NNB GENERATION COMPANY LTD

PROJECT DOCUMENT

SZC PLATFORM HEIGHT: ALARP ANALYSIS DECISION PAPER

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APPROVAL SIGN-OFF: SZC PLATFORM HEIGHT: ALARP ANALYSIS DECISION PAPER

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1 INTRODUCTION

1.1 Purpose

The platform height at SZC is a key element of the defence of the planned nuclear power plant against the external flooding hazard. The ONR has indicated that the choice of platform height will influence its decision on whether to grant a nuclear site licence. Furthermore, following the accident at the Fukushima Dai-ichi nuclear power plant all aspects of coastal flooding defence for new nuclear power stations have received greater regulatory scrutiny to ensure that the lessons learnt from that accident are implemented into design. Setting of the platform height is also vital in order to undertake plot plan layout studies, heat sink engineering studies and the planning assessment studies required as part of the DCO application. Therefore it is imperative that agreement is reached between all stakeholders on the optimum height of the platform prior to the confirmation of the aforementioned studies.

The ONR's position is that NNB must provide an assessment showing that the selected platform height reduces risks from external flooding so far as is reasonably practicable. To that end an ALARP assessment has been produced by Atkins under the technical leadership of the NNB Design Authority and the Project Development Directorate. This ALARP assessment uses a multi-attribute options analysis to examine five different platform heights and proposes that two of the heights could be considered to be ALARP. Therefore the purpose of this current paper is to provide a decision on which of these platform heights should be chosen.

1.2 Scope

The scope of this report is limited to the selection of an ALARP platform height when considering the external flooding hazard. It should be noted that this report utilises the Main Study Report and Flood Levels Analysis reports from the Platform Height ALARP work which contain detailed information on the coastal flooding hazard, but a slightly more limited set of input data for the groundwater hazard. Therefore this report presents the minimum platform height required to demonstrate that an ALARP position has been reached with respect to coastal flooding. The reduced level of information on the groundwater hazard does not negate the results of this study and the subject of protection against the groundwater hazard will be addressed at a later stage of the project development. The selection of the platform height at this stage will not foreclose on any of the standard options for control of the high groundwater hazard [1]:

- ballasting,
- anchoring,
- groundwater drainage.

1.2.1 Lifetime considerations

This ALARP study has been completed using the assumption of a 60 year lifetime for the SZC plant. No consideration has been given to potential lifetime extensions, which will have to be assessed during the plant life and as part of the decadal periodic safety review process. It is not possible at this time to provide sufficiently accurate estimates of sea level rise due to climate change beyond the 2110 date provided within this paper and the associated references, and therefore lifetime extensions cannot be considered further. It is acknowledged that the northern and southern flood barriers could feasibly be altered to accommodate additional climate change at a date after 2110, but at an unknown cost or schedule.

The 2110 date for climate change estimates is generally recognised as the limit for accurate forecasts of climate change. It is noted that the interim spent fuel store will be on site later than 2110, but it is expected that should climate change occur which causes sea level rise greater than currently predicted then the site will be adapted at that time to provide sufficient flooding protection (i.e. through the use of bunds and barriers internal to the site).

1.3 References and Definitions

Ref	Title	Location	Document No.
1	EPR UK – Hinkley Point C – Justification for the installation of a site-wide groundwater drainage gallery	EDRMS	E.T. DOIG/110348A
2	Sizewell C Coastal Flooding ALARP Phase 2: Main Study Report	EDRMS	SZC-NNBOSL-XX-000-RET-100000
3	HPC PCSR3 sub-chapter 15.4: Supporting Radiological Analysis for the HPC Design	EDRMS	HPC-NNBOSL-U0-000-RES-000145
4	HPC PCSR3 – Sub-chapter 23.1 – Fukushima Safety Features	EDRMS	HPC-NNBOSL-U0-000-RES-000223
5	NUCLEAR SAFETY DESIGN ASSESSMENT PRINCIPLES	EDRMS	NNB-202-STA-000002, revision 2
6	SZC platform height – Best estimate dry-site frequency assessment	EDRMS	SZC-SZC-EDFENE-XX-000-CAL-100000
7	Identification of systems to be considered in the hazard studies and consequences when lost – CI/BOP scope	EDRMS	HPC-ETSEEX-AU-ALL-NOT-000047
8	HPC PCSR3 - Sub-chapter 16.1 – PSA Methodology and Scope	EDRMS	HPC-NNBOSL-U0-000-RES-000210
9	Update on Estimation of extreme sea levels at Sizewell	EDRMS	SZC-SZC020-XX-000-REP-100002
10	Interim Report on Failure on-demand of Flood Defence Scheme Components	http://evidence.environment-agency.gov.uk/FCERM/Libraries/FCERM_Project_Documents/SCHO0505BJAX-E-E_pdf.sflb.ashx	R&D Technical Report W5-031/TR
11	SIZEWELL C COASTAL FLOODING ALARP PHASE 2 – FLOOD LEVELS ANALYSIS	EDRMS	SZC-NNBOSL-XX-000-RET-100001

Ref	Title	Location	Document No.
12	HPC PCSR3 Sub-chapter 2.1 – Site Description and Data	EDRMS	HPC-NNBOSL-U0-000-RES-000086
13	SIZEWELL C - TSUNAMI HAZARD ASSESSMENT REPORT	EDRMS	SZC-NNBGEN-XX-000-REP-100008 Rev B

Term / Abbreviation	Definition
ALARP	As Low Reasonably Practicable
HPC	Hinkley Point C nuclear power station
IAEA	International Atomic Energy Agency
LUHS	Loss of Ultimate Heat Sink
mAOD	Metres above Ordnance Datum
mOD	Metres Ordnance Datum
NNB	Nuclear New Build Generation Company
ONR	Office for Nuclear Regulation
RGP	Relevant Good Practice
SAPs	Safety Assessment Principles
SEC	Essential Services Water system
SRU	Ultimate Cooling Water system
SZC	Sizewell C nuclear power station
TLUHS	Total Loss of Ultimate Heat Sink

2 REGULATORY PREFERENCES

The ONR has declared a preference for a “dry site” within their latest Safety Assessment Principles:

261. Facilities should be protected against a design basis flood by adopting a layout based on maintaining the ‘dry site concept’. In the dry site concept, all vulnerable structures, systems and components should be located above the level of the design basis flood, together with an appropriate margin in accordance with Principle EHA.7. This may be accomplished by locating the plant at a sufficiently high elevation, or by structural arrangements that raise the ground level (e.g. by use of fill material). In the latter case, the safety functions delivered by these structures should be assured through appropriate safety management arrangements including the ECS principles (paragraph 158ff).

262. Where it is not practicable to adopt the dry site concept, the design should include permanent external barriers such as levees, sea walls and bulkheads. Applying Principle EHA.7, the design parameters for these barriers may need to be more onerous than those derived from the design basis flooding event. The barriers should be subject to appropriate safety management arrangements (including periodic inspections, monitoring and maintenance (see Principle ECE.23)), even if their locations mean they are not under the direct responsibility of the licensee. In addition, levees, sea walls and bulkheads (etc) *should be designed to ensure that water can leave the site when needed and that they do not act as a dam.*

The dry site concept is derived from the IAEA safety guide, SSG-18 and is defined in a similar way to the ONR's definition above. It is also noted that SSG-18 declares that: "In most States method (a)[the dry site] is preferred to method (b)[use of permanent external barriers] which includes the construction of permanent external barriers."

Finally, the IAEA fact finding mission to Fukshima Dai-ichi contained the following lesson learned:

Plant layout should be based on maintaining a 'dry site concept', where practicable, as a defence-in-depth measure against site flooding as well as physical separation and diversity of critical safety systems.

Taking the above into consideration it is clear that the ONR will accept a site design that includes protection against external flooding through the use of external flooding barriers, but that a robust ALARP argument is required to enable the site to be licensed. The ONR have indicated that this ALARP argument must also include:

- A demonstration that gross disproportionality applies if the dry site option is to be rejected;
- A comparison of the chosen option with relevant good practice, including the identification of what is considered to be relevant good practice by NNB;
- A demonstration that uncertainties within the ALARP assessment have been treated appropriately.

Therefore the scope of this report is extended to include a summary of how these issues are addressed within the main study report. Sections 4 & 5 demonstrate that the selection of a dry site is grossly disproportionate; Section 3 provides the identification of relevant good practice, with Section 12 concluding on how this relevant good practice has been met; Section 4 provides the results of the sensitivity case for the ALARP assessment and thus provides the demonstration that the uncertainties have been treated appropriately.

