101222587
Revision 01
ONR-SZC-21770N

Sizewell C
The power of **good for Britain**

UK PROTECT – COMMERCIAL & CONTRACTS

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For the attention [redacted]

Dear [redacted]

FOR INFORMATION: RESPONSE TO TECHNICAL QUERIES 1, 2 & 3

Following the ONR Level 4 meeting on the 23rd November 2023 please find below, as requested, our written response to ONR's Technical Queries 1, 2 & 3 (as per ONR action 1 of ONR's Regulatory Issue 10806). Action 1 of RI 10806 states:

NNB GenCo should use the best available relevant data source(s) for defining the Extreme Still Water Level hazard. As part of this, NNB GenCo should resolve the Extreme Still Water Level Technical Queries (TQ 1, 2 & 3, see ONR-NR-AR-22-005) and, if relevant, update its Extreme Still Water Level 10^{-4}/yr annual frequency of exceedance event

The Technical Queries are:

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?

TQ2: The Environment Agency Coastal Flooding Boundary model shows that from Lowestoft to Felixstowe, i.e. north to south along that stretch 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 0.4m drop in water levels from Lowestoft to the Sizewell C site?

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?

TQ1 & 2 are similar and therefore a joint response is prepared below to show the justification for selection of the Extreme High Seawater Levels in SDSR revision 5, which utilises work completed after these Technical Queries were posed.

Response to TQ1 & TQ2:

The Extreme High Seawater Levels (EHSLs) for SZC have been reviewed and revised as presented in SDSR Revision 5 (100812635, 005). The site challenge at 10^{-4} p.a. has increased from the value in SDSR Revision 4 to account for historical events in the extreme value analysis for Lowestoft and to incorporate greater conservatism in the translation of Lowestoft extremes to the SZC site (considering all available tide gauge data from Sizewell, and the wider pattern of extremes along the East Anglian coastline).

The supporting analysis for the updated EHSLs is in EDF R&D report ('Additional support for extreme sea level characterisation at Sizewell C', NH-2022-NNB-D63, Issue 2.0) which has been shared previously with the ONR.

Specifically with regards to tidal data, section 2.4.4 of the SDSR, revision 5, states:

> *Reference [23[1]] infers present day astronomical tide levels for Sizewell based on data from the Proudman Oceanographic Laboratory which utilises and maintains the Class A tide gauge network and derives astronomical tidal levels for the tide gauge locations. Data for Lowestoft and Felixstowe were used to derive the Values for Sizewell. Present-day astronomical tidal levels inferred for Sizewell are shown in Table 4.*

Tide Type	*Level mOD*
HAT: Highest Astronomical Tide	*+1.68*
MHWS: Mean High Water Springs	*+1.22*
MHWN: Mean High Water Neaps	*+0.83*
MSL: Mean Sea Level	*+0.16*
MLWN: Mean Low Water Neaps	*-0.42*
MLWS: Mean Low Water Springs	*-1.01*
LAT: Lowest Astronomical Tide	*-1.61*

Table 4: Present-day astronomical tidal levels for SZC

Furthermore, section 3.5.1.2.1 of the SDSR provides a justification for the selection of data to be used within the extreme high seawater level assessments:

> *The evaluations of extreme still seawater levels for SZC make use of the long history of good quality observational data at Lowestoft (since 1964) which is the closest Class A gauge to Sizewell on the UK National Tide Gauge Network. Lowestoft is identified in the Environment Agency's Coastal Flood Boundary Condition Report [59[2]] and [60[3]] as the location from which storm surge shape is to be taken over the coastline from Winterton-on-Sea to Aldeburgh (i.e. the main east-facing stretch of East Anglian coast comprising south Norfolk and north Suffolk). Sizewell is located on this stretch of coastline some 10km north of Aldeburgh. Given the form of the coastline and the nature of surge propagation considered in the Environment Agency's Coastal Flood Boundary Conditions Report [59] and [60], it is reasonable to deduce that the extreme still seawater levels at SZC are better represented by those at Lowestoft than those at Felixstowe (the next gauge location on the UK National Tide Gauge Network further to the south), where the coastline faces south-east towards the greater Thames Estuary rather than*

