beyond the EPRTM ‘power plant block’ that may be important to nuclear safety. Further, I recognise that the collection area of a target influences the frequency of a strike to the target and, therefore, the characterisation of the 10-4/yr AFoE event. Other similar studies have used a 1 km2 area to allow for the potential effects of a strike anywhere on site [51]. Therefore, it is not clear to me that the methodology to define the SZC site challenge is sufficiently conservative, as per the intent of SAP EHA.4.

Climate Change

No allowance for climate change has been incorporated within the lightning site challenge [6]. This is because UKCP18 had not yet provided data for lightning. Given the limited understanding of the impact of climate change on UK lightning intensity and frequency when the SDSR was produced, I consider NNB GenCo (SZC)’s approach to be reasonable. However, the UKCP18 update to local (2.2 km) projections [112], released in July 2021, includes lightning data from the new 2.2 km reruns. Therefore, I consider that NNB GenCo (SZC) should review the UKCP18 lightning data and consider whether a climate change adjustment factor should be included in its site challenge; this is captured by regulatory issue RI-10807.

Design Value

The output of the hazard characterisation is an NNB GenCo (SZC) defined SZC site challenge of 200 kA which is matched by the SZC design value. The design value uses lightning protection level (LPL) 1 (BS EN 62305 [42]) which is designed to protect against a peak current of 200 kA. I recognise that LPL 1 is the upper limit of the design codes. However, BS EN62305‑1 Section 8.2 states that “the maximum values of lightning current parameters relevant to LPL 1 shall not be exceeded, with a probability of 99 %[where LPL 1 relates to a 200 kA strike]”, implying that a 200 kA strike is considered a 10-2/yr AFoE event. Irrespective of the design substantiation and design codes, I expect NNB GenCo (SZC) to adequately characterise the SZC lightning hazard by conservatively defining the 10-4/yr AFoE event, meeting the intent of SAPs EHA.3, EHA.4 and EHA.11.

Summary

In summary:

* No data since 2010 has been included in the lightning hazard analysis. I do not consider this to align with the intent of SAP EHA.2.
* More recent lightning hazard characterisation (for example in GDAs) have suggested that 300 kA represents a 10-4/yr AFoE event for the UK. Therefore, it is not clear the SZC site challenge has been defined in line with RGP.
* I do not consider that NNB GenCo (SZC) has provided sufficient justification for why the 10-4/yr AFoE event at SZC is 90 kA less than that at SZB.
* I do not consider that NNB GenCo (SZC) has provided sufficient justification for the use of its lightning hazard characterisation methodology and it is not clear to me that it enables a conservative definition of the site challenge, as per the intent of SAP EHA.4.

On this basis, I do not consider the lightning hazard characterisation for SZC to be adequate. I have raised regulatory issueRI-10807 for NNB GenCo (SZC) to update its lightning hazard analysis for the SZC site, using the latest data and a methodology that aligns with RGP, or equivalent. If the lightning hazard analysis update results in a higher lightning site challenge, there would not be an unmanageable impact on nuclear safety and so it would not preclude the SZC site as suitable. Rather, a higher site challenge would potentially require a design change, and/or substantiation work to be undertaken. Therefore, I do not consider that this finding impacts my overall external hazards judgement on the adequacy of the SZC site.

**Lightning Hazard RI-10807**: For lightning hazard, NNB GenCo (SZC) should ensure that derivation of the 10-4/yr annual frequency of exceedance event uses:

* + the best available relevant data source(s)
  + methodologies that align with relevant good practice
  + an appropriate climate change adjustment factor, if considered relevant from a review of relevant good practice for lightning climate change projections
    1. Heat Sink Hazards
       1. High Sea Temperature

|  |  |  |
| --- | --- | --- |
| Hazard | SZC site challenge (2100) | SZC design value |
| High sea temperature | 27.2°C  *(24.2°C + 3°C for climate change)* | 28.5 °C |

Data

The data used to characterise the SZC high sea temperature present climate site challenge is taken from SZB. The data is from in-situ observations from the SZB cooling water intake system between 1994-2020. Instantaneous temperature was recorded every hour by five temperature monitors (sensors), located in the SZB forebay. EDF R&D acknowledge in [90] that, in each of the datasets, there are short periods of missing data, mostly focused in 1994, 1995, and 2020, predominantly due to maintenance of the cooling water intake system. Data from SZB was corroborated against the Waverider buoy, located near the planned SZC cooling water intakes. The Waverider buoy is part of the wavenet network and was installed in 2008 for SZB. I consider use of SZB data to be appropriate, given that it is proximal to the SZC locality, with a dataset several years longer than the Waverider buoy.

Out of the five sensors, one (RD T0009) was discounted due to its location above the SZB forebay thermocline. I consider this a reasonable approach, given that this is likely to be warmer than the SZC intake location ~ 10 m below sea level. Of the remaining four SZB sensors, [90] claims that “the CWS [cooling water system] TG2 sensor has the least spread and fewest clear outliers … and therefore likely to be the most well-calibrated”; therefore, only data from the CWS TG2 sensor is used. However, no evidence supporting this claim is provided. This is particularly relevant for the CWS TG1 sensor, which has the same level of reported accuracy as CWS TG2 (see Table 1 of [90]), but a lower percentage of missing data*.* I do not consider that sufficient justification has been provided for discounting the data from the three sensors; therefore, it is not clear to me that the intent of SAP EHA.2 has been met. NNB GenCo (SZC) should provide further justification for its use of the selected SZB sensor for its high sea temperature site challenge, and/or incorporate data from additional SZB sensors into the SZC site challenge. I do not consider this to be an issue for licensing as the addition of further data is unlikely to have a significant impact on site suitability.

As noted by [90], the proposed design for the SZC cooling water intake heads is between 10.0 m and 12.1 m below mean sea level. The SZB intake head is 6.1 m below mean sea level, with the SZB sensors located in the SZB forebay, and the Waverider data is recorded at the sea surface. Given that seawater temperature generally decreases with depth, using data recorded closer to the surface than the SZC intakes can be considered conservative, in line with the intent of SAP EHA.4.

Methodology

I recognise that the 24.2°C SZC high sea temperature site challenge value, excluding climate change, is markedly different from the range of 25.5-28°C previously reported as the present day SZC site challenge. I asked for clarity as to why the previous studies [88] [89] are no longer considered valid [113]. Appendix 2 *Comparison with previous research* is included in [90] and provides justification for why it supersedes previous research. The EVA approach used is of particular relevance and I discuss this below.

In contrast to the threshold exceedances (peaks over threshold) EVA approach used in TR489 [88], the new EDF R&D study [90] uses the block maxima approach for EVA. The use of the block maxima approach, which divides data into sections or blocks (for example years) and then retains the maximum value in each block, is justified due to the high thermal inertia of water. The report [90] further explains that the same oceanic processes are likely to cause extreme temperatures clustered in the same week, month, or year, making them dependent events. By contrast, the TR489 report assumes each extreme value is independent, suggesting that a greater number of separate events occurred than happened in reality, resulting in a higher hazard value. Given that it is important that events are considered independent for EVA, I consider that this justification for the block maxima approach is reasonable, and that the methodology used aligns with the intent of SAP EHA.4.

Climate Change

1. UKCP18 does not currently provide outputs for sea temperature. Therefore, EDF R&D reported that it used POLCOMS climate projections for its analysis. This is driven by one model that is part of Coupled Model Intercomparison Project Phase 5 (CMIP5). The model uses the RCP 8.5 emissions scenario and provides daily mean surface temperature projections for 2006-2099 at ~11 km spatial resolution.
2. The use of one model contrasts to UKCP18 or UKCP09, which use an ensemble of models. Nevertheless, UKCP18 has not provided sea temperature outputs and TR489 [88] reports that “UKCP09 only produced one run for sea temperature so estimates of temperature increase are means, unlike for sea level where an ensemble of runs was undertaken”. Therefore, I consider that the approach taken appears reasonable, particularly given POLCOMS use in other UK projects [114].
3. In [90], EDF R&D consider three methods in the study: 1) linear regression, 2) EVA applied to present and future epochs and 3) month-specific temperature change. Linear regression (monthly maximum, summer months) results are recommended to be taken forward, the reasoning being that the linear model fits the dataset well and represents a mean of all adjustment factors. Whilst I consider the justification for using a 3°C climate change adjustment factor to be reasonable, in line with SAP EHA.11 paragraph 259, further justification for why the month-specific temperature change method was discounted would be beneficial. However, I recognise that the climate adjustment factors from the three methods, ranging from +2.6 to +3.7°C, are all bounded by the SZC design value. Therefore, sea temperature will be part of ONR’s routine engagement on climate change and I would expect future analysis of the SZC high sea temperature to incorporate updated sea temperature climate change projections, as part of normal business. For example, periodic safety reviews, LC15 [108].
4. Further, I consider that a climate change adjustment factor to 2100 is reasonable, given that the hazard impacts cooling capability, which is predominantly required for the operational stage of the plant’s life.

Design Value

The defined SZC high sea temperature site challenge results are bounded by the SZC design values, with a claimed margin of 1.3°C. Notwithstanding paragraph 169, I consider the design value bounding the site challenge to be suitably conservative, in line with the intent of SAP EHA.4.

Summary

In relation to my NSL assessment, I consider that the high sea temperature site challenge is adequately defined for NSL, given the methodology used and recognising the margin that exists between the design value and site challenge. However, I expect NNB GenCo (SZC) to consider future sea temperature climate projections and their impact on the SZC site challenge, where available and relevant, as part of normal business. For example, periodic safety reviews, LC15 [108]. I advised NNB GenCo (SZC) to provide further justification for its use, or not, of the Sizewell B sensors for its high sea temperature site challenge, which should be taken into account by NNB GenCo (SZC) during the maturation of the external hazards safety case.

**High Sea Temperature Hazard ONR Advice**: NNB GenCo (SZC) should provide further justification for its use of the selected Sizewell B sensor for its high sea temperature site challenge, and/or incorporate data from additional Sizewell B sensors into its Sizewell C site challenge.

* + - 1. Low Sea Level

|  |  |  |
| --- | --- | --- |
| Hazard | SZC site challenge | SZC design value |
| Low sea level | -3.4 mOD | -3.7 mOD |

Data

The data used to characterise the SZC site challenge is reported in Appendix B of TR489 [88], copied from TR139 [91]. Hourly and 15-minute water level data for Lowestoft between 1964-2009 are used, as well as water level records for the tide gauge operated at SZB for the period between March 2009 and July 2010. The Lowestoft data was used to characterise the site challenge, with SZB data used to provide an adjustment for the SZC locality. I consider that studies for SZC should have included data from 2009-present, to allow for a longer dataset to be utilised and recent variation to be captured. However, I recognise that more recent data is likely to record low sea levels that are higher than previous decades, due to the trend of sea level rise. Therefore, it is unlikely that the absence of recent data will have a significant impact on the hazard characterisation.

TR489 justifies the use of Lowestoft data as it provides the longest time series for a Class A tide gauge in the vicinity of SZC. SZB is referred to as a limited dataset in terms of duration and reliable quality, and therefore is used for site adjustment purposes only. TR489 reports that, rather than use the 20 cm difference in lowest astronomical tide between Lowestoft and SZB from the published tables (using models; see Table 7 TR139 [91]), the more conservative 24 cm derived from Lowestoft versus SZB data observations has been applied as an offset; in other words the SZB/SZC low seawater level is assumed to be 24 cm lower than Lowestoft. Whilst I recognise that the site adjustment factor uses the more conservative estimate, use of more recent SZB data in the analysis would help to provide more confidence in the site adjustment factor.

The use of Lowestoft data is consistent with the characterisation of extreme still water level (see Section 4.1.4.1.1) and, given the quality of data, I consider it to be a suitable gauge. However, as with the extreme still water level characterisation, it is not clear why data from the Felixstowe tide gauge has not been utilised; see regulatory issue RI-10806.

Methodology

The SDSR states that the extreme low seawater level has been defined as a best estimate. This is contrary to NNB GenCo (SZC)’s own commitment to define the site challenge at the 84th percentile; see Section 4.1.2. Therefore, it is not clear that NNB GenCo (SZC) has defined the 10-4/yr AFoE event conservatively, in line with SAP EHA.4. However, the absence of a climate change addition adds some conservatism, as discussed in paragraph 185.