3 RELEVANT GOOD PRACTICE FOR SETTING OF PLATFORM LEVEL

As stated above, it is necessary for NNB to define what it considers to be Relevant Good Practice for the setting of site platform heights and then to make a comparison with the approach adopted for Sizewell C.

The Nuclear Safety Design Assessment Principles for NNB have been reviewed and these show limited guidance which could help in the setting of Relevant Good Practice. Therefore it is proposed to use the ONR's guidance, itself derived from the IAEA, to define the following Relevant Good Practice for NNB:

Facilities should be protected, where practicable, against a design basis flood by adopting a layout based on maintaining the 'dry site concept'. In the dry site concept, all vulnerable structures, systems and components should be located above the level of the design basis flood, together with an appropriate margin. This may be accomplished by locating the plant at a sufficiently high elevation, or by structural arrangements that raise the ground level (e.g. by use of fill material). In the latter case, the safety functions delivered by these structures should be assured through appropriate safety management arrangements.

Where it is not practicable to adopt the dry site concept, the design should include permanent external barriers such as levees, sea walls and bulkheads. The design parameters for these barriers may need to be more onerous than those derived from the design basis flooding event. The barriers should be subject to appropriate safety management arrangements (including periodic inspections, monitoring and maintenance). In addition, levees, sea walls and bulkheads, etc. should be designed to ensure that water can leave the site when needed and that they do not act as a dam.

4 SUMMARY OF ALARP ASSESSMENT STUDY

The ALARP assessment (Reference 2) examined five options for the platform height:

1. 6.4m: Same as adjacent SZB site and above maximum still water level for 10,000 year return period with reasonably foreseeable climate change (height currently used for all engineering studies).
2. 7.3m: Enhanced level of protection and distinct differences in the coastal flood protection required when compared to 6.4m (provides margin of 1.35m above maximum still water level for 10,000 year return period with reasonably foreseeable climate change and therefore a low (5%) probability of exceedance).
3. 8.8m: Height exceeds credible maximum still water levels for 10,000 year return period and hence no external barriers are required to provide protection against still water level (eastern sea defence still required to provide protection against wave over-topping).
4. 10.5m: Dry site for reasonably foreseeable climate change – no external barriers are required to provide flooding protection for the reasonably foreseeable climate change scenario.
5. 15m: Dry site for credible maximum climate change – no external barriers are required to provide flooding protection for the credible maximum climate change scenario.

The ALARP study provides a synopsis of the flood levels analysis and the barrier requirements for each of the platform height options which have been chosen. Following this each option is assessed using a comparative scoring mechanism against a common set of impact areas which are grouped into broader aspect categories. The set of aspects and the underlying set of impact areas cover the full range of benefits and disbenefits (nuclear safety and other) associated with raised platform levels and external flood barriers.

The list of aspects is shown below:

- Nuclear safety
- Design & construction
- Environment
- Operation

Each of these aspects is given a weighting, as is each of the impact areas under each of the aspects (e.g. the nuclear safety aspect has a total aspect weighting of 30%, of which the coastal flooding protection impact area is considered to have a weighting of 30%, or 9% of the total weighting (30% x 30%)). Each impact area is then scored between 0 and 10 for each of the platform height options, with the lowest score referring to the option considered to be most favourable for that impact area.

Using this scoring mechanism the following results were found:

	Platform height	Score
Option 1	6.4m	4.97
Option 2	7.3m	2.70
Option 3	8.8m	2.78
Option 4	10.5m	4.19
Option 5	15m	6.84

Table 1: Results from Main ALARP study

It should be noted that the scores presented in Table 1 have been derived by the Atkins engineers and not as part of a working group. This method was agreed by the project team due to the large number of variables which are required to be assessed. These scores have been subject to review by the appropriate discipline engineers and therefore are considered robust for use within this assessment.

Sensitivity cases for the options scoring were also produced within the ALARP study, in particular there is a sensitivity case for providing extra weight to the nuclear safety aspects; this produced the following results for the 7.3mAOD and 8.8mAOD options:

Sensitivity case	Option 2 (7.3mAOD)	Option 3 (8.8mAOD)
Extra weight on nuclear safety	3.02	2.67

Table 2: Sensitivity case results: extra weight on nuclear safety

These results in Table 2 show that Option 3 is preferable when consideration is made of the nuclear safety benefits, disregarding to some degree the detriments of setting such a height, the effects of which are shown in Table 1.

5 CONCLUSIONS DRAWN FROM MAIN STUDY RESULTS

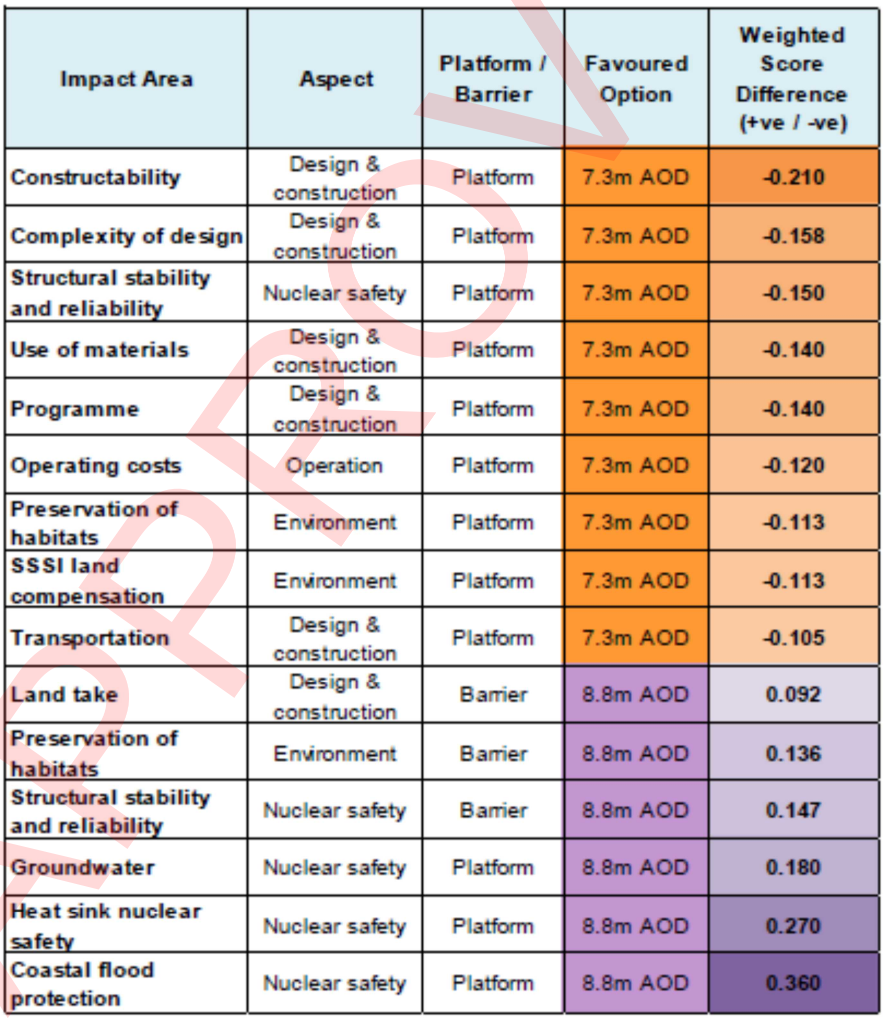
From the results above, and the discussion in the main study report, the following conclusions can be drawn:

1. The nuclear safety benefits of a dry site (either 10.5m or 15m) are massively outweighed by the detriments of choosing such a height (i.e. time, costs & trouble) such that it can be considered grossly disproportionate to choose to adopt a dry site philosophy.
2. The heights of 7.3m an 8.8m are considered to provide significant nuclear safety benefits above the 6.4m level, and hence this height is screened out from the decision making process.
3. Both the 7.3m and 8.8m levels are considered to provide the basis for an ALARP argument. However, the nuclear safety benefits are considered to be improved by the 8.8m height, particularly when examining the sensitivity case of additional weight on nuclear safety (in comparison with the 7.3m height, albeit at additional cost).

Increasing the height beyond 8.8m is not considered to provide any additional nuclear safety benefit, and there could be little difference between 8.8m and the range just below 8.8m (e.g. 8.5-8.8m).