[1] Reference [23] of the SDSR (revision 5) is Joint probability of waves and sea levels and structure response, Revision 2, May 2010, SZC-EDFENE-XX-000-RET-000002

[2] Reference [59] of the SDSR (revision 5) is Environment Agency - Coastal flood boundary conditions for the UK: update 2018 - Technical summary report, May 2019, SC060064/TR6

[3] Reference [60] of the SDSR (revision 5) is Environment Agency - Coastal flood boundary conditions for the UK: update 2018 - User guide, May 2019, SC060064/TR7

eastwards into the open North Sea. This is further supported by the pattern of extreme still seawater level values presented in the Environment Agency's Coastal Flood Boundary Conditions Report [59] and [60]. The magnitude of extreme still water levels (and astronomical tides) around the UK coastline is consistently amplified in large bays and channels. This can be clearly seen from inspection of the graphical data in the Environment Agency's Coastal Flood Boundary Conditions Report, which shows significant amplification in the Bristol Channel, Liverpool Bay and Thames Estuary (continuing upstream to Felixstowe). According to the results of the Environment Agency's Coastal Flood Boundary Condition Report [59] and [60], which uses tide and surge modelling to interpolate between Class A tide gauge stations, the extremes at Sizewell are lower than those at Lowestoft which in turn are lower than those at Felixstowe. For less extreme cases (dominated by astronomical tides), the values are similar for Lowestoft and Sizewell while still being greater for Felixstowe.

As well as incorporating the most recent observational data at Lowestoft up to 2022, the latest study by EDF Energy R&D UK Centre [58[4]] provides a more robust evaluation of extreme still seawater levels at Sizewell for the purpose of definitively setting the site challenge for the coastal flooding hazard. It examines the effect of incorporating large historical surge events (from 1900 to 1964) in the SSJPM for Lowestoft and it compares the observed magnitude of high still seawater level events between Lowestoft and Sizewell since 2009 (examining the full dataset available from the tide gauge on the SZB intake; operational with some quality issues and missing data from 2009 to 2014/15; more complete data following upgrade in 2016). The inclusion of the four greatest historical events (including the 1953 event), with suitably extended background data for the period back to 1900, has the effect of raising extreme still seawater levels by approximately 0.35m at 1E-4 p.a. return frequency. Given the potential multi-decadal pattern of storminess driving skew surges around the UK over the lifetime of SZC, it is considered appropriate to include this effect in the derivation of the design basis. Comparison of high seawater levels at Lowestoft and Sizewell indicates that the magnitude of more frequent high water level events (driven predominantly by astronomical tides) tends to be slightly greater at Sizewell than Lowestoft. However, the magnitude of less frequent high water level events (where storm surge is more significant, out to around 1E-1 p.a. in the available dataset) is similar on average at Sizewell and Lowestoft. The pattern of the comparative data suggests that the magnitude of storm surge may tend to be slightly greater at Lowestoft than Sizewell, and that the scale of this effect may increase towards the extremes. While this inference would be consistent with the relative values calculated in the Environment Agency's Coastal Flood Boundary Conditions Report, it is considered appropriate for setting the site challenge for nuclear safety to err on the conservative side and to take the SZC extreme high still seawater levels as being the same as those calculated at Lowestoft. This has the effect of raising the adopted extreme still seawater levels by approximately 0.45m at 1E-4 p.a. return frequency.

Given the robust and expected conservative approach used in its derivation, it is reasonable and conservative to take the standard confidence level of 84th centile for evaluating the site challenge EHSL at 1E-4 p.a. return frequency.

Following this addition to the SDSR report, the Technical Queries, TQ1 & TQ2, are considered closed.