The EVA methodologies used in the site challenge calculation are outlined in Section 5.2 of TR139 [91]. A variety of methods are used, including annual maxima and peaks over threshold; the results are summarised in Table 25 of TR139 [91]. The annual maxima methods provide lower sea level values for the 10-4/yr AFoE event, when compared to peaks over threshold. Table 16 in TR489 [88] is a modification of Table 25 from TR139, and it includes only a selection of the annual maxima method results; these are then summarised in SDSR Table 34. The SDSR states that the SZC site challenge is “taken as ‑3.4 mOD as the statistical method used to derive this value results in the best fit of the data”. Given that TR489 and TR139 provide no, or limited, discussion of the most suitable EVA method for derivation of low sea level, and no information is provided which method results in the best fit of data, I do not consider sufficient evidence or justification is provided for the SZC low sea level site challenge value. However, I do not consider this to be an issue for licensing, given the proposed design for the SZC cooling water intake heads, discussed in paragraph 186.

Low still water levels in conjunction with tsunami drawdown has been considered in [77]. As with high still water level in conjunction with tsunami, NNB GenCo (SZC) considers a low still water level value that is exceeded 90% of the time in conjunction with tsunami. In addition, low still water level exceeded 99% of the time is also considered. NNB GenCo (SZC) concludes that the intake heads would remain submerged by at least 4-5 m of water during the tsunami wave drawdown and there is no credible threat of intake head exposure or significant air entrainment. Based on the material sampled, I do not consider tsunami wave drawdown to be a significant hazard. However, it would be beneficial for the tsunami hazard report to be updated using the latest tidal data, as part of regulatory issue RI-10806.

Climate Change

NNB GenCo (SZC) does not include a climate change addition for low seawater level, given that seawater level is expected to rise in all climate scenarios within UKCP18. I consider this approach to be suitably conservative, particularly as the site challenge is only defined as best estimate.

Design Value

TR489 states that “the design requirement for the Sizewell C intakes is that they are placed deep enough so that a continuous water supply is available at all states of the tide and the weather conditions and that air is not drawn into the intakes”*.* The site challenge value is given as -3.4 mOD, with the design value of -3.7 mOD, which is aligned with the de-risking value from GDA, providing a claimed margin of 0.3 m. I therefore consider the design value to be adequate for the SZC site. Further, as noted by [90], the proposed design for the SZC cooling water intake heads is between 10.0 m and 12.1 m below mean sea level. It is reasonable to assume, given that mean sea level is usually used for Ordnance Datum, that there is likely to be a much greater margin between the location of the SZC intake heads and the SZC low sea level challenge. In summary, I consider the design value to be adequate, given that it bounds the site challenge by 0.3 m. Furthermore, I am cognisant that, in reality the SZC intake heads depth will provide a greater margin to the site challenge.

Summary

My assessment has highlighted the following areas where further work would strengthen the site challenge characterisation:

* NNB GenCo (SZC) currently defines the site challenge as best estimate; this is contrary to its own requirement for the 10-4/yr AFoE event to be defined as the 84th percentile.
* NNB GenCo (SZC) has not used data post-2009 in the low sea level studies.
* NNB GenCo (SZC) has not provided sufficient justification for why the EVA methodology used to define the SZC site challenge is appropriate.

Therefore, I have advised NNB GenCo (SZC) to refine its low sea level hazard characterisation, in line with its own requirements and RGP, during the maturation of the external hazards safety case.

**Low Seawater Level Hazard ONR Advice**: For low seawater level hazard, NNB GenCo (SZC) should ensure that derivation of the 10-4/yr annual frequency of exceedance event uses:

* + the best available relevant data source(s)
  + methodologies that align with relevant good practice

Whilst recognising the areas summarised above, I am cognisant that no adjustment for climate change is considered, that the SZC intakes are currently planned to be ~10 m below mean sea level and that there is a 0.3 m margin between the site challenge and the design value. Therefore, whilst I consider that NNB GenCo (SZC) should update its low sea level hazard characterisation as part of normal business, I do not consider that the low sea level hazard would preclude granting of a nuclear site licence, from an external hazards perspective.

* + 1. Aircraft Impact

Accidental Aircraft Impact

Data used to define the SZC accidental aircraft impact site challenge is outlined in the SDSR [6]. I have not sampled the accidental aircraft impact case in detail, in line with my sampling strategy outlined in Section 2.2. For NSL purposes, I am content that accidental aircraft impact is included as a design basis hazard. Furthermore, given that the adjacent SZB site is operational, with a mature external hazards safety case that addresses aircraft impact, I do not consider that accidental aircraft impact is likely to challenge the suitability of the SZC site.

Malicious Aircraft Impact

No information is provided in the NSL application for SZC in relation to malicious aircraft impact. However, NNB GenCo (SZC) has confirmed that the malicious aircraft impact case will be included in the SZC security case and that it will be a replication of the HPC malicious aircraft impact case [92].

The HPC case relies on that produced for GDA. The UK EPRTM design was assessed for malicious aircraft impact by ONR as part of the UK EPRTM GDA, e.g., [115] [116]. The civil engineering and external hazards GDA assessment report concluded that the UK EPRTM “design against accidental and malicious aircraft impact has been found to be satisfactory”[115]. Furthermore, ONR assessment of malicious aircraft impact in relation to HPC has been conducted, providing confidence in the case, for example [117] [118]. Given that the SZC malicious aircraft impact case will be based on the HPC and, therefore, the GDA case, I am content for NSL that the ONR assessments for HPC and GDA provide adequate confidence in the future SZC malicious aircraft impact case.

Plot Plan Considerations

The main consideration for NSL, in relation to aircraft impact, is whether plot plan changes affect the aircraft impact hazard.

1. Section 3.3.6.6 of the plot plan summary report [60] provides confidence that SZC plot plan changes will have limited impact on the aircraft impact hazard – “it is not expected that there will be any significant change in the risk of aircraft crash at SZC as a result of plot plan changes versus that assessed at HPC”. Further, JSSR Section 2.2.4 [5] states “Although there are changes to the SZC plot plan versus that of HPC, the spacing of the units and the key nuclear safety important buildings belonging to SZC and HPC are identical. Additionally, SZC has the same redundancy within its overall design as HPC and therefore it is not expected that there will be any significant change in the risk of aircraft crash at SZC as a result of the plot plan changes”.I consider that these statements, and confirmation that they remain valid from NNB GenCo (SZC) [92], provide adequate confidence for NSL that changes to the plot plan have been and will be considered by NNB GenCo (SZC) as part of aircraft impact hazard characterisation.

Summary

In summary, I have not identified anything for the purposes of NSL that would challenge the suitability of the SZC site in relation to aircraft impact.

* 1. ONR Licensing Questions

Given my assessment in Section 4.1, I have addressed each ONR licensing question that is relevant to external hazards in turn, see Table 5.

* + 1. The site is of a sufficient size [to accommodate all necessary systems to ensure safe operation]
       1. Relevant Parts of NNB GenCo (SZC)’s Safety Case

The relevant JSSR Claim is Claim 1: The site is of sufficient size to accommodate all necessary systems to ensure safe operation.

As per my sampling strategy outlined in Section 2.2, the key external hazards considered are aircraft impact. The supporting references for this hazard are outlined in Section 3.

* + - 1. Comparison with Standards, Guidance and Relevant Good Practice

Standards and guidance used as part of my assessment of this licensing question are covered in Section 2.4 and under the relevant hazard assessments within Section 4.1.

* + - 1. Interface with Other Topic Areas

Consideration of this licensing question predominately lies with civil engineering and internal hazards. I have interfaced with the civil engineering inspector on plot plan considerations relating to aircraft impact.

* + - 1. Summary

From an external hazards perspective, I consider that this question has been adequately addressed for NSL. This is based on:

* NNB GenCo (SZC)’s consideration of aircraft impact in relation to the plot plan. The JSSR [5] and plot plan summary report [60] provide confidence that changes to the plot plan have been and will be considered by NNB GenCo (SZC) as part of aircraft impact hazard characterisation; and
* from my assessment, and information sampled, no other external hazards have challenged this conclusion.
  + 1. There is adequate cooling capability for all normal and fault conditions
       1. Relevant Parts of NNB GenCo (SZC)’s Safety Case

The relevant JSSR Claim is Claim 3: Adequate cooling capability can be provided for all normal and fault conditions.

As per my sampling strategy outlined in Section 2.2, the key external hazards considered are high sea temperature, low seawater level, high air temperature and enthalpy. The supporting references for these hazards are outlined in Section 3.

* + - 1. Comparison with Standards, Guidance and Relevant Good Practice

Standards and guidance used as part of my assessment of this licensing question are covered in Section 2.4 and under the relevant hazard assessments within Section 4.1.

* + - 1. Interface with Other Topic Areas

I have engaged with the mechanical engineering inspector on high and low seawater level, seawater temperature and high air temperature. Consideration of the hazard characterisation is included within my external hazards assessment report, with implications on structures, systems and components (SSCs) addressed within the mechanical engineering assessment report [56].

I have engaged with the civil engineering inspector on low seawater level and seawater temperature. Consideration of the hazard characterisation is included within my external hazards assessment report, with implications on SSCs addressed within the civil engineering assessment report [55].

* + - 1. Summary

From an external hazards perspective, I consider that this question has been adequately addressed for NSL, and I will continue to engage on the regulatory issues and advice raised in this assessment report. This summary is based on:

* the summary of my assessment of high sea temperature, Section 4.1.6.1;
* the summary of my assessment of low seawater level, Section 4.1.6.2; and
* the summary of my assessment of high air temperature, Section 4.1.5.1.
  + 1. The environmental conditions would not preclude the use of the site with respect to external hazards
       1. Relevant Parts of NNB GenCo (SZC)’s Safety Case

The relevant JSSR Claim is Claim 4: There are no external hazards that would preclude the use of the site (including the external hazards presented by SZB to SZC).

The site-specific external hazards are relevant for this question. My assessment focuses on those hazards identified in my sampling strategy outlined in Section 2.2. These include seismic hazards, flooding hazards, high air temperature, lightning, high sea temperature, low seawater level and aircraft impact. The supporting references for these hazards are outlined in Section 3.

* + - 1. Comparison with Standards, Guidance and Relevant Good Practice

Standards and guidance used as part of my assessment of this licensing question are covered in Section 2.4 and under the relevant hazard assessments within Section 4.1.

* + - 1. Interface with Other Topic Areas

I have interfaced with electrical engineering on lightning hazard and GIC. The GIC hazard is addressed within the electrical engineering assessment report [42], given the relevance to electrical engineering equipment and the existing GDA assessment finding AF-UKEPR-EE-026. Consideration of lightning hazard characterisation is included within my external hazards assessment report, with implications on SSCs addressed within the electrical engineering assessment report.

I have also engaged with the civil engineering, mechanical engineering and internal hazards inspectors on relevant external hazards. These hazards, relate to other licensing questions, where the interface is discussed in more detail.

* + - 1. Summary

From an external hazards perspective, I consider that this question has been adequately addressed for NSL and I will continue to engage on the regulatory issues and advice raised in this assessment report. This summary is based on:

* The summaries of my assessment of the sampled external hazards, Section 4.1.

The related regulatory issues arising from my NSL assessment are:

* RI-10805
* RI-10806
* RI-10807
  + 1. The geology of the site will provide a secure long term support to the necessary structures, systems and components
       1. Relevant Parts of NNB GenCo (SZC)’s Safety Case

The relevant JSSR Claim is Claim 5: The geology of the site provides secure long term support to the necessary structures, systems and components.

As per my sampling strategy outlined in Section 2.2, the key external hazards considered are capable faulting and seismic hazard. The supporting references for these hazards are outlined in Section 3. Groundwater is considered within the civil engineering assessment report [55].

* + - 1. Comparison with Standards, Guidance and Relevant Good Practice

Standards and guidance used as part of my assessment of this licensing question are covered in Section 2.4 and under the relevant hazard assessments within Section 4.1.

* + - 1. Interface with Other Topic Areas

I have engaged with the civil engineering inspector on seismic hazard, the DBE, soil-structure interaction and ground investigations. Groundwater, ground model and ground investigations are covered within the civil engineering assessment report [55].

I have engaged with the mechanical engineering inspector on the DBE, given that it will inform the future development of the SZC FRS.

* + - 1. Summary

From an external hazards perspective, I consider that this question has been adequately addressed for NSL, and I will continue to engage on the regulatory issues and advice raised in this assessment report. This summary is based on:

* My assessment of seismic hazards, Section 4.1.3.

The related regulatory issue arising from my NSL assessment is:

* RI-10805
  + 1. That operations of the site will not adversely affect the safety case for any adjoining nuclear licensed site
       1. Relevant Parts of NNB GenCo (SZC)’s Safety Case

The relevant JSSR Claim is Claim 6: Operations on the SZC site will not adversely affect the ability to maintain an adequate safety case for the adjoining nuclear licensed site (SZB).