6 QUALITATIVE DIFFERENCES BETWEEN OPTION 2 & OPTION 3

The following section provides an assessment of the qualitative differences between the 7.3mAOD and 8.8mAOD platform heights. The information contained in this section is drawn from the main ALARP study report [2], which provides the following table of the largest differences in the weighted scores between the two platform heights:



Impact Area	Aspect	Platform / Barrier	Favoured Option	Weighted Score Difference (+ve / -ve)
Constructability	Design & construction	Platform	7.3m AOD	-0.210
Complexity of design	Design & construction	Platform	7.3m AOD	-0.158
Structural stability and reliability	Nuclear safety	Platform	7.3m AOD	-0.150
Use of materials	Design & construction	Platform	7.3m AOD	-0.140
Programme	Design & construction	Platform	7.3m AOD	-0.140
Operating costs	Operation	Platform	7.3m AOD	-0.120
Preservation of habitats	Environment	Platform	7.3m AOD	-0.113
SSSI land compensation	Environment	Platform	7.3m AOD	-0.113
Transportation	Design & construction	Platform	7.3m AOD	-0.105
Land take	Design & construction	Barrier	8.8m AOD	0.092
Preservation of habitats	Environment	Barrier	8.8m AOD	0.136
Structural stability and reliability	Nuclear safety	Barrier	8.8m AOD	0.147
Groundwater	Nuclear safety	Platform	8.8m AOD	0.180
Heat sink nuclear safety	Nuclear safety	Platform	8.8m AOD	0.270
Coastal flood protection	Nuclear safety	Platform	8.8m AOD	0.360

Table 3: Differences in weighted scores for options 2 & 3

It can clearly be seen that the 7.3mAOD options scores very favourably for the construction, design and costs elements when compared to the 8.8mAOD option. For the remaining elements related to the platform height the following discussion is taken into account (all information in this section is taken from reference [2], except the conclusions sections which represent the latest assessment):

6.1 Coastal flood protection

The differences between the 7.3mAOD and 8.8mAOD height with regard to coastal flood protection and safety margin are:

6.1.1 Option 2: 7.3mAOD

Based on the postulated scheme for barrier provision, a minimum platform exceedance margin of 0.5m above the 10,000 year return period condition would be experienced at some point in the station lifetime for 20% of the projected climate change trajectories. A margin of 0.5m is estimated to have an exceedance return period of 30,000 years which is more frequent than 10^{-5} p.a..

The beyond design basis margin of this option averaged over the station lifetime is similar to that of the 6.4m AOD platform level option because the greater margin at the start of life is offset by the reduced probability of (and benefit from) from the northern and southern barriers. The mean margin (time-averaged) is calculated to be 1.5m which is estimated to have an exceedance return period of 200,000 years.

6.1.2 Option 3: 8.8mAOD

The mean margin for the 8.8m AOD platform level option over the station lifetime is calculated to be 2.87m. Although the minimum margin is only 0.5m, it should be noted that this is only approached on the upper end (credible maximum) trajectory over the last few years prior to 2110. Over the majority of projections, the 8.8m AOD platform level option has a margin in excess of 2m which is estimated to have an exceedance return frequency of about 10^{-6} p.a..

6.1.3 Conclusion

Whilst there is an exceedance frequency difference between the two heights it is noted that both these exceedance frequencies are less than the 10^{-4} p.a. design basis requirement. It can also be seen in section 8.3 that sufficient coastal flooding protection is provided to ensure that the site will not be flooded even under credible maximum climate change scenarios. The qualitative difference between the two heights is that there will be a reduced margin for the 7.3mAOD option when compared to the 8.8mAOD option, this is to be expected, but at the very low frequencies of occurrence is not considered to be a fundamental differentiator between the two platform heights.

6.2 Heat sink nuclear safety

The differences between the 7.3mAOD and 8.8mAOD height with regard to Heat Sink nuclear safety are:

6.2.1 Option 2: 7.3mAOD

This platform level:

(i) places a demand on projecting filter bay head walls and other protective measures (e.g. wash water gulley closures, forebay perimeter wall) to achieve adequate design basis protection for nuclear safety against flooding internal to the pumping station and onto the site platform for climate change exceeding reasonably foreseeable;

(ii) involves a relatively impractical and inefficient postulated configuration of the pumping station with a separate filter floor at a higher level than the service floor and potential raising of the cranes and roof to maintain adequate clearances over the filter floor.

6.2.2 Option 3: 8.8mAOD

This platform level option:

(i) provides adequate design basis protection for nuclear safety against flooding internal to the pumping station and onto the site platform via all pathways without additional protective measures for credible maximum climate change;

(ii) involves the most practical and efficient postulated configuration of the pumping station with the service floor serving as a common filter floor at the optimal level for credible maximum climate change.

6.2.3 Conclusion

Whilst there is an obvious benefit seen from selecting the 8.8mAOD option for the design of the pumping station and forebay, this design effort has to be offset against the cost and schedule constraints outlined in Section 8.1 and the frequency of flooding events occurring in Section 8.2. It should also be noted that the pumping station design for SZC will need to be updated from the Hinkley Point C (HPC) design regardless of the platform height chosen. Therefore this aspect is not considered to be a fundamental differentiator between the two platform heights.

6.3 Groundwater

The differences between the 7.3mAOD and 8.8mAOD height with regard to groundwater are:

6.3.1 Option 2: 7.3mAOD

The margin between the platform level and the estimated extreme groundwater level (unmitigated) is:

- 4.6m for present-day

- 3.8m for reasonably foreseeable climate change (end-of-life)
- 1.5m for credible maximum climate change (end-of-life)

This platform level satisfies the screening margin of 4m to 5m under present-day groundwater conditions. The margin under estimated reasonably foreseeable groundwater conditions is within 1m of the desired range indicating that it is likely to be possible to substantiate adequate stability against uplift for this case through further analysis of groundwater conditions and building-by-building stability assessment. The 7.3m AOD platform level does not satisfy the screening margin of 4m to 5m under credible maximum groundwater conditions by a significant degree suggesting that special measures (e.g. ballasting, or the introduction of active groundwater control) may be required in this case.

6.3.2 Option 3: 8.8mAOD

The margin between the platform level and the estimated extreme groundwater level (unmitigated) is:

- 6.1m for present-day
- 5.3m for reasonably foreseeable climate change (end-of-life)
- 3.0m for credible maximum climate change (end-of-life)

This platform level satisfies the screening margin of 4m to 5m under present-day and reasonably foreseeable groundwater conditions. The margin under estimated credible maximum groundwater conditions is within 1m to 2m of the desired range indicating that it may be possible to substantiate adequate stability against uplift for this most severe case through further analysis of groundwater conditions and building-by-building stability assessment.

6.3.3 Conclusion

Whilst there is a preference within the study for the 8.8mAOD platform height the ALARP study clearly shows that there are non-novel engineering solutions available for the mitigation of the groundwater hazard and therefore this hazard is not considered to be a fundamental differentiator between the two platform heights.

6.4 Qualitative differences conclusion

For the three areas related to the platform height, and which show clear qualitative differences between the 7.3mAOD and 8.8mAOD heights that are not just related to cost, a new summary assessment has been undertaken. This assessment shows that whilst there are some clear advantages to the 8.8mAOD platform height there are non-novel engineering and design solutions available to provide suitable mitigation of the risks, and that the other flooding protection measures shown in Sections 8.3 & 9 ensure that the site is suitably protected against the coastal flooding hazard at the 7.3mAOD platform height.

7 FLOOD PROTECTION DESCRIPTION

The flooding protection provided by the various sea defences proposed for the SZC site against both extreme sea level and extreme waves is summarised below:

- Eastern sea defence (see Figure 1): Protects against effects of design basis waves and can be adapted to provide protection against credible maximum climate change should this scenario be foreseen to occur.
- Northern barrier (see Figure 2): Not required within the design basis. Limits ingress of water into the Sizewell belts adjacent to SZC should credible maximum climate change occur.
- Southern barrier (see Figure 2): Not required within the design basis. Prevents ingress of water into the Sizewell belts adjacent to SZC should credible maximum climate change occur.

These sea defences work in conjunction with the platform height to ensure that an extreme high sea water event, combined with an extreme wave height event, will not result in a flooding of the SZC site such that any of the safety classified SSCs will become compromised and fail to operate as required.