Response to TQ3

The most appropriate statistical method of extreme value analysis (EVA) has been selected and used to derive Extreme High Seawater Levels (EHSLs) for the SZC site, based on Relevant Good Practice and consideration of the methods available. SDSR revision 5 notes the following regarding the selection of the method:

[4] Reference [58] of the SDSR revision 5 is Additional support for extreme sea level characterisation at Sizewell C, EDF R&D UK Centre, April 2022, Issue 2.0, Report No. NH - 2022-NNB-D63

The assessments in References [57[5]] and [58[4]] evaluate extreme still seawater levels at extreme return periods using the Skew Surge Joint Probability Method (SSJPM). The SSJPM involves fitting a statistical distribution to the highest observed skew surges. It then evaluates the joint probability of skew surges and high astronomical tides (which can be treated as deterministic and independent). The SSJPM is considered to be the most robust method for determining extreme still seawater levels. It is used to derive a comprehensive set of extreme still seawater levels around UK coastline in the Environment Agency's Coastal Flood Boundary Conditions Report [59] and [60]. This is supported by the review of possible methods in [57[5]] which finds that the SSJPM makes best use of the available data and the well-defined nature of astronomical tides. As would be expected from the similarity in the methodology, there is evident consistency in the results of [57[5]] and [58[4]] and the Environment Agency's Coastal Flood Boundary Conditions Report [59[2]] and [60[3]].

Furthermore, the SSJPM (incorporating thresholds exceedance approach for large skew surge) is considered Relevant Good Practice for evaluating Extreme High Seawater Levels for the following reasons:

- The SSJPM ensures the best use of available data, with the least reliance on extrapolation of data to extreme values.
  - SSJPM focuses the statistical analysis on the stochastic surge component by recognising that the astronomical tide component is deterministic;
  - SSJPM obtains high numbers of skew surge data points; one at every high water/tide (i.e. approximately two per day), thus maximising the amount of data to be used;
  - SSJPM is not affected by the time shift in high water/tide (by using skew surge rather than residuals);
  - SSJPM ensures that threshold selection and GPD parameters (location, scale, shape) are tested for goodness of fit and sensitivity

- SSJPM is an evolution of previous joint probability methods (e.g. Dixon & Tawn, 1997), all of which are based on same joint probability principle and use of thresholds exceedance approach for surge component. The use of skew surge joint probability method emerged as best practice leading up to 2010.
  - SSJPM is recognised as the RGP method in the UK and internationally, which is evidenced by its general use in deriving all EHSLs in the Environment Agency's UK Coastal Flood Boundary Conditions (2011, 2018) and its identification as the RGP method for extreme sea level evaluation in Section 3.2.1.1 of ONR TAG 13 Annex 3 (Issue 1.2, October 2023):

Probabilistic methods are usually used to estimate the extreme sea level elevation for the hazard analysis for a storm surge and are taken to represent RGP. Since extreme sea levels at coastal locations depend upon tidal processes and the co-occurrence of storm surges, the accepted method for combining the deterministic tidal distributions with stochastic storm surge distributions is the JPM. This is an improvement on previous techniques that fitted extreme value distributions to either annual maximum sea levels, or a fixed number of extreme levels in each year. JPMs make the most efficient use of all recorded sea level data, and yield probabilities that have less dependence on extrapolation. However, as with any statistical method, the accuracy and timing of observations must be of high quality. The best dataset of extreme levels is obtained by calculating the probabilities of (deterministic) tide and skew surge.

[5] Reference [57] of the SDSR revision 5 is Update to Estimation of extreme high-water levels at SZC, EDF R&D UK Centre, January 2021, Revision 3, 100859811.

Following the additions made to SDSR revision 5, and the responses above, we consider that TQ3 can be considered closed.

Should you have any questions or comments we are happy to provide further information as part of our ongoing Level 4 interactions.

SZC Ltd Review	Role	Name	Signature
Peer Check	[redacted]		
Independent Verification			
Approval	[redacted]		N/A- Letter Author

Yours sincerely,

[redacted]

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