As per my sampling strategy outlined in Section 2.2, the key external hazards considered are coastal flooding and pluvial flooding. The supporting references for these hazards are outlined in Section 3. Whilst the SZC sea defence design is out of scope of my NSL assessment, I expect the SZC sea defence design and safety case to consider any potential negative impacts on the SZB sea defences.

* + - 1. Comparison with Standards, Guidance and Relevant Good Practice

Standards and guidance used as part of my assessment of this licensing question are covered in Section 2.4 and under the relevant hazard assessments within Section 4.1.

* + - 1. Interface with Other Topic Areas

I have engaged with the internal hazards inspector on pluvial flooding and turbine disintegration. Whilst, my assessment considers pluvial flooding, turbine disintegration is covered within the internal hazards assessment report [11].

* + - 1. Summary

From an external hazards perspective, I consider that this question has been adequately addressed for NSL, and I will continue to engage on the regulatory issues and advice raised in this assessment report. This summary is based on:

* the summary of my assessment of pluvial flood hazard, Section 4.1.4.3; and
* the summary of my assessment of coastal flood hazard, Section 4.1.4.1.

The related regulatory issue arising from my NSL assessment is:

* RI-10806
  1. Licence Condition Compliance

The ONR SZC assessment framework [4] highlighted LC10, 12 and 14 as LCs related to the external hazards NSL assessment. These are considered in the subsequent sections. I also comment on LC6 compliance, given my related intervention.

* + 1. LC6 (Documents, records, authorities and certificates)

I conducted a civil engineering and external hazards LC6 intervention on geotechnical records [14]. This intervention was undertaken to underpin Claim 5 of the JSSR that “The geology of the site provides secure long term support to the necessary structures, systems and components”*.* This was one of several interventions in this area, with the organisational capability specialism leading on procedural development; to this end, the intervention focused on the technical records rather than the procedural development.

1. The overall inspection rating was given as green. This was on the basis of the ability of the individuals put forward in presenting the records and evidence of capturing decision making, that sampled records were produced in line with the relevant Technical Specification, and that there were no findings that impacted NSL grant. This intervention provided confidence in LC6 compliance from an external hazards perspective.
   * 1. LC10 (Training) and LC12 (Duly authorised and other suitably qualified and experienced persons)

I have supported ONR’s assessment on organisational capability, through two interventions [15] [16]. These interventions focused on intelligent customer, training and SQEP arrangements for SZC. These interventions have informed my consideration of LC10 and 12.

Overall, for external hazards, based on the evidence sampled and discussions held, I was content that the individuals present during the interventions understood the process for completing training role profile assessments and that they are SQEP or have training or experience identified for SQEP development.

Issues were identified as part of the interventions, and these are outlined within the contact records [15] [16]. These findings are captured as part of the wider organisational capability assessment [119] [9]. For external hazards, I consider that NNB GenCo (SZC) is sufficiently compliant with LC10 and 12 for NSL purposes; this provides confidence that it can be compliant as a future licensee.

* + 1. LC14 (Safety documentation)

My external hazards NSL assessment has informed my consideration of LC14 for NSL purposes.

As set out in Section 3, NNB GenCo (SZC)’s NSL application uses high level claims supported by arguments and evidence. For external hazards, my assessment has shown that the golden thread through the safety case is clear, with a link from the JSSR claims, to the SDSR and on to the supporting references. However, I have noted some areas for future development:

* I consider that the ‘golden thread’ for the origin of the SZC design basis values, whether from GDA or HPC, could be improved, and potentially demonstrated via a comparison table. This improvement can be developed as part of the external hazards safety case maturation and I am content that this can be addressed as part of normal business.
* In some areas, such as coastal flooding, the contribution of past studies and data is not always obvious and clarity could be improved. I am content that this can be addressed via normal business, as part of the external hazards safety case maturation.

Overall for external hazards, I consider that the suite of documents provides a suitable structure for demonstrating site suitability, thereby, meeting its intended purpose. Given this, I consider that NNB GenCo (SZC)’s NSL application meets the intent of SAP SC.4 for NSL purposes. Furthermore, I consider that the NNB GenCo (SZC) NSL application broadly meets the intent of SAP SC.5 for NSL purposes. This judgement is based on NNB GenCo (SZC)’s conservative definition of the majority of its external hazards site challenges, with acknowledgement of where there is uncertainty in climate change effects on hazards, such as tornado [6].

Notwithstanding the above, I am cognisant that the safety case will need to develop in order to meet the requirements of a PCSR and a pre-commissioning safety case, with progression in the following areas:

* maturation of hazard studies, as required (see regulatory issues);
* beyond design basis analysis;
* combined and consequential hazard analysis;
* hazard verification studies; and
* hazard schedules.

In summary, from an external hazards perspective I consider that NNB GenCo (SZC) is compliant with LC14 for NSL purposes and I will continue to engage on the regulatory issues and advice raised in this assessment report.

* 1. Assessment of NNB GenCo (SZC) Organisation and Systems

With respect to external hazards, I have considered LC 6, 10, 12 and 14 compliance, as documented above. From my assessment, I am content that the level of maturity of the prospective licensee with regards to external hazards is adequate for NSL. For a full NSL assessment of NNB GenCo (SZC)’s organisation and systems, please refer to the ONR organisational capability assessment report [9].

* 1. ONR Assessment Rating

1. My assessment of the external hazards aspects of the SZC licensing application has been assigned an ONR assessment rating of green. I have used guidance on assessment ratings provided by Appendix 1 of NS‑TAST‑GD‑096 [7] to form my judgement. I consider a green rating to be appropriate given that:

* NNB GenCo (SZC)’s documentation, provided to support its nuclear site licence application, was well structured and allowed for my assessment of site-specific external hazards;
* from the information sampled, I have not identified any issues that would preclude the use of the SZC site to construct and operate two UK EPR™ reactors; and
* relevant good practice has generally been met and I have raised regulatory issues where I have identified shortfalls. Regulatory issues raised in my assessment can all be addressed post-NSL, as part of the maturation of the external hazards safety case.

1. Conclusions and Recommendations
   1. Conclusions
2. This report presents the findings of my assessment of the external hazards aspects to inform and support ONR’s decision to grant a nuclear site licence to NNB GenCo (SZC) to construct and operate a nuclear power station at SZC.
3. The scope of my assessment has been to consider whether:

* the site is of a sufficient size to accommodate all necessary systems to ensure safe operation;
* there is adequate cooling capability for all normal and fault conditions;
* the environmental conditions would not preclude the use of the site with respect to external hazards;
* the geology of the site will provide a secure long term support to the necessary structures, systems and components; and
* that operations of the site will not adversely affect the safety case for any adjoining nuclear licensed site.

NNB GenCo (SZC)’s documentation, provided to support its nuclear site licence application, was well structured and allowed for my assessment of site‑specific external hazards. Through the information that I have sampled, I consider that each of the above have been adequately addressed.

1. Further to the above, my sampling of LC compliance and organisation capability has shown that NNB GenCo (SZC) is developing a competent organisation to support delivery of technical activities post‑licensing.
2. Whilst my assessment highlighted areas requiring further work, I do not consider that any of my findings preclude the use of the SZC site. I have captured the most important areas requiring further work as regulatory issues in my assessment, to track their resolution, which can be resolved post NSL grant:

* **RI-10805:** In relation to seismic hazards, NNB GenCo (SZC) should:

define an offshore design basis earthquake for both the horizontal and vertical that meets relevant good practice for the minimum design basis earthquake, in line with the onshore design basis earthquake;

formally include the revised design basis earthquake definitions within the Sizewell C safety case; and

adequately address all of the capable faulting study comments raised within ONR Expert Panel Paper, SZC-SH-EP-2022-1.

* **RI-10806:** In relation to coastal flood hazards, NNB GenCo (SZC) should:

for all components of the coastal flood hazard, ensure that derivation of the 10-4/yr annual frequency of exceedance event uses:

the best available relevant data source(s); and

methodologies that align with relevant good practice.

ensure resolution of all the ONR platform height observations.

* **RI-10807:** For lightning hazard, NNB GenCo (SZC) should ensure that derivation of the 10-4/yr annual frequency of exceedance event uses:

the best available relevant data source(s);

methodologies that align with relevant good practice; and

an appropriate climate change adjustment factor, if considered relevant from a review of relevant good practice for lightning climate change projections.

1. In addition, I consider the following are required to be carried out by NNB GenCo (SZC) in the future as part of normal business, the resolution of which do not require to be formally tracked by ONR:

* NNB GenCo (SZC) should review the UK Climate Projections 2018 rainfall 2.2 km x 2.2 km resolution data and determine whether its rainfall climate change adjustment factor should be updated. Should the review result in an increase to the climate change adjustment factor, the Sizewell C rainfall site challenge and design value should be updated accordingly.
* Should NNB GenCo (SZC)’s substantiation of the Sizewell C heating, ventilation and air conditioning equipment place significant reliance on the Sizewell C high air temperature site challenge, NNB GenCo (SZC) should undertake further sensitivity studies, to account for the uncertainties in the extreme value analysis.
* NNB GenCo (SZC) should provide further justification for its use of the selected Sizewell B sensor for its high sea temperature site challenge, and/or incorporate data from additional Sizewell B sensors into its Sizewell C site challenge.
* For low seawater level hazard, NNB GenCo (SZC) should ensure that derivation of the 10-4/yr annual frequency of exceedance event uses:

the best available relevant data source(s); and

methodologies that align with relevant good practice.

* 1. Recommendations

1. My recommendation is as follows:

* I recommend that from an external hazards perspective a nuclear site licence should be granted to NNB GenCo (SZC) to construct and operate a nuclear power station at Sizewell C.