7.1 Eastern sea defence

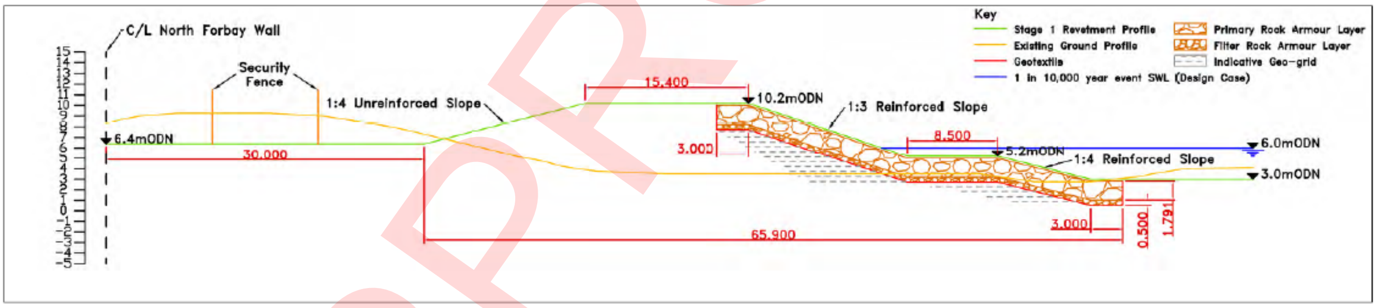


Figure 1: Eastern sea defence schematic for 10mAOD height sea defence

Note that the eastern sea defence is not a sheer face of concrete in immediate contact with the sea. From Figure 2 below we can see that the SZC site platform is located >>65m from the normal high spring tide line (~1.2mAOD) and ~40m from the 6mAOD extreme high seawater tide line. The sea defence is therefore built up as a reinforced slope to prevent mass wave overtopping in design basis conditions. It is not considered credible for seawater to directly penetrate through the sea defence causing a direct flood pathway through a breach within a single tidal cycle, although a generic failure probability for flood barriers has been applied in Section 8.3 for this sea defence in order to provide a frequency assessment of flooding causing a radiological consequence.

7.2 Northern and Southern Sea Defences

The locations of the potential Northern and Southern sea defences can be seen in Figure 2 below:

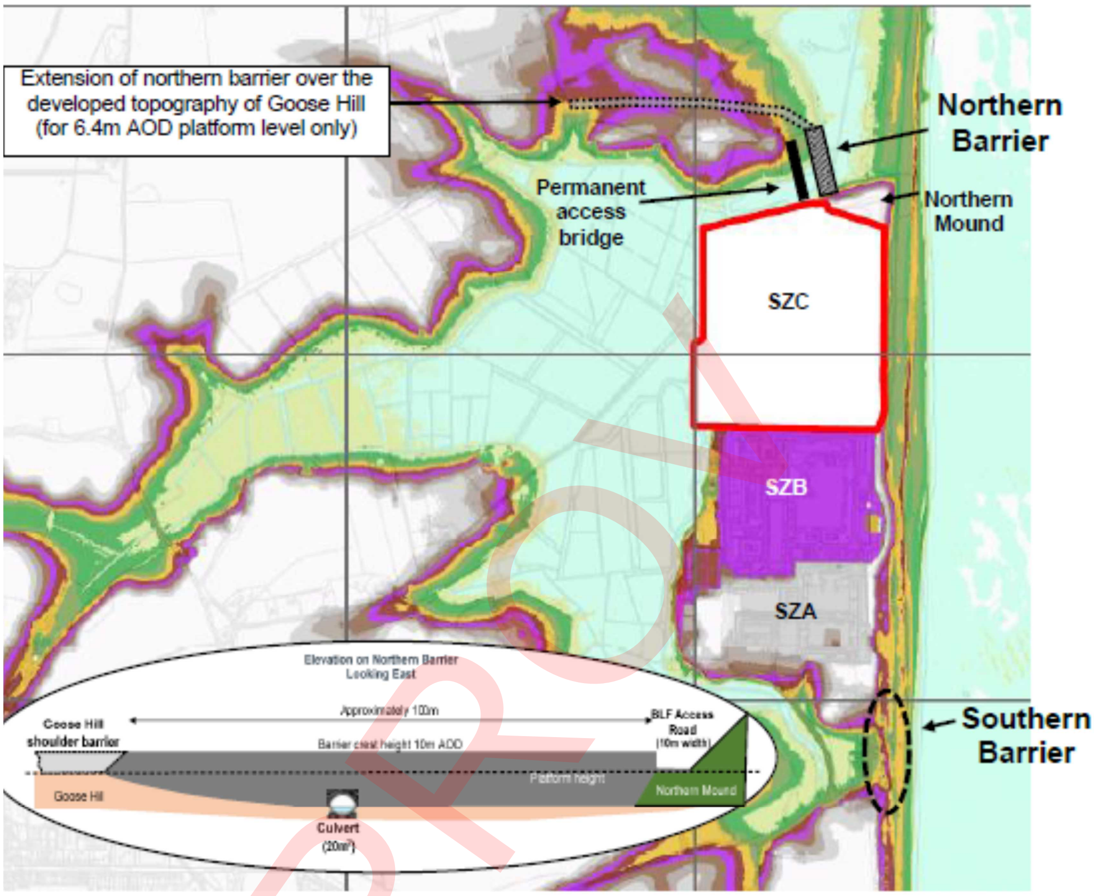


Figure 2: Proposed Northern and Southern flood barriers

The designs of the northern and southern flood barriers have not been executed. Figure 2 shows that the northern barrier could be designed with a crest height of 10mAOD to ensure protection against the credible maximum climate change sea level rise, which would elevate static water levels to a maximum of 8.32mAOD (see section 8.2). The northern flood barrier will have to be designed with a culvert to allow the discharge of water from the Sizewell belts into the sea, as currently occurs. This culvert would allow water into the Sizewell belts adjacent to the SZC site in an extreme high sea water event, but Table 12 of reference [11] shows that the water levels from this ingress would be less than the two platform height options at 6.45mAOD.

The southern flood barrier will also have to be designed to a similar height to the northern barrier to ensure protection against the credible maximum climate change sea level rise.

7.3 On-site flooding protection

The flooding protection systems described above relate to protection mechanisms off-site from SZC. There are also protection mechanisms on site which will prevent flooding from causing a radiological consequence even if there is water on the site platform. These protection mechanisms are:

- Surface water run-off system: this is a combination of the platform topography and channels formed on the platform which will ensure the rapid transit of any surface water away from the safety classified building and to a discharge point on the northern edge of the site into the small valley between Goose Hill and the SZC site (and land-side of the northern barrier).
- Each of the safety classified buildings will be constructed with a floor level 20cm above the site platform level[i] , thus providing a threshold into each building.
- Doors to the safety classified buildings will be designed to withstand a surface water depth of at least 0.3m with a leak rate of less than 10 litres per hour[ii].
- Each of the buildings will be designed with protection against an internal flooding case. This design ensures that safety classified components are not located in areas which would be prone to flooding (i.e. at low levels within rooms, etc.). This assessment of the internal flooding case can only occur at the D2 design state following production of the 3D model, so it is not possible at this time to make any specific claims on this protection mechanism.

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[i] Note that the buildings required to provide the post-Fukushima resilience enhancements will be equipped with a 30cm threshold above the platform level.

[ii] Currently being verified by CNEPE.

8 COST BENEFIT ANALYSIS

Using the results above it has been decided to undertake a cost benefit analysis of raising the platform height from 7.3mAOD to 8.8mAOD (i.e. the choice between Option 2 and Option 3). The costs of the platform height increase can be found within the Main Study Report [2], and an estimate has been made of the cost of the programme increase that would be caused by the increase in platform height (i.e. the costs from additional interest payments necessitated from increasing the time between commencing construction and beginning commercial operation).

8.1 Baseline costing assumptions

The main study report includes information on the additional construction and operational costs of increasing the platform height, these are shown below:

	Additional construction time	Additional use of material - platform	Additional use of material - barrier	Additional transportation - platform	Additional transportation - barrier	Additional plant activity - platform	Additional plant activity - barrier	Additional operating costs	Loss of generation revenue[iii]
Option 1	0	£ -	[redacted]	£ -	[redacted]	£ -	[redacted]	£ -	[redacted]
Option 2	2	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 3	5	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 4	9	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 5	18	[redacted]	£ -	[redacted]	£ -	[redacted]	£ -	[redacted]	[redacted]

Table 4: Additional costs per option

These additional capital expenditure (CAPEX) and operational expenditure (OPEX) costs have been simplified and inserted into the financial model for the SZC project alongside the additional construction time to provide an assessment of the costs to the project of implementing options 2 or 3. These costs are expressed in terms of Net Present Value (NPV) and are shown below:

[iii] This is loss of generation revenue caused by controlled reactor shutdowns to protect against the CWS pump trip surge hazard. Figures are taken from A4.2 of the main study report.

[redacted]

Table 5: Changes to Net Present Value per option

The cost difference between options 2 & 3 is therefore [redacted] The largest component of this cost to the Net Present Value is from the delayed revenue caused by the additional construction time. As a rule of thumb it has been assessed that each month of construction delay reduces the internal rate of return by three basis points.