1. References

|  |  |
| --- | --- |
| [1] | ONR, “SZC504197N - SZC - HPC replication feedback,” (CM9 2022/2097). |
| [2] | ONR, “Licensing Nuclear Installations,” November 2021. [Online]. Available: https://www.onr.org.uk/licensing-nuclear-installations.pdf. |
| [3] | ONR, “Sizewell C New Build Project - ONR strategy up to licence grant,” 2022, (CM9 2021/91337). |
| [4] | ONR, “Sizewell C Licensing ONR Assessment Framework,” January 2022, (CM9 2020/154838). |
| [5] | NNB GenCo (SZC), “Justification of Site Suitability Report, Rev 3,” SZC-SZC-NNBOSL-XX-000-REP-100006 (CM9 2021/72608). |
| [6] | NNB GenCo (SZC), “Site Data Summary Report, Rev 4,” SZC-NNBGEN-XX-000-REP-100022 (CM9 2021/72600). |
| [7] | ONR, “Technical Assessment Guides,” [Online]. Available: https://www.onr.org.uk/operational/tech\_asst\_guides/index.htm. |
| [8] | ONR, “Safety Assessment Principles (SAPs),” https://www.onr.org.uk/saps/ (CM9 2019/367414). |
| [9] | ONR, “Organisational Capability assessment of an application by NNB GenCo (SZC) Ltd for a Nuclear Site Licence,” (CM9 2022/23095). |
| [10] | ONR, “ONR-CNRP-AR-12107 - Hinkley Point C Assessment Report - External Hazards,” (CM9 2012/373106). |
| [11] | ONR, “ONR-NR-AR-21-035 Internal Hazards assessment of an application by NNB GenCo (SZC) Ltd for a Nuclear Site Licence,” (CM9 2022/25321). |
| [12] | ONR, “ONR-NR-CR-21-517 - SZC - Level 3 SZC Design Basis Earthquake and RI8992,” (CM9 2022/8898). |
| [13] | ONR, “ONR-NR-CR-21-290 Sizewell C Turbine Disintegration and Pluvial Flooding Site Visit,” 1-2 September 2021 (CM9 2021/65861). |
| [14] | ONR, “ONR-NR-CR-21-571 - LC6 Intervention- SZC – Geotechnical Records – Civil Engineering and External Hazards,” 27 Janurary 2022 (CM9 2022/12642). |
| [15] | ONR, “ONR-NR-CR-21-583 - Sizewell C Licensing - IOC1 and IOC2 Interventions - Intelligent Customer,” 31 January 2022 (CM9 2022/14827). |
| [16] | ONR, “ONR-NR-CR-21-641 - Sizewell C (SZC) I-OC6 Intervention - 3-16 March 2022,” (CM9 2022/22986). |
| [17] | IAEA, “Fundamental Safety Principles,” 2006. |
| [18] | IAEA, “Safety of Nuclear Power Plants: Design,” 2016. |
| [19] | IAEA, “Site Evaluation for Nuclear Installations,” 2019. |
| [20] | IAEA, “External Events Excluding Earthquakes in the Design of Nuclear Power Plants,” 2003. |
| [21] | IAEA, “Qualification for Nuclear Power Plants Safety Guide,” 2002. |
| [22] | IAEA, “External Human Induced Events in Site Evaluation for Nuclear Power Plants,” 2002. |
| [23] | IAEA, “Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants,” 2005. |
| [24] | IAEA, “Specific Safety Guide SSG-9 Seismic Hazards in Site Evaluation for Nuclear Installations,” 2010. |
| [25] | IAEA, “Specific Safety Guide SSG-9 Seismic Hazards in Site Evaluation for Nuclear Installations,” Revision 1, 2022. |
| [26] | IAEA, “Specific Safety Guide SSG-67 Seismic Design for Nuclear Installations,” 2021. |
| [27] | IAEA, “Safety Guide No. NS-G-2.13, Evaluation of Seismic Safety for Existing Nuclear Installations,” 2009. |
| [28] | IAEA, “Design of Nuclear Installations Against External Events Excluding Earthquake Specific Safety Guide No. SSG-68,” 2021. |
| [29] | IAEA, “Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations,” 2011. |
| [30] | IAEA, “Safety Aspects of Nuclear Power Plants in Human Induced External Events: General Considerations,” 2017. |
| [31] | IAEA, “Safety Aspects of Nuclear Power Plants in Human Induced External Events: Assessment of Structures,” 2018. |
| [32] | IAEA, “Safety Aspects of Nuclear Power Plants in Human Induced External Events: Margin Assessment,” 2017. |
| [33] | WENRA, “Reactor Safety Reference Levels,” 2008. |
| [34] | WENRA, “Safety Objectives for New Power Reactors,” 2009. |
| [35] | WENRA, “Statement on Safety Objectives for New Nuclear Power Plants,” 2010. |
| [36] | WENRA, “Statement on Safety Objectives for New Nuclear Power Plants,” 2013. |
| [37] | WENRA, “Safety of New Nuclear Power Plant Designs,” 2013. |
| [38] | WENRA, “Guidance Document Issue TU: External Hazards, Head Document: Guidance for the WENRA Safety Reference Levels for External Hazards,” 2020. |
| [39] | WENRA, “Guidance Document Issue TU: External Hazards Guidance on Seismic Events: Annex to the Guidance Head Document,” 2020. |
| [40] | WENRA, “Guidance Document Issue TU: External Hazards, Guidance on External Flooding: Annex to the Guidance Head Document,” 2020. |
| [41] | WENRA, “Guidance Document Issue TU: External Hazards, Guidance on Extreme Weather Conditions: Annex to the Guidance Head Document,” 2020. |
| [42] | BSI, “BS EN 62305 Protection against lightning,” 2011. |
| [43] | U.S. NRC, “NUREG-2213 Updated Implementation Guidelines for SSHAC Hazard Studies,” 2018. |
| [44] | U.S. NRC, “NUREG-2117 Practical implementation guidelines for SSHAC Level 3 & 4 hazard,” Revision 1, 2012. |
| [45] | ASCE, “Seismic Analysis of Safety-Related Nuclear Structures and Commentary ASCE/SEI 4-16,” 2017. |
| [46] | ASCE, “Seismic Design Criteria for Structures, Systems, and Components In Nuclear Facilities ASCE/SEI 43-19,” 2020. |
| [47] | ONR/EA/NRW/SEPA, “Use of UK Climate Projections 2018 (UKCP18), Position Statement, Revision 1,” November 2020, https://www.onr.org.uk/documents/2020/ukcp18-position-statement-rev-1.pdf. |
| [48] | ONR/EA, “Principles for Flood and Coastal Erosion Risk Management, Version 1,” July 2017, Office for Nuclear Regulation and Environment Agency. https://www.onr.org.uk/documents/2017/principles-for-flood-and-coastal-erosion-risk-management.pdf. |
| [49] | ONR, “ONR693 - Provision of Technical Support on Sizewell C Site-Specific External Hazards Assessment - Work Order Specification - July 2020,” (CM9 2020/171709). |
| [50] | Mott MacDonald, “Technical Support on Sizewell C Site-Specific External Hazards Assessment - Task 1 High-Level Review of Documents Supporting Sizewell C Nuclear Site Licence Application,” June 2021 (CM9 2022/23296). |
| [51] | Mott MacDonald, “Technical Support on Sizewell C Site-Specific External Hazards Assessment - Task 2 Review of Documents Supporting Sizewell C Nuclear Site Licence Application,” December 2021 (CM9 2022/23297). |
| [52] | ONR, “ONR Expert Panel on Natural Hazards,” https://www.onr.org.uk/external-panels/natural-hazards-panel.htm (accessed 27/04/2022). |
| [53] | ONR Expert Panel on Natural Hazards, “Expert Panel Paper - SZC-SH-EP-2022-1 - ONR Expert Panel Review of Sizewell C PSHA and CFS,” (CM9 2022/14454). |
| [54] | ONR Expert Panel on Natural Hazards, “Expert Panel Paper - SZC-MCFH-EP-2021-1 - ONR Expert Panel Review of SZC NSL Application High Air Temperature and Enthalpy,” (CM9 2022/14461). |
| [55] | ONR, “ONR-NR-AR-22-006 Civil Engineering assessment of an application by NNB GenCo (SZC) Ltd for a Nuclear Site Licence,” (CM9 2022/23784). |
| [56] | ONR, “ONR-NR-AR-22-003 Mechanical Engineering assessment of an application by NNB GenCo (SZC) Ltd for a Nuclear Site Licence,” (CM9 2022/23282). |
| [57] | ONR, “ONR-NR-AR-22-001 Electrical engineering assessment of an application by NNB GenCo (SZC) Ltd for a Nuclear Site Licence,” (CM9 2022/22763). |
| [58] | ONR and U.S. NRC, “Email exchange between U.S. NRC and ONR: Re minimum design basis earthquake expectations,” January 2022 (CM9 2022/4135). |
| [59] | ONR and STUK, “Email exchange between STUK and ONR: Re minimum design basis earthquake expectations,” December 2021 (CM9 2022/4134). |
| [60] | NNB GenCo (SZC), “SZC Plot Plan Summary Report, Rev 4,” SZC-SZ0100-XX-000-REP-100033 (CM9 2021/72610). |
| [61] | NNB GenCo (SZC), “SZC Heat Sink Summary Report, Rev 5,” SZC-SZ0100-XX-000-REP-100032 (CM9 2021/72607). |
| [62] | NNB GenCo (SZC), “Arguments and Evidence Supporting JSSR Claim 6,” 2021, (CM9 2021/72593). |
| [63] | NNB GenCo (SZC)/Hyder Consulting (UK) Ltd, “Sizewell C Hazard Listing Report,” (CM9 2021/72636). |
| [64] | NNB GenCo (SZC), “Use of UKCP18 to Define Reasonably Foreseeable Climate Change Rev. 1,” (CM9 2021/72641). |
| [65] | NNB GenCo (SZC), “Sizewell C CFS & PSHA – NNB Position on Minimum Magnitude Value for PSHA Studies Rev.1,” (CM9 2021/43293). |
| [66] | NNB GenCo (SZC), “ONR-SZC-21655N - Level 4 Regulatory Issue 8992 Escalated to Level 3 By The EPR Sub-Division Board,” 10 February 2022 (CM9 2022/10167). |
| [67] | NNB GenCo (SZC), “ONR-SZC-21568N - Letter - Sizewell C Extant PSHA/DBE Queries,” 12 April 2022 (CM9 2022/24294). |
| [68] | NNB GenCo (SZC), “Project Deliverable Sizewell C DBE Definition,” April 2022 (CM9 2022/24298). |
| [69] | NNB GenCo (SZC), “Email from NNB to ONR, RE: Extant PSHA and DBE queries,” 28 March 2022 (CM9 2022/20349). |
| [70] | EDF Energy, “Generation of 3 Sets of Free-Field Time-Histories for the Sizewell-C Site Interim DBE for the Replication/Design Studies,” 2020 (CM9 2021/70757). |
| [71] | NNB GenCo (SZC), “Flooding Summary Report Rev.4,” SZC-SZC-NNBOSL-XX-000-REP-100005, 2021, (CM9 2021/72604). |
| [72] | NNB GenCo (SZC)/EDF R&D UK, “Update to Estimation of extreme high-water levels at SZC, Revision 3,” SZC-PD0202-XX-000-REP-100005, 2021, (CM9 2021/73776). |
| [73] | EDF/HR Wallingford, “Sizewell Power Station Extreme Sea Level Studies. Joint Probability of Waves and Sea Levels and Structure Response, Technical Note 01,” SZC-EDFENE-XX-000-RET-000002 (CM9 2021/72623). |
| [74] | EDF/CEFAS, “BEEMS Technical Report TR319: Derivation of extreme wave and surge events at Sizewell with results of the coastal wave modelling, climate change and geomorphic scenario runs, Edition 2,” SZC-SZC020-XX-000-REP-100001 (CM9 2021/72634). |
| [75] | NNB GenCo (SZC), “Main Development Site Flood Risk Assessment Appendices 1-7,” 2020, (CM9 2021/73805). |
| [76] | Royal HaskoningDHV, “Sizewell C Safety Case – Coastal Flood Risk Modelling, Version 2,” June 2020 (CM9 2020/295357). |
| [77] | NNB GenCo (SZC)/Atkins, “Sizewell C – Tsunami Hazard Assessment Report, Rev B,” 2016 (CM9 2020/304467). |
| [78] | NNB GenCo (SZC), “SZC Platform Height: ALARP Analysis Decision Paper, Version 3,” SZC-NNBOSL-U9-ALL-RES-100000 (CM9 2017/208858). |
| [79] | ONR, “ONR-NR-AR-18-034 Sizewell C Platform Height ALARP Analysis,” (CM9 2018/232578). |
| [80] | NNB GenCo (SZC)/Atkins, “EW0601 Sea Defences Calculation Report,” SZC-EW0601-XX-000-REP-100007, 2020, (CM9 2021/72618). |
| [81] | NNB GenCo (SZC)/EDF Energy R&D UK Centre, “Extreme Rainfall at SZC, Revision 2,” October 2019 - SZC-PD0202-XX-000-REP-100001 (CM9 2020/295365). |
| [82] | Royal HaskoningDHV, “Sizewell C Safety Case - Fluvial Flood Risk Modelling, version 2,” SZC-SZ0200-XX-000-REP-100140 (CM9 2020/295445). |
| [83] | NNB GenCo (SZC), “Justification of Extreme Heat (Air) Temperature Design Basis Value at Sizewell C, Rev 4,” SZC-SZ0100-XX-000-REP-100031, 2021, (CM9 2021/72595). |
| [84] | NNB GenCo (SZC)/EDF R&D UK Centre, “Extreme air temperatures at Sizewell C, Rev 5,” SZC-SZ0500-XX-000-REP-100000, 2019, (CM9 2021/58251). |
| [85] | NNB Geno (SZC)/EDF R&D UK, “Advanced heatwave profile for SZC,” SZC-PD0202-XX-000-REP-100003, 2019, (CM9 2020/295417). |
| [86] | EA Technologies, “Lightning Data Analysis for Hinkley Point and Sizewell Power Station Sites, Issue 3,” HPC-NNBOSL-U0-000-RET-000005, March 2011, (CM9 2021/72635). |
| [87] | EDF Energy, “Analysis Of Impacts In The Case Of Strikes On The OHL With Or Without A Failure From The Surge Protection,” 2020, (CM9 2021/73808). |
| [88] | NNB GenCo (SZC)/CEFAS, “TR489 Sizewell extremes for maximum sea temperature and combined sea levels and waves at the Sizewell C intakes,” 2019, (CM9 2022/15255). |
| [89] | NNB GenCo (SZC)/EDF R&D UK, “Reproducing CEFAS analysis on extreme sea temperature and salinity for SZC,” 2020 (CM9 2022/25328). |
| [90] | NNB GenCo (SZC)/EDF R&D UK Centre, “Sizewell C extreme high sea water temperatures, Rev 3,” 2021, (CM9 2021/72649). |
| [91] | NNB GenCo (SZC)/Kenneth Pye Associates Ltd., “TR139 Sizewell Extremes Report, Rev. 1,” SZC-SZ0200-XX-000-REP-100152, 2014 (CM9 2022/15256). |
| [92] | ONR and NNB GenCo, “Emails between ONR and NNB, RE: SZC Aircraft Impact,” March-April 2022 (CM9 2022/26957). |
| [93] | Jacobs, “Level 1 Report, Overview of CFS & PSHA for Sizewell C,” 2021 (CM9 2021/68133). |
| [94] | ONR, “ONR-NR-CR-20-1035 - Sizewell C Peer Review Team Meeting,” 2021 (CM9 2021/25227). |
| [95] | R. McGuire, “Issues in probabilistic seismic hazard analysis for nuclear facilities in the US.,” Nuclear Engineering and Technology 41(10): 1235-1242, 2009. |
| [96] | R. McGuire, “Precision of seismic hazard evaluations in central and eastern North America,” Proceedings of the 15th World Conference on Earthquake Engineering. Lisbon, Portugal, 10pp, 2012. |
| [97] | NNB GenCo (SZC)/Jacobs, “Sizewell CFS and PSHA: Capable Faulting Study,” August 2021 (CM9 2021/68136). |
| [98] | ONR Expert Panel on Natural Hazards, “ONR Expert Panel on Seismic Hazard - SZC PSHA Margin Advice Note - Janaury 2022,” (CM9 2022/4143). |
| [99] | NNB GenCo, “Email from NNB to ONR, RE: SZC Seismic Information Request - NNB Response,” 16 August 2021 (CM9 2021/64380. |
| [100] | NNB GenCo, “Email from NNB to ONR, RE: Confirmation of SZC Seismic Monitoring Installation - 3 May 2022,” (CM9 2022/27501). |
| [101] | EDF Energy, “Sizewell C – Phase 2 Ground Investigation Report, Rev C,” 2021, (CM9 2021/83162). |
| [102] | Environment Agency, “Coastal flood boundary conditions for the UK: update 2018 Technical summary report,” 2019, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\_data/file/827778/Coastal\_flood\_boundary\_conditions\_for\_the\_UK\_2018\_update\_-\_technical\_report.pdf. |
| [103] | Environment Agency, “Coastal flood boundary conditions for the UK: 2018 update,” https://www.gov.uk/government/publications/coastal-flood-boundary-conditions-for-uk-mainland-and-islands-design-sea-levels (accessed 31/03/2022). |
| [104] | NNB GenCo (SZC), “Email from NNB to ONR, RE: SZC coastal flood hazard characterisation & detailed sea defence commitments,” 5 April 2022 (CM9 2022/24314). |
| [105] | Environment Agency, “Flood and coastal risk projects, schemes and strategies: climate change allowances,” 2020, https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances (accessed 31/03/2022). |
| [106] | Met Office, “UKCP18 Marine report,” November 2018, https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-marine-report-updated.pdf (accessed 31/03/2022). |
| [107] | NNB GenCo (SZC), “Justification of Extreme Heat (Air) Temperature Design Basis Value at Sizewell C, Rev 2,” SZC-SZ0100-XX-000-REP-100031, 2020, (CM9 2020/266406). |
| [108] | ONR, “Licence condition handbook,” February 2017, https://www.onr.org.uk/documents/licence-condition-handbook.pdf. |
| [109] | ONR, “ONR-NR-CR- 21-222 - Sizewell C External Hazards High Air Temperature Level 4,” 20 July 2021 (CM9 2021/59894). |
| [110] | ONR, “Step 4 Assessment of External Hazards for the UK Advanced Boiling Water Reactor (ONR-NR-AR-17-027),” https://www.onr.org.uk/new-reactors/uk-abwr/reports/step4/onr-nr-ar-17-027.pdf (accessed 14/04/2022). |
| [111] | EDF Energy, “EU Stress Test - Sizewell B,” January 2012. https://www.edfenergy.com/sites/default/files/jer-srt-stt-pub-fin-007\_szb\_stress\_test\_v1.1.pdf (accessed 14/04/2022). |
| [112] | Met Office, “Update to UKCP Local (2.2km) projections,” 2021, https://www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/ukcp18\_local\_update\_report\_2021.pdf. |
| [113] | ONR, “ONR-NR-CR-21-126 - Sizewell C External Hazards Level 4 - Extreme Heat (Sea),” 28 May 2021 (CM9 2021/45189). |
| [114] | National Oceanography Centre - British Oceanographic Data Centre, “Proudman Oceanographic Laboratory Coastal Ocean Modelling System (POLCOMS),” https://www.bodc.ac.uk/data/documents/nodb/254621/ [accessed 28.03.2022]. |
| [115] | ONR, “ONR-GDA-AR-11-018 Step 4 Civil Engineering and External Hazards Assessment of the EDF and AREVA,” 2011 (https://www.onr.org.uk/new-reactors/uk-epr/reports.htm). |
| [116] | ONR, “[OFFICIAL-SENSITIVE] ONR-GDA-AR-11-036 Step 4 Aircraft Impact Assessment of the UK EPR™ Reactor - DRAFT,” 2011, (CM9 2011/555713) (Note: Final version in secure room). |
| [117] | ONR, “ONR-NR-AR-17-005 Civil Engineering Aircraft Impact Assessment to Inform Agreement to Commence Start of the Hinkley Point C Pumping Station,” 2017 (CM9 2017/322546). |
| [118] | ONR, “ONR-NR-AR-16-061 NNB GenCo – Civil Engineering Assessment of CSJ-01.V2, Revision 3,” 2016 (CM9 2016 /302064). |
| [119] | ONR, “ONR-NR-AR-22-008 Safety Case (SC1) assessment of an application by NNB GenCo (SZC) Ltd for a Nuclear Site Licence,” (CM9 2022/23980). |
| [120] | ONR, “Sizewell C External Hazards Nuclear Site Licensing Related Contact Records,” (CM9 2022/26488). |

Table 8: Relevant Safety Assessment Principles (SAPs) considered during the assessment

|  |  |  |
| --- | --- | --- |
| SAP No. | SAP Title | Description |
| **Engineering principles: external and internal hazards** | | |
| EHA.1 | Identification and characterisation | An effective process should be applied to identify and characterise all external and internal hazards that could affect the safety of the facility. |
| EHA.2 | Data sources | For each type of external hazard either site-specific or, if this is not appropriate, best available relevant data should be used to determine the relationship between event magnitudes and their frequencies. |
| EHA.3 | Design basis events | For each internal or external hazard, which cannot be excluded on the basis of either low frequency or insignificant consequence (see Principle EHA.19), a design basis event should be derived. |
| EHA.4 | Frequency of initiating event | For natural external hazards, characterised by frequency of exceedance hazard curves and internal hazards, the design basis event for an internal or external hazard should be derived to have a predicted frequency of exceedance that accords with Fault Analysis Principle FA.5.  The thresholds set in Principle FA.5 for design basis events are 1 in 10 000 years for external hazards and 1 in 100 000 years for man-made external hazards and all internal hazards (see also paragraph 629). |
| EHA.5 | Design basis event operating states | Analysis of design basis events should assume the event occurs simultaneously with the facility’s most adverse permitted operating state (see paragraph 631 c) and d)). |
| EHA.6 | Analysis | The effects of internal and external hazards that could affect the safety of the facility should be analysed. The analysis should take into account hazard combinations, simultaneous effects, common cause failures, defence in depth and consequential effects. |
| EHA.7 | Cliff-edge effects | A small change in design basis fault or event assumptions should not lead to a disproportionate increase in radiological consequences. |
| EHA.8 | Aircraft crash | The total predicted frequency of aircraft crash, including helicopters and other airborne vehicles, on or near any facility housing structures, systems and components should be determined. |
| EHA.9 | Earthquakes | The seismology and geology of the area around the site and the geology and hydrogeology of the site should be evaluated to derive a design basis earthquake (DBE). |
| EHA.11 | Weather conditions | Facilities should be shown to withstand weather conditions that meet design basis event criteria. Weather conditions beyond the design basis that have the potential to lead to a severe accident should also be analysed. |
| EHA.12 | Flooding | Facilities should be shown to withstand flooding conditions up to and including the design basis event. Severe accidents involving flooding should also be analysed. |
| EHA.18 | Beyond design basis events | Fault sequences initiated by internal and external hazards beyond the design basis should be analysed applying an appropriate combination of engineering, deterministic and probabilistic assessments. |
| EHA.19 | Screening | Hazards whose associated faults make no significant contribution to overall risks from the facility should be excluded from the fault analysis. |
| **The regulatory assessment of safety cases** | | |
| SC.4 | Safety case characteristics | A safety case should be accurate, objective and demonstrably complete for its intended purpose. |
| SC.5 | Optimism, uncertainty and  conservatism | Safety cases should identify areas of optimism and uncertainty, together with their significance, in addition to strengths and any claimed conservatism. |

# Appendix A – SZC NSL External Hazards Engagements

A summary of the SZC NSL external hazards related formal engagements, also provided in [120]. Seismic hazard PSHA and CFS workshops are highlighted in blue. All meetings were level 4 meetings, unless otherwise indicated.

|  |  |  |
| --- | --- | --- |
| **SZC External Hazards related NSL formal engagements** | | |
| **Date** | **Engagement** | **Relevant topics** |
| 03/09/2019 | Meeting | Safety case |
| 23-24/09/2019 | Workshop | Seismic hazards |
| 15/01/2020 | Meeting | External hazards |
| 11/03/2020 | Meeting | External hazards |
| 22/04/2020 | Meeting | Seismic hazards |
| 21/05/2020 | Meeting | Seismic hazards |
| 28/05/2020 | Meeting | External hazards |
| 15/07/2020 | Meeting | Seismic hazards |
| 23-24/07/2020 | Meeting | Safety case |
| 11/09/2020 | Meeting | External hazards |
| 21/09/2020 | Meeting | Seismic hazards |
| 24/09/2020 | Meeting | Seismic hazards |
| 12/10/2020 | Meeting | Seismic hazards |
| 13/10/2020 | Meeting | Lightning hazard |
| 27/10/2020 | Meeting | External hazards |
| 13/11/2020 | Workshop | Seismic hazards |
| 30/11/2020 - 01/12/2020 | Workshop | Seismic hazards |
| 10/12/2020 | Meeting | External hazards |
| 15/12/2020 | Workshop | Coastal flood hazards |
| 02/02/2021 | Workshop | Seismic hazards |
| 09/02/2021 | Meeting | External hazards |
| 25/02/2021 | Meeting | Seismic hazards |
| 09/03/2021 | Workshop | Seismic hazards |
| 11/03/2021 | Meeting | Seismic hazards |
| 17/03/2021 | Meeting | GDA assessment findings |
| 23/03/2021 | Meeting | External hazards |
| 30/03/2021 | Workshop | SZC/SZB hazard interactions |
| 19-20/05/2021 | Workshop | Seismic hazards |
| 26/05/2021 | Meeting | Seismic hazards |
| 28/05/2021 | Meeting | High sea temperature hazard |
| 17/06/2021 & 29/06/2021 | Workshop | Seismic hazards |
| 20/07/2021 | Workshop | Seismic hazards |
| 20/07/2021 | Meeting | High air temperature hazard |
| 29/07/2021 | Meeting | Flood hazard |
| 1-2/09/2021 | Site visit | Turbine disintegration and pluvial flooding |
| 22/09/2021 | Meeting | Seismic hazards |
| 21/10/2021 | Meeting | Seismic hazards |
| 22/10/2021 | Meeting | External hazards |
| 16/11/2021 | Meeting | Seismic hazards |
| 29/11/2021 | Meeting | Seismic hazards |
| 20/12/2021 | Meeting | Seismic hazards |
| 19/01/2022 | Meeting (Level 3) | Seismic hazards |
| 27/01/2022 | Intervention | LC6 geotechnical records |
| 03/02/2022 | Intervention | Intelligent customer |
| 24/02/2022 | Meeting | Seismic hazards |
| 08/03/2022 | Meeting (ONR observer) | DCO meeting |
| 11/03/2022 | Intervention | Training SQEP and appointments |