8.2 Frequency of flooding event

To understand the benefits that could be accrued from the expenditure outlined above it is necessary to understand the frequency of an external flooding event leading to a radiological consequence (i.e. harm) and the precise radiological consequences.

Each of the selected platform heights is above the design basis extreme still seawater level[iv] (called the Maximum Design Flood Level in GDA PCSR (2012)) of 5.95mAOD. This design basis extreme still seawater level also includes the effects of reasonably foreseeable climate change up to the year 2110. The effects of credible maximum climate change (i.e. beyond the current design basis assumptions for climate change effects on sea water level) raise the extreme still seawater level to 8.32mAOD[v] in the year 2110.

The amount of sea level rise which would have to occur to cause a flood of the platform levels for the two remaining options (without any other protection), is shown below:

[iv] The design basis extreme sea water level is formed from the combination of extreme still sea water levels, maximum surge, and climate change.

[v] Including an additional allowance for growth in surge.

	Present day 10,000 year return period extreme sea level	Platform height Option 2	Platform height Option 3
Height (mAOD)	5.2[vi]	7.3	8.8
Sea level rise required to reach platform height (m)		2.1	3.6

Table 6: Sea level rise required to reach platform height

8.2.1 Sea level rise due to climate change

Using the cumulative probability function from the main study report (Figure 3 below) we can see that the probability of climate change causing sea level to rise above the two platform heights is:

	Platform height Option 2	Platform height Option 3
Platform Height (mAOD)	7.3	8.8
Sea level rise (m)	2.1	3.6
Cumulative probability (exceedance)	5%	Tends to 0%

Table 7: Probability of climate change causing sea level rise to exceed platform height

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[vi] No allowance for climate change is considered within this figure.

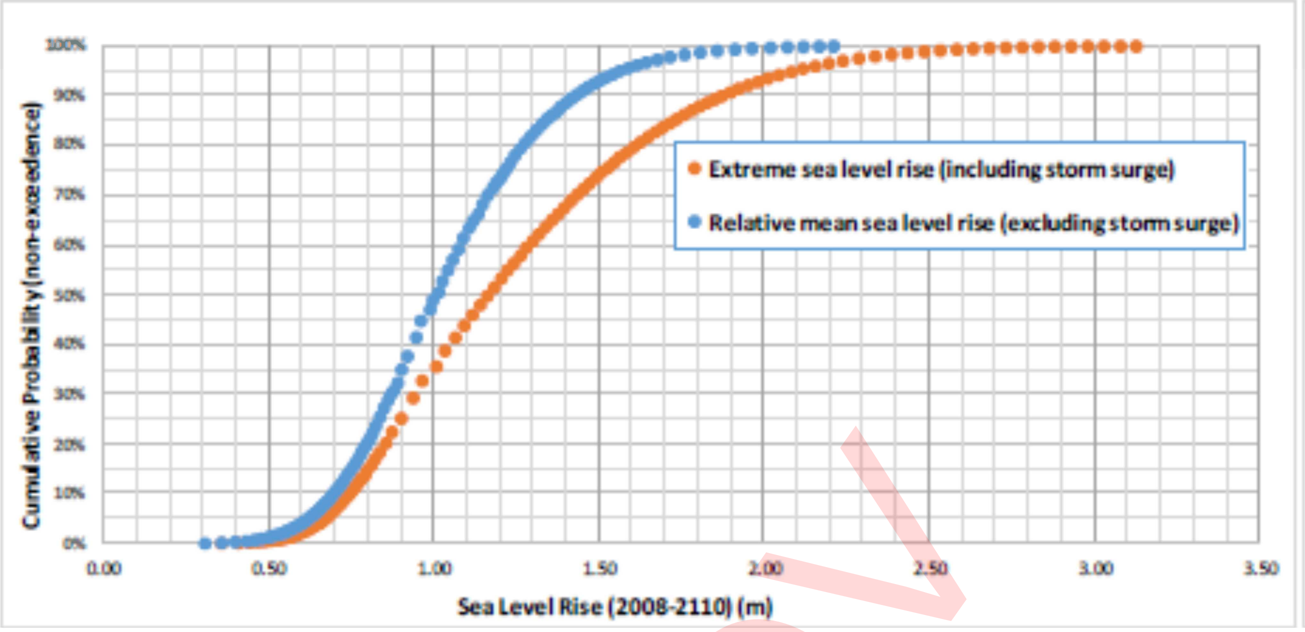

Figure 3: Cumulative Probability Functions

This 5% difference has to be understood as a 5% probability of climate change causing the sea level to exceed the platform height if it were coincident to a 10,000 year return period flooding event (without taking any account of flood barriers or sea defences).

8.2.2 Return frequency of platform height exceedance

Using the input data for the main ALARP study [Reference 2] it is possible to extrapolate the return frequency of the sea level rising to the various platform heights. Reference 9 shows the sea level heights at various frequencies, from this information it is possible to extrapolate the sea level heights at frequencies beyond those assessed in reference 9 (which ends its analysis at the 10,000 year return period).

Assessment of the available information within reference 9 shows that the sea level rises logarithmically with return period, with an addition made for each of the climate change scenarios. Specifically the equation is:

$$y = 0.3068\ln(x) + A$$

Where *A* is associated with the climate change scenario in question.

From this equation we can assess for potential cliff-edge effects beyond the design basis where flooding could occur due to extreme high sea water levels (ignoring the presence of the sea defences). At the 100,000 year return period the flooding levels are:

	Climate change scenario		
Return period (years)	Present Day	Reasonably Foreseeable	Credible Maximum
100,000	5.64mOD	6.53mOD	8.76mOD

Table 8: Flooding levels at 100,000 year return period by climate change scenario

Therefore, from Table 8, we can see that the platform heights of both 7.3mOD and 8.8mOD provide adequate protection against the 10^{-5} y^{-1} extreme high sea water event (assuming reasonably foreseeable climate change).

If we invert this equation we can establish the frequency of the extreme high sea water event where the static seawater level would exceed the platform height (and thus the site platform could be flooded if this event occurred and there were no sea defences). For this analysis it is necessary to assess both the platform heights of 7.3mOD and 8.8mOD and also the level where flooding of the buildings would occur (ignoring the presence of the sea defences), taking into account the 20cm threshold into each building, thus the heights of 7.5mOD and 9.0mOD are added to the analysis:

		Climate change scenario		
	Flooding height (mOD)	Present Day	Reasonably foreseeable	Credible Maximum
Frequency (/y) of flooding level	7.3	4.51E-08	8.21E-07	1.18E-03
	7.5	2.35E-08	4.28E-07	6.14E-04
	8.8	3.40E-10	6.18E-09	8.87E-06
	9	1.77E-10	3.22E-09	4.62E-06

Table 9: Frequency of flooding levels by climate change scenario

Some caution should be applied when analysing these results, the main source of uncertainty within these calculations is how the climate scenarios interact with the increasing return period of the flooding event in question, but these results do give a good indication of the order of magnitude of the flooding frequency.

Table 9 shows that, taking into account the threshold into the buildings and reasonably foreseeable climate change, a flooding event with the potential to cause a radiological consequence would occur with a frequency of ~4 x 10^{-7} y^{-1} (ignoring the presence of the sea defences and notwithstanding any further flood protection measures which exist inside each building) for a platform height of 7.3mOD. The equivalent frequency for the 8.8mOD platform height is ~3 x 10^{-9} y^{-1}.

8.3 Flooding pathways

From the information provided in Section 7 we can see that the methods for seawater transfer onto the site platform can be described as:

1. Wave overtopping of the eastern sea defence.
2. Breach of the eastern sea defence leading to additional wave overtopping onto the platform. In beyond design basis conditions the most probable location for this breach would be at the location of the marine off-loading facility interface with the site platform (should this design option be taken forward) or where wave energy is most focussed along the site frontage (just north of the off-loading facility). This event is not considered credible within the design basis of the SZC facility due to the width of the sea defences (65m at base, ~40m at the design basis high sea water level (5.95mOD)).
3. Failure of the northern or southern barriers during a beyond design basis extreme flooding event caused by credible maximum climate change. These barriers would be designed and built to withstand the credible maximum climate change, but consideration has to be given to random failure of the barriers to perform their safety functional requirements.[vii]

It should be noted that any method for transfer of seawater onto the site will be for a limited time during peak tidal periods combined with a surge which lasts for a small number of hours. These types of event are predictable, and routinely predicted, therefore there will be time to ensure that all site protection mechanisms are fully available and deployed.