# Appendix B – Status of ONR Platform Height Observations and NNB GenCo (SZC) responses

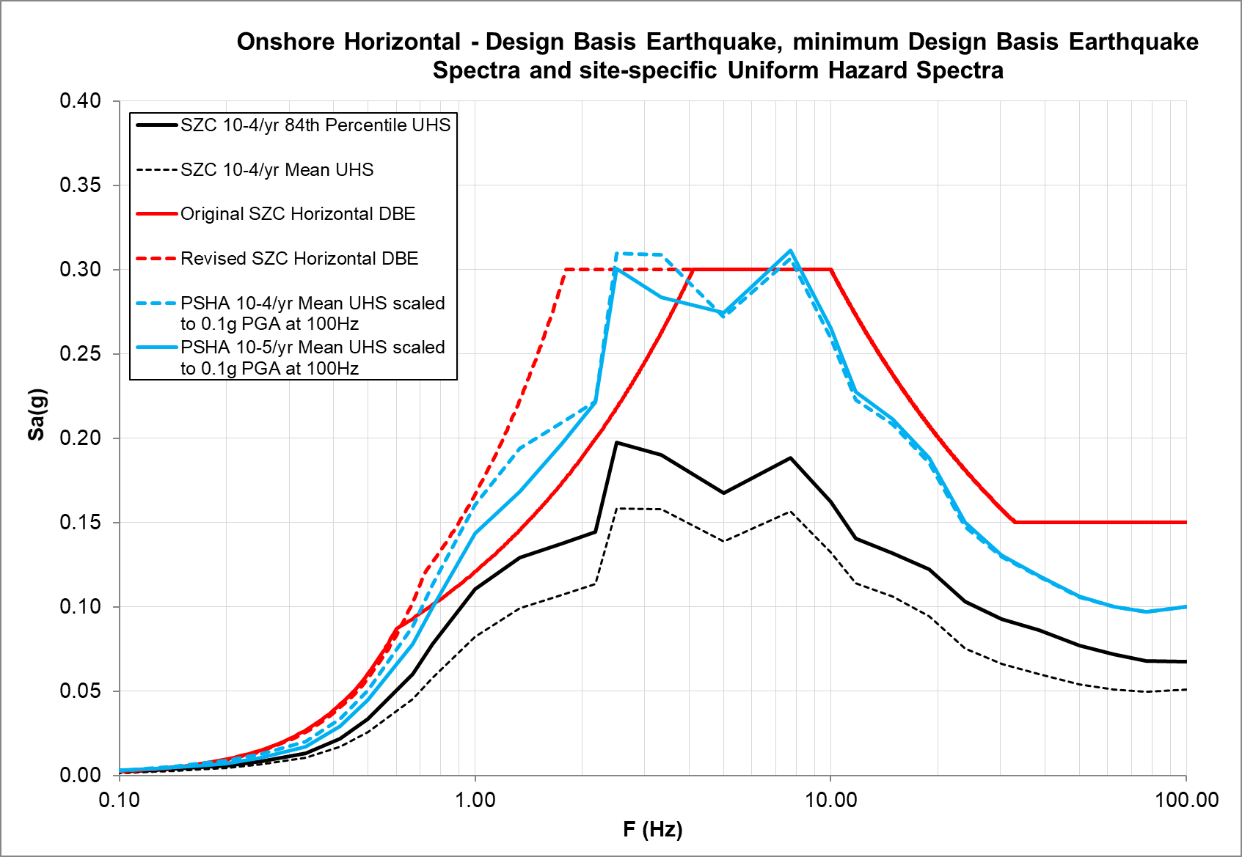
The ONR assessment of the SZC platform height raised a number of ONR platform height observations [79]. NNB GenCo (SZC) provided a progress update on these for NSL in Appendix A of the flooding summary report [71]. The observations and NNB GenCo (SZC) responses are copied into the table below. I have assessed NNB GenCo (SZC)’s responses and stated whether the observation is closed or remains open. Resolution of the open observations will be part of RI-10806.

Please note that:

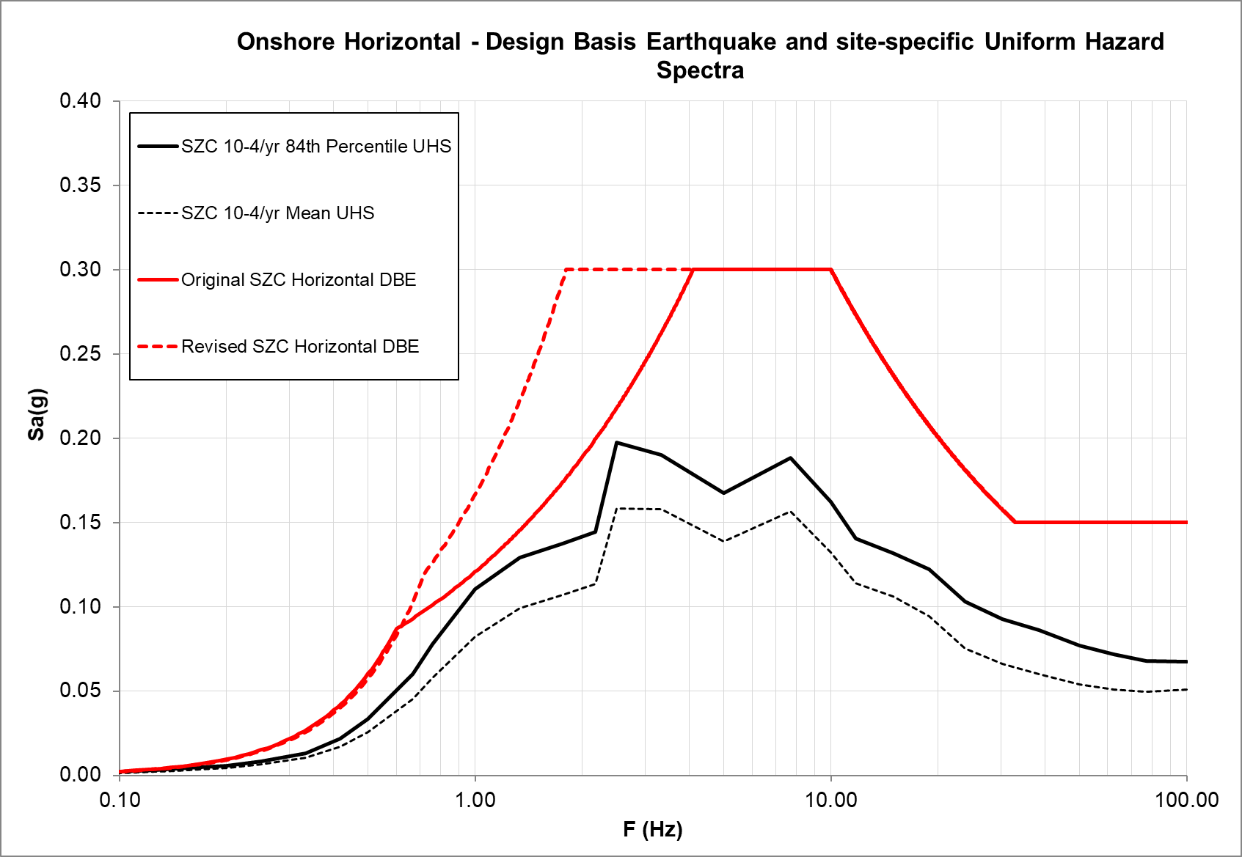
* The NNB GenCo (SZC) progress update is taken directly from the flooding summary report [71], and this should be used to locate the references referred to by NNB GenCo (SZC).
* The FSRS is the first safety related structure report. NNB GenCo (SZC) has since advised that the permeant sea defences may not be the first safety related structure. However, ONR still expect a safety case to be provided for the permeant sea defences.
* Where “EDF-NNB” is used in the ONR observation text, this should be considered synonymous with “NNB GenCo (SZC)”.

|  |  |  |  |
| --- | --- | --- | --- |
| **No.** | **ONR Observation** | **NNB GenCo (SZC) Progress Update** | **Status** |
| 1 | EDF-NNB should address the additional coastal flooding pathways that were not included in the ALARP study. These pathways include: |  | Open – see below for status of each part of observation 1. |
| * Via the coastal frontage at Minsmere | Reference [9] provides information on flooding via the frontage at Minsmere given the design at the time of the assessment. Work is progressing on this aspect of the design including the SSSI *[site of special scientific interest]* crossing. Part of the ongoing work will be to carry out overtopping and platform flooding assessments in order to demonstrate that flooding from this direction does not result in a water depth on the platform which overtops the platform door threshold heights. The final safety demonstration will be provided in the First Safety Related Structure (FSRS) Report10/PCSR. | Open – resolution of the observation will be part of RI-10806. |
| * Via the cooling water intake/discharge tunnels which link the offshore heads to the forebays, pumping stations and discharge ponds. | Flooding via this route is considered as an internal hazard because it is linked to a number of operational factors. These include the intake and outfall tunnels roughness of both units, the operational state of systems that circulate seawater as well as transients in those systems. Analyses have been carried out and conclude that even in the most conservative scenario (a loss of offsite power resulting in a double CRF pump trip at extreme high water level 5.95m AOD), the resulting rise in the water column (surge) does not overtop the protection in place [Ref. 46]. Note the use of 5.95m AOD is in line with the expected operating lifetime of the plant plus margin (see Section 2.1.2). | Open – whilst analyses have been undertaken, this should be reviewed following any updates to the site challenge.  Resolution of the Observation will be part of RI-10806. |
| * Via the fish return routes and tunnel which connect the debris recovery buildings and fish lifts to the outfall below low tide level. | At Sizewell C, the fish return system has been designed to minimise the mechanical handling of fish by providing a direct route back to the sea. The system has been designed to provide the head required for the system to flow adequately. In order to provide the appropriate flow characteristics, an overflow is included in the design. When the seawater level is above the overflow level, water passing through the system will recirculate back to the Forebay. Therefore, in a design basis extreme still sea water level conditions of +5.95m AOD, which is in line with the expected operating lifetime of the plant plus margin (see Section 2.1.2), no flooding occurs as seawater is routed back to the Forebay [Ref. 47]. | Open – whilst analysis has been undertaken, this should be reviewed following any updates to the site challenge.  Resolution of the Observation will be part of RI-10806. |
| * Overtopping onto the SZA or SZB sites leading to surface flooding onto the south of the SZC site via SZB. | Due to the SZC platform having being set at 7.3m AOD, and the SZB platform being set at 6.4m AOD, SZC is protected from surface flooding on the SZB platform due to SZC’s higher altimetry. | Closed – I consider NNB GenCo (SZC)’s response, in addition to information submitted as part of NNB GenCo (SZC)’s NSL application, adequately addresses the ONR Observation. |
| 2 | EDF-NNB should demonstrate as part of its safety case that the Interim Spent Fuel Store (ISFS) will be adequately protected against the risks from external flooding in line with the requirements of ONR SAP EHA.12. | As discussed in Section 3.2 and 3.3, the sea defence has a design life of 110 years out to 2140. The flooding assessments discussed in those sections have also considered conservative inputs out to 2140. Even in the most conservative scenario (not including expected mitigations) discussed in Section 3.3.2.2, flooding on the platform in the region of the ISFS structure is less than +0.2m above platform level. Therefore, there is a high degree of confidence that this structure will be adequately protected from external flooding. | Open – whilst NNB GenCo (SZC)’s response provides confidence that the ISFS will be protected, this is not yet demonstrated in its safety case.  Resolution of the Observation will be part of RI-10806. |
| 3 | EDF-NNB should review whether it is relevant good practice to add an allowance for climate change to its estimate of reasonably foreseeable storm surge feeding into its calculation of extreme sea levels. | UKCP18 guidance on this topic is used. UKCP18 suggests a relatively small contribution from storm surge changes to the extreme water levels, and currently there is low confidence in predicting whether storm surges will become more severe, less severe or remain the same [Ref. 13]. Since UKCP18 does not provide clear guidance on potential changes to storm surge in the future, no specific additional increase for storm surge is added when defining the site challenge or design basis for extreme still seawater level. However as discussed in Section 2.1.2 additional margins are included between the site challenge and the design basis used throughout the design.  Furthermore, an additional increase for surge is included in the credible maximum (H++) design case used to size the managed adaptive sea wall (with a crest height 16.4m AOD) [Ref. 34]. Therefore, there is a high degree of confidence that the SZC sea defences will be adequately sized to meet the coastal flooding hazard challenge even when considering an increase in storm surge as a result of climate change. | Closed – I consider NNB GenCo (SZC)’s response adequately addresses the ONR observation.  However, NNB GenCo (SZC) should consider advances in relevant good practice, when available, and revise its position as necessary, to ensure that the site challenge is conservatively defined, in line with SAPs EHA.4 and EHA.12. |
| 4 | EDF-NNB should refine its estimates of tide levels at SZC based on the inclusion of further data from the SZB tide gauge in its calculations. | Section 2.1.2 covers how the extreme still seawater levels have been defined for SZC. Reference [6] provides information on the approach taken which is in line with RGP on this topic.  In regard to the SZB tidal data it states “At the Sizewell B site, there is a tide gauge that has intermittent data available from 1995 to 2019. However, there are several years with no data or very sparse data. Additionally, even for the years where data is available, the quality of the data is unknown. Therefore, for the extreme value analysis for the present climate in this report, we choose not to use this data and instead analyse data that we can have more confidence in, namely, the tide gauge at Lowestoft.”  Furthermore:   * Given the additional margin that is included in extreme still seawater design basis over the site challenge (see Section 2.1.2), additional safety margin exists in the design. * The sea defences have been designed to meet a 2l/m/s overtopping criteria (see Section 3.2.3). When this rate of overtopping has been run through an inundation model to determine the flooding depths on the platform, the maximum water depth was below the +0.2m door threshold height. This door threshold level was also not exceeded when considering an overtopping rate of 5.2l/m/s (see Section 3.2.3).   Therefore, it is judged that there is sufficient conservatism in the design of the coastal flooding defences to account for any variations in tide level that may exist above and beyond how the difference between Sizewell and Lowestoft has been accounted for when characterising the extreme still seawater site challenge. | Open – further work is being undertaken by NNB GenCo (SZC) in this area [104].  Resolution of the observation will be part of RI-10806. |
| 5 | EDF-NNB should consider the potential importance of bi-modal sea conditions in its joint probability analysis of extreme sea levels and waves, rather than assuming that waves have a single, uniform wave steepness. This should also include an analysis of the sensitivity to wave period. | The latest understanding of bi-modal conditions is reported in Reference [49]. Going forwards in the design process, the latest understanding of bimodal conditions will be given further consideration as part of normal business in the sea defence design activities. Nevertheless, given the conservatisms adopted in the design process to date (see response to Observation #4) as well as the verification activities summarised in Section 3.2, there is a high degree of confidence that the existing design will be demonstrated to be adequate. | Open – resolution of the observation will be part of RI-10806. |
| 6 | EDF-NNB should further provide further evidence for its assumptions with regards to erosion and coastline change, taking into account the possibility of longshore movement. | Studies on erosion and coastline change have been carried out as part of the DCO process and are summarised in the DCO Environmental Statement [Ref. 48]. The relevant information is referenced in SDSR Version 3.  As the design process of the sea defences is iterative (and the fact that new marine structures will alter erosion and coastline change), the sea defence design has used the latest available information. Section 3.2.5 provides the details on design activities carried out to date. Notably, in regard to erosion and coastline change, sensitivity studies of the beach profile were carried out considering 20m and 40m erosion compared to the baseline case beach profile. Furthermore, a number of geo-scenarios of the future coastal environment were considered when modelling the nearshore wave conditions discussed in Section 3.2.5.1 [Ref. 10].  Ultimately, the FSRS/PCSR will provide the final demonstration of how erosion and coastline change are considered in the sea defence design process as well as the adequacy of that approach given the context and risk of the coastal flooding hazard. | Open – work undertaken by NNB GenCo (SZC) to date provides confidence that erosion and coastline change have been considered in the site hazard analyses.  Resolution of the observation will be part of RI-10806. |
| 7 | EDF-NNB should demonstrate how the beach and the armour can withstand extreme and concurrent events and how this will be managed for the lifetime of Sizewell C. | Information on the design activities carried out to date are summarised in Section 3.2.5. Ultimately, the FSRS/PCSR will provide the required information to respond to this observation. | Open – resolution of the observation will be part of RI-10806. |
| 8 | The approach utilised for wave transformation and joint probability should be reviewed for the Safety Case to ensure that it is aligned with relevant good practice and consistent between the sea protection design and FRA (Flood Risk Assessment). The use of physical modelling to confirm the final design should also be considered. | TOMAWAC has been used to model the transformation of offshore waves to the nearshore (as discussed in 3.2.5.1). This has been used as input to the sea defence design activities in Section 3.2.4 as well as the FRA assessments summarised in Section 3.2.5. The FRA overtopping studies have been performed using AMAZON modelling of nearshore conditions and have resulted in overtopping rates equivalent to what has been calculated by the design activities.  For information, the JoinSea joint probability approach that has been used to date to characterise offshore wave conditions (see Section 2.1.3) will be reviewed ahead of the next stage in the sea wall design process. The joint probability approach will be discussed in the FSRS/PCSR.  The use of physical modelling will be considered as part of the sea wall design process and reported in the FSRS/PCSR.  Given the +0.79m margin between the extreme still seawater site challenge and design basis in 2140 (Section 2.1.2); the conservative 2l/m/s overtopping design criteria set for the design of the sea defences (Section 3.2.3); and the maximum water depth on the platform when considering conservative inputs (a flat platform, the most penalising rainfall profile, and a 10,000 year rainfall event that includes 100 years of climate change occurring at the same time as 3l/m/s of threshold height (Section 3.3.2.2), there is a high degree of confidence in the robustness of the existing design of the sea defences to the coastal flooding hazard. Furthermore, the sea defence includes the provision to raise the crest height if required including as a result of climate change related sea level rise being greater than has been estimated by considering RCP8.5 at the 95th centile. | Open – further work is being undertaken by NNB GenCo (SZC) in this area [104].  Resolution of the observation will be part of RI-10806. |
| 9 | EDF-NNB should perform further work to define inshore conditions including the transformation of the entire offshore climate inshore and then converting this into discrete run-up and overtopping values. | Since the Observation was raised based off concept design of the sea defences, further design and assessment work has been undertaken (see Section 3.2) including how the inshore conditions have been modelled.  The final approach to define the inshore conditions used in the sea wall design and substantiation process will be justified in the FSRS/PCSR. | Open – further work is being undertaken by NNB GenCo (SZC) in this area [104].  Resolution of the observation will be part of RI-10806. |
| 10 | EDF-NNB should ensure that the full potential range of geometries has been included in the overtopping assessment for the coastal flooding safety case, taking into account the final design of the sea protection. | As discussed in response to Observation #6, different beach profiles have been assessed through sensitivity studies to account for potential future erosion rates due to different climate change scenarios. The overtopping assessments discussed in Section 3.2 have also considered the latest sea defence design.  The geometries considered in the final assessments of the sea defences will be discussed in the FSRS/PCSR. | Open – resolution of the observation will be part of RI-10806. |
| 11 | EDF-NNB should perform an analysis of the drainage channel (or alternative proposal) to remove surface water from the platform. This should include an assessment of the impacts overtopping could have on the drainage system. | The means by which water on the platform will be evacuated is covered by ongoing activities (the Roads and Networks design package). This work considers rainfall, overtopping as well as combinations when designing the features that will be included in the design to evacuate water on the platform.  Sections 3.2.7.1 and 3.3.2 summarise the latest information on this topic and provide a high degree of confidence that the water on the platform from overtopping and rainfall can be evacuated while ensuring the maximum water depths on the platform remain below the required door threshold limits. | Open – this topic is considered in Section 4.1.4.3 of this assessment report, where NNB GenCo (SZC)’s work to date provides confidence in resolution of observation 11.  Resolution of the observation will be part of RI-10806. |
| 12 | EDF-NNB should consider whether the selection of a 1 in 10 year return period rainfall event in combination with a 1 in 10,000 year coastal flood is adequately conservative and provide evidence to substantiate its selection. | The Extreme Rainfall Assessment (ERA) performed by RHDHV for the DCO (see Section 3.3.2.1) assessed overtopping and rainfall combinations. Using a significance factor based on evidence from publications, it identified the return periods of rainfall and coastal flooding dominated events which would give a combined return period of 10,000 years. It found the 1 in 10,000-year joint probability event would be equivalent to a 1 in 1,000-year coastal event combined with approximately a 1 in 3-year rainfall event. A more conservative combined scenario of a 1 in 10 year rainfall and an over-topping rate of 3.18 l/m/s was also assessed. This combined scenario was found to be bounded by 1 in 10,000 year rainfall scenario for which maximum water depths on the platform remained below the platform door threshold limit.  Section 3.3.2.2 summarises ongoing design activities on the roads and networks design package. For its baseline case, the assessment considers a 1 in 10,000 year rainfall event in combination with a rate of overtopping that is greater than the rate from a 1 in 10,000 year coastal flooding event. This provides assurance that the features in the design to manage and evacuate water on the platform will be sized adequately such that flooding remains below the required door threshold limits. | Open – NNB GenCo (SZC) has provided further information on its consideration of rainfall and coastal flooding events occurring in combination. Consideration of *“*a 1 in 10,000 year rainfall event in combination with a rate of overtopping that is greater than the rate from a 1 in 10,000 year coastal flooding event” is a conservative approach. The issue remains open, given that it is not fully clear how the combined rainfall and coastal flood hazard will be addressed within the safety case.  Resolution of the Observation will be part of RI-10806. |
| 13 | EDF-NNB should provide a demonstration that the barriers can be designed to withstand adequately the conditions under which they are required to operate. | Design activities carried out to date are summarised in Section 3.2.4.  The full demonstration that the sea defences meet their safety requirements and ensure the fulfilment of the safety objectives will be covered by the FSRS/PCSR. | Open – resolution of the observation will be part of RI-10806. |
| 14 | As part of its arrangements under Licence Condition 15, EDF-NNB should identify a “trigger point” when barriers construction will need to commence as part of its overall periodic review process. This trigger point will need to be far enough in advance that EDF-NNB will be able to construct the barrier before sea level rise reaches the point where the barrier could be needed. | Sea levels and the latest climate change science will continue to be reviewed over the life time to the plant to ensure that the sea defences provide the required level of protection. As discussed in Section 3.2.4, the design includes the provision to be raised if required. As part of the FSRS/PCSR, the required trigger points will be identified to ensure that any on site activities are completed when required. | Open – resolution of the observation will be part of RI-10806. |