Limited wave overtopping of the eastern sea defence is expected to be handled via the surface water run-off system, which is an area of low-lying platform forming a drainage channel immediately between the sea defence and the safety classified structures. This area of the platform will be designed to provide a water run-off route from the platform and into the Minsmere South Levels to the north of the site. The topography of the entire site will be designed to facilitate flow of surface water from all locations on the platform to this eastern run-off channel.

Examination of the relative locations of the safety classified buildings on the SZC site leads us to consider that, in the improbable event, the structures most likely to be affected by external flooding are the balance of plant structures of Unit 1 & Unit 2 (i.e. pumping station, outfall building, etc.). From the analysis above we can see that the following sequence of events will have to occur before these structures will experience any ingress of seawater:

[vii] Note that for the 7.3mAOD platform height there is a requirement to monitor the sea level rise from the start of operation as part of the periodic review of safety to determine the requirement to install the northern and southern barriers.

	Option 2 (7.3mAOD)	**Option 3 (8.8mAOD)**
Causes for water on platform	Beyond design basis wave overtopping of eastern sea defence. Breach of the eastern sea defence. Credible maximum climate change followed by breach of northern or southern barrier (5% probability of exceedance of platform height due to climate change).	Beyond design basis wave overtopping of eastern sea defence. Breach of the eastern sea defence.
Barrier to prevent consequence	Failure of surface water run-off system to discharge water off the site.	Failure of surface water run-off system to discharge water off the site.
Barrier to prevent consequence	Surface water will have to build up to a height of >20cm at the entrance to the safety classified buildings. Note that the doors at the entrances to the safety classified buildings are designed to withstand a surface water depth of at least 0.5m with a leak rate of less than 10 litres per hour[viii].	Surface water will have to build up to a height of >20cm at the entrance to the safety classified buildings. Note that the doors at the entrances to the safety classified buildings are designed to withstand a surface water depth of at least 0.5m with a leak rate of less than 10 litres per hour.

From the analysis in Section 8.2.2 we can see that the frequency where a consequence could occur for each of the options (assuming reasonably foreseeable climate change) is:

- Option 2: $4.28 \times 10^{-7}\ y^{-1}$
- Option 3: $3.22 \times 10^{-9}\ y^{-1}$

To understand the frequency of flooding occurring which potentially leads to a radiological consequence we need to combine these frequencies with a postulated frequency of the failure of the sea barriers[ix]. For option 2 the site platform can be flooded if any of the eastern, northern or southern barriers is breached. For option 3 the site platform can only

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[viii] Currently being verified by CNEPE.

[ix] The frequency of flooding due to overtopping is not calculated here because the breach is considered to be a bounding event in terms of consequence.

be flooded following a breach of the eastern sea defences[x]. The equation to calculate the flooding frequency from this scenario is:

$$f = n \times f_f \times P_b$$

Where:

f = frequency of flooding event leading to a radiological consequence

n = the number of barriers which could be breached

f_f = frequency of flooding event (from Table 9)

Pb = Probability of failure on demand of the barrier (The probability of failure on demand of a flooding barrier has been taken from R&D work undertaken by the Environment Agency [10], which shows a pfd of 6.67 x 10^{-3}).

Therefore for the two options the frequency of a flooding event leading to a radiological consequence is:

Option 2: f = 3 x $4.28\text{x}10^{-7}$ x $6.67\text{x}10^{-3}$ = $8.56\text{x}10^{-9}$ y^{-1}.

Option 3: f = 1 x $3.22\text{x}10^{-9}$ x $6.67\text{x}10^{-3}$ = $2.15\text{x}10^{-11}$ y^{-1}.

Note that this frequency does not take any account of the protection mechanism provided by the surface water run-off system or the leak tightness of the doors, and therefore is very much a bounding case calculation.

8.3.1 Additional mitigation measures

Water ingress into the structures will not immediately result in a radiological consequence, the water will have to build up to a point where the water causes short-circuits in the electrical circuits, which in turn leads to the failure of safety classified systems. All four trains of the SEC system (i.e. all four pumps) would have to be affected by this flooding, as well as the two pumps for the SRU system. Following this Total Loss of Ultimate Heat Sink event (TLUHS) there is still potential cooling water capacity available through the use of the SEG system, which has three safety features outlined within chapter 23 of HPC PCSR3 [4]:

1. [SEG-SF-01] Distribution of water to replenish the ASG emergency feedwater tank
2. [SEG-SF-02] Distribution of make-up water to the HK spent fuel pool
3. [SEG-SF-03] Supply of water to EVU mobile thermally driven pump

The flooding depth where the loss of the SEC and SRU pumps occurs will have to be assessed following the production of the D2 design state model for the Pumping Station. But it is not considered feasible that all the safety classified systems required to enable a safe shutdown of the plant will be rendered inoperable by a small intake of water into the balance of plant buildings.

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[x] As discussed earlier in Section 8.3, this is not really considered credible due to the width of the eastern sea defence, but an assessment of breach frequency has been made here for the sake of comparison of the two options, and because an incredibility of failure argument is not proposed for the sea defences.

8.3.2 Conclusion of flooding frequency analysis for the flooding pathways

In conclusion it can be seen that an external flooding event causing a radiological consequence will occur with a frequency of <1 x 10^{-8} per year for a platform height of 7.3mOD, and that there are multiple physical barriers in place to prevent an external flooding event from causing radiological consequences.

8.4 Radiological consequences

8.4.1 Introduction

This section will present the radiological consequences from a flooding event occurring which causes a total loss of ultimate heat sink due to the assumed failure of all pumps (and hence cooling water capacity) within the pumping station. The protection of the HPC site outlined within this report shows that the flooding of the site can only occur in very low frequency scenarios (i.e. non-credible scenarios) where the sea water overtops the sea defences, or where the sea defence is breached. The nature of these scenarios is such that the platform height is an irrelevant variable, i.e. the scenario will cause a total loss of ultimate heat sink to occur at all platform heights. Therefore the factor of the radiological consequences should not be considered further when assessing which platform height reduces risks so far as is reasonably practicable.

8.4.2 Assessment of radiological consequences

Notwithstanding the implausibility of such an event, it is possible to estimate the worst case consequences from a massive flooding of the balance of plant structures using the results from the Hinkley Point C study “Identification of systems to be considered in the hazard studies and consequences when lost – CI/BOP scope” [Reference 7]. This shows that the following safety functions may potentially be lost:

1. Cooling of the fuel building pond
2. Cooling of the RIS/RA trains in the RHR mode
3. Supply to the primary pump thermal barrier cooling lines
4. Cooling of the DEL

The following events under these safety functions have been assessed to understand the radiological consequence, the results from this assessment are summarised below:

Function	Event	Reactor state	Radiological consequences from Ref [7]	Dose for CBA	Assumptions
Cooling of the fuel building pond	Loss of SEC1&2, and SRU1 or loss of >2 SEC trains but SRU and 1 JAC train available	A to D	Not zero, but below authorised limits.	<50mSv	DEC-B authorised dose limit for evacuation
	Loss of >3 SEC trains and 1 or 2 SRU train	A to D	Not estimated, but not zero.	<0.1mSv	JAC assumed to be operational, thus fuel pool boiling may occur, but with no clad failure. (see Table 4 of Ref [8]).
	Loss SEC 1 & 3 or 2 & 4	E and F	Not zero, but below authorised limits.	<50mSv	DEC-B authorised dose limit for evacuation
	Loss of >2 SEC trains but SRU and 1 JAC train available	E and F	Not zero, but below authorised limits.	<50mSv	DEC-B authorised dose limit for evacuation
	Loss of >2 SEC trains and SRU system or/and loss of JAC system	E and F	Not estimated	<1Sv	See explanation below
Cooling of the RIS/RA trains in the RHR mode	Loss of >2 SEC trains but SRU and 1 JAC train available	C to E	PCC-4 if scenario duration <100h	5.50E-03	Worst case PCC-4 event
	Loss of >2 SEC trains and SRU system or/and loss of JAC system	C to E	Not estimated	<1Sv	See explanation below

Function	Event	Reactor state	Radiological consequences from Ref [7]	Dose for CBA	Assumptions
Supply the primary pump thermal barrier cooling lines	Loss of >2 SEC trains	A to C	PCC-3	1.40E-03	Worst case PCC-3 event
Cooling of the DEL	Loss of the SEC trains 2 and/or 3	A	PCC-2	2.50E-05	Worst case PCC-2 event

Note: The radioactive doses for PCC events are taken from [3] HPC PCSR3 sub-chapter 15.4.1 Table 4 and 15.4.2.2.2. The doses shown are the worst cases for the scale of event identified (e.g. PCC-2, PCC-4, etc.)

The table above shows that there are two events for which reference [7] does not provide an estimate of the radiological consequences; these events are linked to the functions of:

- Loss of cooling to the fuel building pond
- Loss of cooling of the RIS/RA trains in RHR mode

The event leading to these losses of functions therefore needs to be assessed to evaluate the potential radiological consequences. The description of the event is imprecise and could be considered to describe two events, therefore it is interpreted as:

Event 1	Event 2
• Loss of >2 SEC trains and SRU system; OR • Loss of >2 SEC trains and loss of JAC system.	• Loss of >2 SEC trains and SRU system and JAC system.

For our fault scenarios it is assumed that all SEC trains are lost (i.e. >>2) and the SRU systems. So given the imprecision of the event language we are left with two specific events to assess for each of the loss of safety function scenarios:

Specific Event 1	**Specific Event 2**
Loss of all SEC and SRU trains; JAC remains.	Loss of all SEC and SRU trains; loss of JAC system.

The protection mechanisms and fault sequence for Specific Event 1 and the safety function of loss of cooling to the fuel building pond can be summarised as:

- JAC is assumed to be operating.
- Spent fuel pool make-up is therefore sustained from the JAC/ASG systems.
- Fuel elements should not become uncovered or damaged.
- Whilst not deemed reasonably foreseeable to have a boiling event, it is noted that the dose from such an event is documented in sub-chapter 16.1, section 3, table 4 [reference 8]:
  - Fuel Building pool boiling, no clad failure, no filtration: <0.1 mSv

The protection mechanisms and fault sequence for Specific Event 2 and the safety function of loss of cooling to the fuel building pond can be summarised as:

- JAC is not operating.
- Fuel pool boiling will occur.
- Damage to multiple fuel assemblies may occur.
- In PSA terms this event is bounded by the LUHS event (doses for this event are shown below).

The protection mechanisms and fault sequence for Specific Event 1 and the safety function of loss of cooling of the RIS/RA trains in RHR mode can be summarised as:

- JAC is assumed to be operating.
- JAC/ASG will provide cooling to NSSS in all plant states except D & E.
- Therefore no core damage should occur.
- Therefore there are zero radiological consequences.
- Time at risk argument is made for states D & E – the plant only operates in these states for 165 hours per year. Doses for these states would be bounded by LUHS (doses for this event are shown below).

The protection mechanisms and fault sequence for Specific Event 2 and the safety function of loss of cooling of the RIS/RA trains in RHR mode can be summarised as:

- JAC is not operating.
- In PSA terms this event can be considered to be bounded by the specific LUHS event where core damage occurs and the EVU sprays are unavailable for reduction of the source term.
- Doses from this event are considered to contribute to multiple release categories, but of most importance (in terms of off-site risk) are RC503 & RC504. RC203 & RC205 are also considered to be important in terms of radiological consequence.
- All these Release Categories are associated with Dose Band 5 events.
- Maximum dose of >1 Sv associated with Dose Band 5 events.
- It should be noted that the frequency of the postulated event is similar in frequency to RC504 (1.35 x 10^{-7}). Therefore these events are considered comparable.

Given the low frequency of each of these events and losses of safety functions (<10^{-8} per year) these predicted doses (of up to >1Sv) are considered acceptable when compared to the frequency-dose targets in the NSDAPs (Section 6.8, Table 1).

8.4.3 Radiological consequences conclusion

In conclusion, It is not possible to provide consequences for the differing platform height options, the radiological consequences shown above are based on the initiation of a LUHS-type event due to simultaneous flooding of all four divisions of the pumping station, and in the case of JAC failure, flooding of the HOJ. Due to the very infrequent nature of the postulated event the consequences are not platform height dependent (and would occur even for a “dry site”).

9 BOW-TIE DRAWINGS

Bow-tie drawings have been developed for both options showing the barriers for protection and mitigation against the coastal flooding hazard at the two platform heights. These drawings are shown in the appendix.

10 BEST ESTIMATE COMPARISON

The assessment of the platform height presented within this report and the Main ALARP study report [2] was undertaken using conservative assumptions in line with expectations within the NSDAPs [5] and the ONR’s Safety Assessment Principles. An assessment [6] has been undertaken to understand how the use of best estimate assumptions would alter the platform height that could be considered “dry” under the criteria laid out in Section 2. The results of this assessment are presented below:

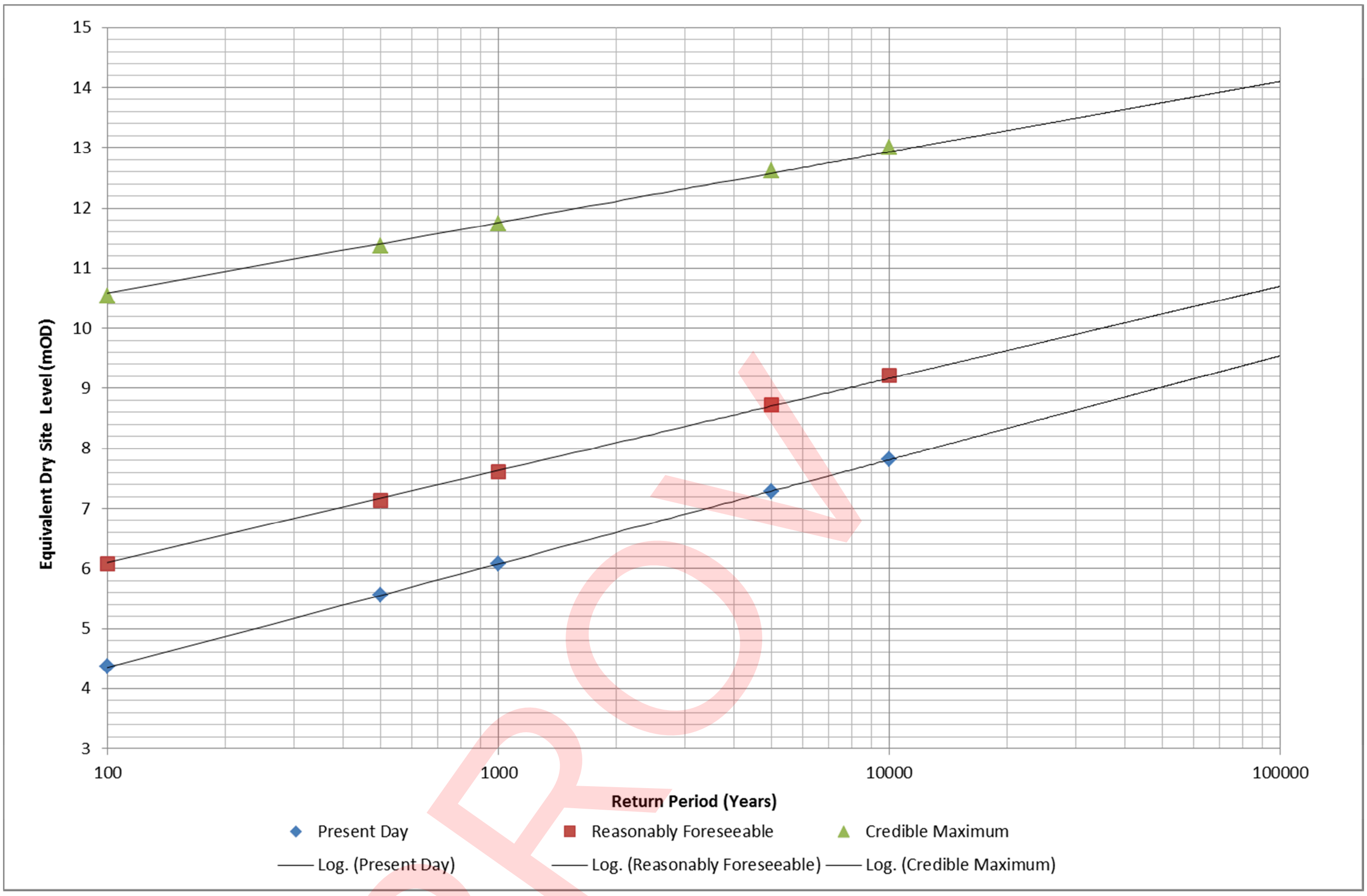


Figure 4: Best estimate dry site frequency assessment

It has to be noted that the results in Figure 4 do not contain any margin, so should not be considered as acceptable for the setting of a platform height, even on a best estimate basis. Additionally the results are subject to large variation based on the geometry of the coastal plain leading up to the site, and should be treated with appropriate caution. The results shown assume the same geometry (1:3 slope) as for the current design, as this is considered to be the best estimate assumption.