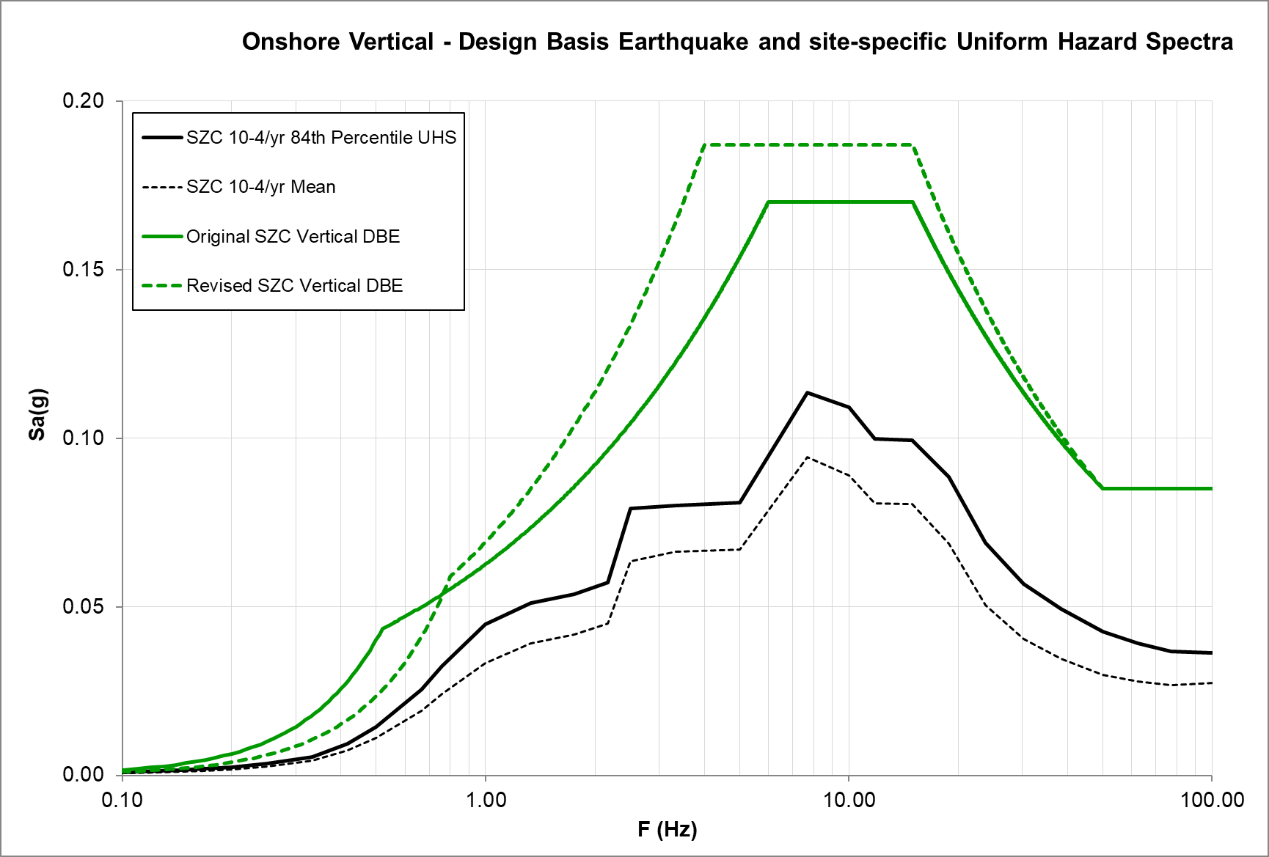
# Appendix C – Seismic Hazard Graphs



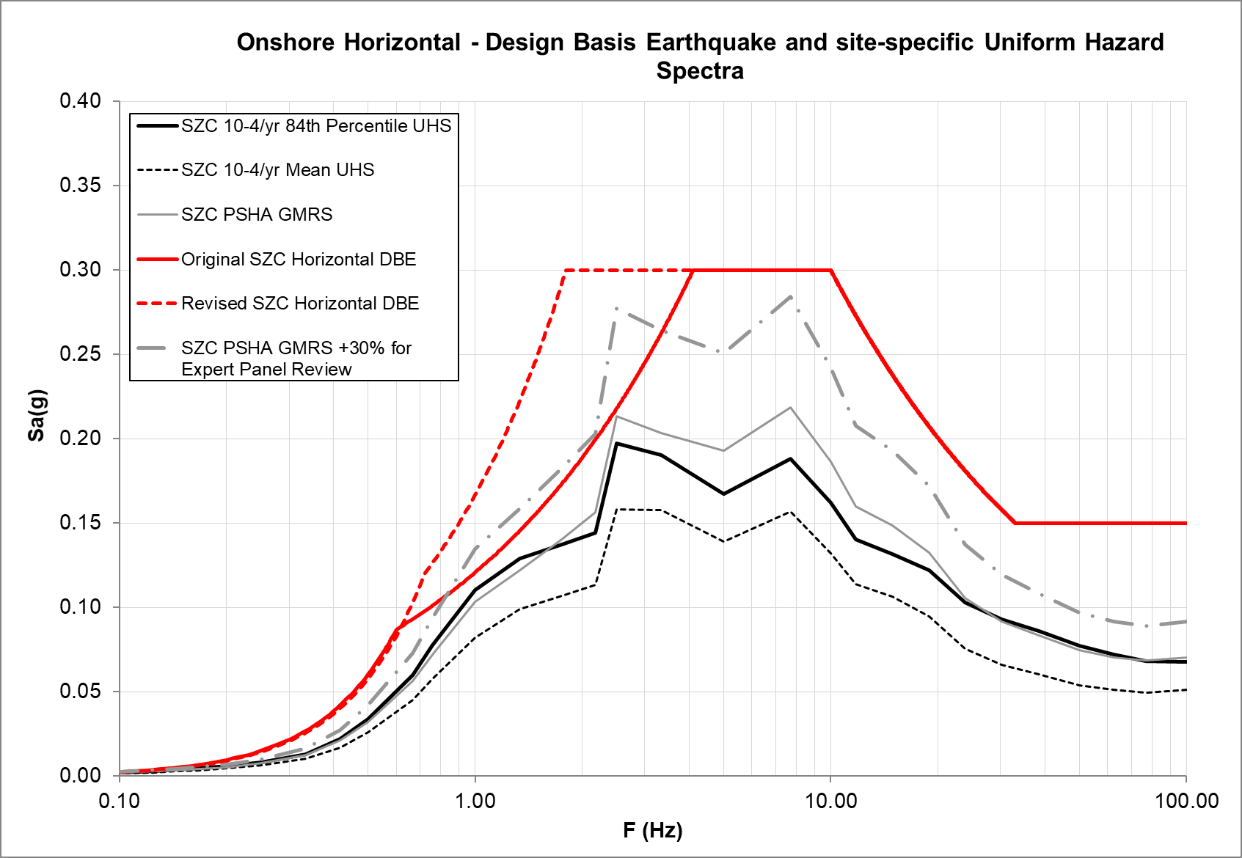
B



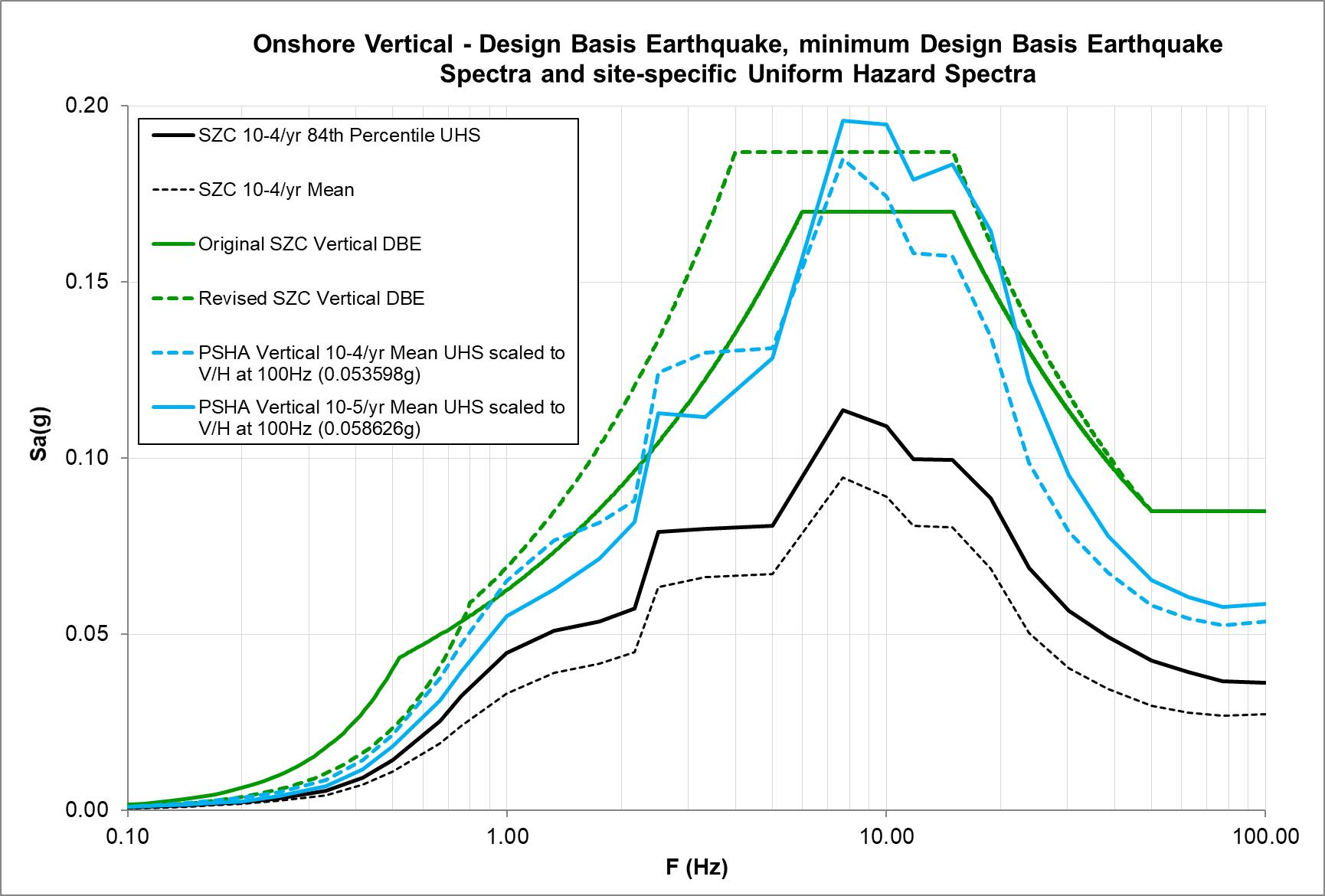
A



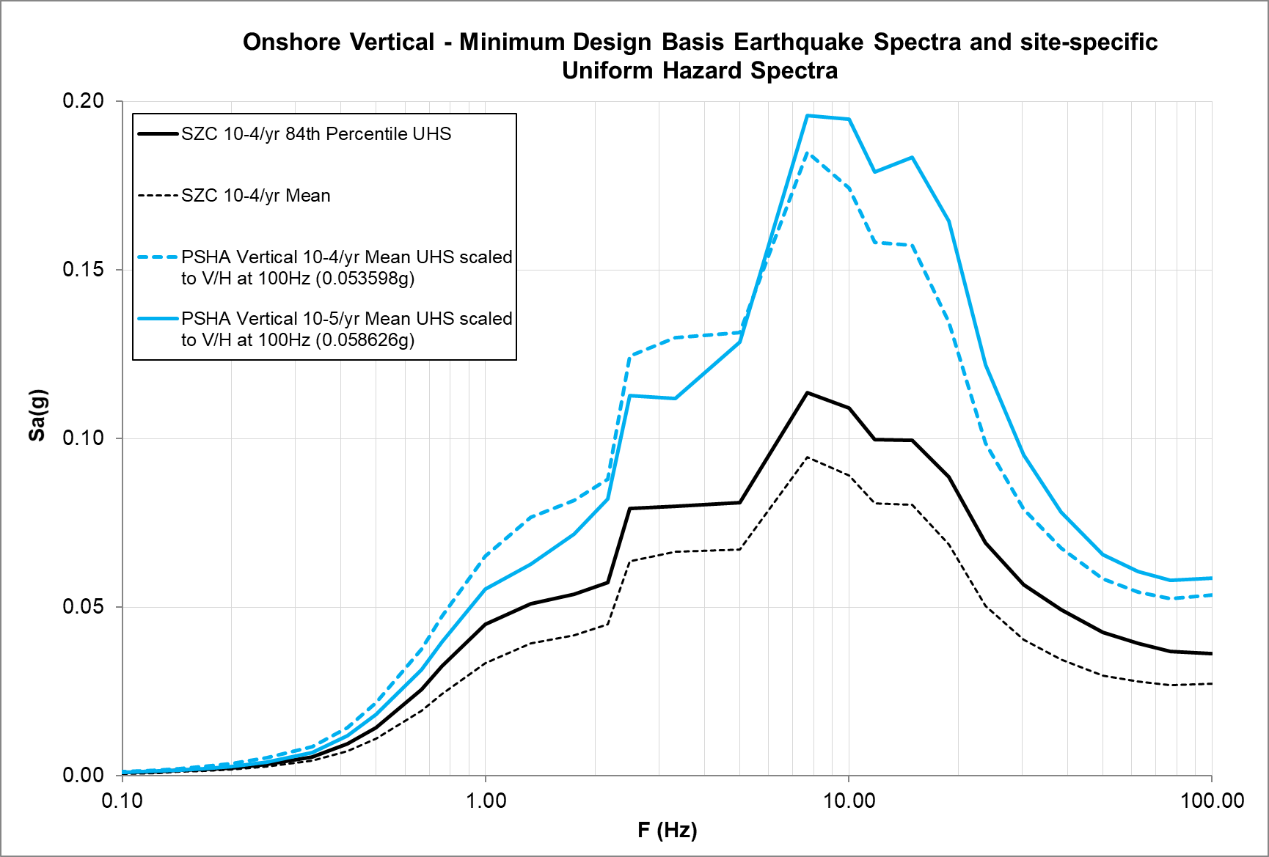
D



C



F



E

# Appendix D – Coastal Flood Hazard Technical Queries

|  |  |  |
| --- | --- | --- |
| **Technical Query Reference** | **ONR Query** | **Status** |
| **TQ1** | The Sizewell C site is approximately equidistant from Lowestoft and Felixstowe. Given that the Environment Agency’s Coastal Flooding Boundary model estimates higher water levels for Felixstowe than Lowestoft, why has only the tide data at Lowestoft been analysed without consideration of the Felixstowe tide data? | Open – resolution of this query will be addressed as part of RI‑10806. |
| **TQ2** | The Environment Agency Coastal Flooding Boundary model shows that from Lowestoft to Felixstowe, i.e. north to south along that stetch of the coastline, the water levels increase. This suggests that the Sizewell C site, which lies in between Lowestoft and Felixstowe, would have higher water levels than Lowestoft. Why then does the skew surge joint probability method (SSJPM) produce results that closely match the Environment Agency Coastal Flooding Boundary model estimates for Lowestoft but show a 0.4 m drop in water levels from Lowestoft to the Sizewell C site? | Open – resolution of this query will be addressed as part of RI‑10806. |
| **TQ3** | The threshold exceedance approach is used in deriving the extreme sea levels. Given that the block maxima approach is widely used for deriving extreme values and has the potential to produce higher values than the thresholds exceedance approach, why was the block maxima approach not considered? | Open – resolution of this query will be addressed as part of RI‑10806. |

1. CM9 revision to be identified upon completion of activity and incorporation of any changes to document. [↑](#footnote-ref-1)
2. Where required in accordance with [NS-PER-GD-016](https://how2.prod.onr.gov.uk/CtrlWebIsapi.dll/D2B97868F9C04F9F97117C7B56DFC8B7.cwl?__id=webFile.save&doc=3B55AFB1AFAC46B48A5EF6D7C306666C&dpt=1&save=1). [↑](#footnote-ref-2)
3. Hard-copy of document signed-off, CM9 version updated with authors / approver / acceptor names and dates and record finalised [↑](#footnote-ref-3)