Nevertheless, these results show that, under a best estimate assessment, the platform heights options of 7.3mAOD and 8.8mAOD would be exceeded (assuming no flood barriers) on the following return periods:

Platform height	Return period of exceedance (Present day scenario)	Return period of exceedance (Reasonably foreseeable climate change)
7.3mAOD	5,000 years	600 years

8.8mAOD	40,000 years	6,000 years

Table 10: Best estimate dry site frequency analysis

These results show that, under best estimate conditions, a platform height of 7.3mAOD would provide adequate protection against all forms of coastal flooding to a return period of 5,000 years (in present day conditions). Combined with the coastal flooding protection structures outlined in Section 8.3 the assessment above shows that the SZC site will be adequately defended against the coastal flooding hazard at either of the platform options of 7.3mAOD or 8.8mAOD.

Note that care should be taken if attempting to compare the results presented above with the results in Section 8.2; the results presented in this section are for the best estimate dry site analysis, whereas the results in section 8.2 are the 95th percentile confidence level analysis for static water levels, and also include incorporation of the 20cm threshold to the buildings in their assessment.

11 RELIABILITY / MAINTENANCE OF FLOOD DEFENCE BARRIERS

The reliability and maintenance requirements of the flood barriers (eastern, northern & southern) have been discussed within this report, this section summarises the previously provided information.

The eastern sea defences are made up of rock armour and back-fill materials to form a solid defence (see Figure 1). These defences are approximately 65m wide, with the sea water at the normal high spring tide mark not actually touching the sea defence. At the 5.95mOD extreme sea level the sea defences are ~40m wide. Therefore any breach of the sea defence leading to a gross flooding of the platform would have to penetrate a very wide sea defence. Breaches could occur at higher heights on the sea defence, but at its narrowest point the defence is still 3m wide and any height over 5.95mOD can only be impacted by a short term wave action at the peak of the tidal cycle within the design basis (and hence is time limited to ~4-6 hours maximum).

The northern and southern sea defences are man-made structures, with predicted crest heights of 10mOD. The northern barrier will contain a culvert to allow discharge of water from the Sizewell belts to the sea. These northern and southern barriers are not required at the beginning of life and will only be installed should sea level rise above that expected within the design basis be observed. So these barriers must be considered as adaptability measures.

The sea defences at SZC will be subjected to the Sizewell shoreline management plan to ensure that appropriate maintenance is undertaken regularly, and this will ensure that any potential areas for breach are identified and repaired.

Therefore, whilst no incredibility of failure arguments are made for the SZC sea defence, it is noted that the sea defences are inherently resistant to potential breaches, and are regularly inspected and maintained to ensure that weaknesses are identified and repaired. For the purposes of this assessment a failure rate has been assigned to these barriers in Section 8.3, which has been derived from generic data for flood barriers. By assigning a failure rate it is possible to make a more informed conclusion on the vulnerability of the SZC site to radiological consequences occurring following a coastal flooding event.

12 CONCLUSION

In conclusion, this paper provides additional assessment to aid in the selection of the platform height for the SZC nuclear power plant. The main study report for the ALARP assessment has already shown that the 6.4mAOD, 10.5mAOD & 15mAOD platform height options are not ALARP and therefore this paper provides additional information to aid in the selection between the 7.3mAOD & 8.8mAOD options.

For the three areas related to the platform height, and which show clear qualitative differences between the 7.3mAOD and 8.8mAOD heights that are not just related to cost, a summary qualitative assessment has been undertaken. This assessment shows that whilst there are some clear advantages to the 8.8mAOD platform height there are non-novel engineering and design solutions available to provide suitable mitigation of the risks, and that the other flooding protection measures shown in Sections 8.3 & 9 ensure that the site is suitably protected against the coastal flooding hazard at the 7.3mAOD platform height.

This paper has shown that the construction costs of increasing the platform height from 7.3mAOD to 8.8mAOD is in the order of [redacted]. Furthermore this paper has shown that the frequency of water ingress into the safety classified buildings causing radiological consequences is extremely low ($<1\times10^{-8}$ y^{-1}) and that the difference between the two options can be simplified down to the 5% difference in the probability of climate change causing a sea level increase which would cause an exceedance of the platform height (without taking any account of flood barriers or sea defences) if the increase were coincident with a 10,000 year return period extreme sea water event.

This paper shows, through the Bowtie diagrams that there are multiple barriers which prevent coastal flooding causing an ingress into the classified structures and then multiple barriers which prevent this flooding causing a release of radioactive material. Finally the consequences of the flooding event occurring have been assessed and it is shown that these doses are bounded by doses currently assessed within the conventional fault sequences for the plant, and are acceptable when compared to the frequency-dose targets contained in the NSDAPs.

Given the low frequency of the flooding event within the design basis parameters it is considered grossly disproportionate to spend [redacted] to increase the platform level from 7.3mAOD to 8.8mAOD.

The selection of the 7.3mAOD height meets the requirements of the relevant good practice identified in Section 3 through the provision of multiple barriers to prevent sea water ingress onto the site platform. The safety management arrangements for these barriers will be further developed within the PCSR for the site. Therefore it is concluded that the site platform should be set at a height of 7.3mAOD.

12.1 Comparison to Hinkley Point C

It is interesting to compare this platform height decision of 7.3mOD with the platform height for the HPC site.

12.1.1 Hinkley Point C

At HPC the site naturally sits on top of a small cliff, and therefore it was decided to set the platform height at a height where protection could be provided against the maximum design flood level and against wave effects. Therefore the following parameters were taken into account when setting the platform level:

- Extreme still sea water level (10,000 year Return Period)
- Climate change (reasonably foreseeable)
- Surge
- Extreme waves heights (1/2 height of 10,000 year Return Period nearshore waves)
- Tsunami was assessed to be below the height of the extreme wave height (from DEFRA tsunami report on Canary Island slip, and looking at the Lisbon earthquake). A detailed tsunami study was also performed which confirmed that the platform height was adequate.
- Seiche (height considered to be very low)

The latest assessment [12] using these parameters shows a design basis height of 12.92mOD (called the Reference High Sea Level). A platform height of 14mOD was chosen to provide an additional 1.08m of margin above this Reference High Sea Level and 4.27m above the Maximum Design Flood Level. Due to the height of the platform there are no nuclear safety claims made on the sea wall and this has been installed to provide protection against coastal erosion effects. Recent physical modelling studies show that an additional sea defence wall (the ‘set-back wall’) is not required to protect against the design basis coastal flooding hazard, but may be required near the end of the HPC lifetime, should credible maximum climate change occur.

12.1.2 Sizewell C

As discussed earlier in this report, due to the natural lie of the land at Sizewell it was originally decided to locate the site behind a man-made sea defence, similar to that used for the SZB power station site, and to set the platform height at a height above the maximum design flood level (as per the GDA requirements). The natural sea defences of the beach are being artificially increased to provide protection against extreme waves. Additional sea defences to the north and south of the site are also planned, should climate change cause a sea level rise in excess of that currently foreseen.

Therefore the platform height has been set according to the following parameters:

- Extreme still sea water level (10,000 year Return Period)
- Climate change (reasonably foreseeable)
- Surge

In comparison to HPC:

- Extreme waves are considered to be protected against using the sea defences.
- Tsunami was assessed to be below the height of the extreme wave height (from DEFRA tsunami report on Canary Island slip, and looking at the Lisbon earthquake). A detailed tsunami study has being undertaken [13] to help inform the sea defence design. This study demonstrates that the threat from high amplitude meteorite impact tsunamis at the SZC site can be discounted on low frequency grounds (frequency of impact $<10^{-8}$ p.a.). All other tsunami sources are found not to be capable of generating waves at the SZC site of an amplitude that could exceed the coastal flooding run-up protection (assuming a 7.3m AOD platform level and 10m AOD sea protection embankment) or expose the intake heads through drawdown.
- Seiche is not considered a relevant parameter for Sizewell because the North Sea is too big for standing waves.

The design basis for SZC was calculated to be 5.95mOD (based on the definition of the Maximum Design Flood Level). The platform height has been set at 7.3mOD to provide an additional 1.35m of margin above this design basis.

12.1.3 The conclusion of comparison between the platform heights of HPC and SZC

Both of the SZC and HPC sites have been designed with a platform level that is in accordance with the GDA requirement to be higher than the Maximum Design Flood Level. The HPC site is naturally at a high elevation and this has been retained in order to provide the protection against extreme waves. The SZC site is naturally at a low elevation, this elevation is being increased to provide protection against sea water levels, and the natural sea defences of the beach are being artificially increased to provide protection against extreme waves. Additional sea defences to the north and south of the SZC site are also being planned, should climate change cause a sea level rise in excess of that currently foreseen.

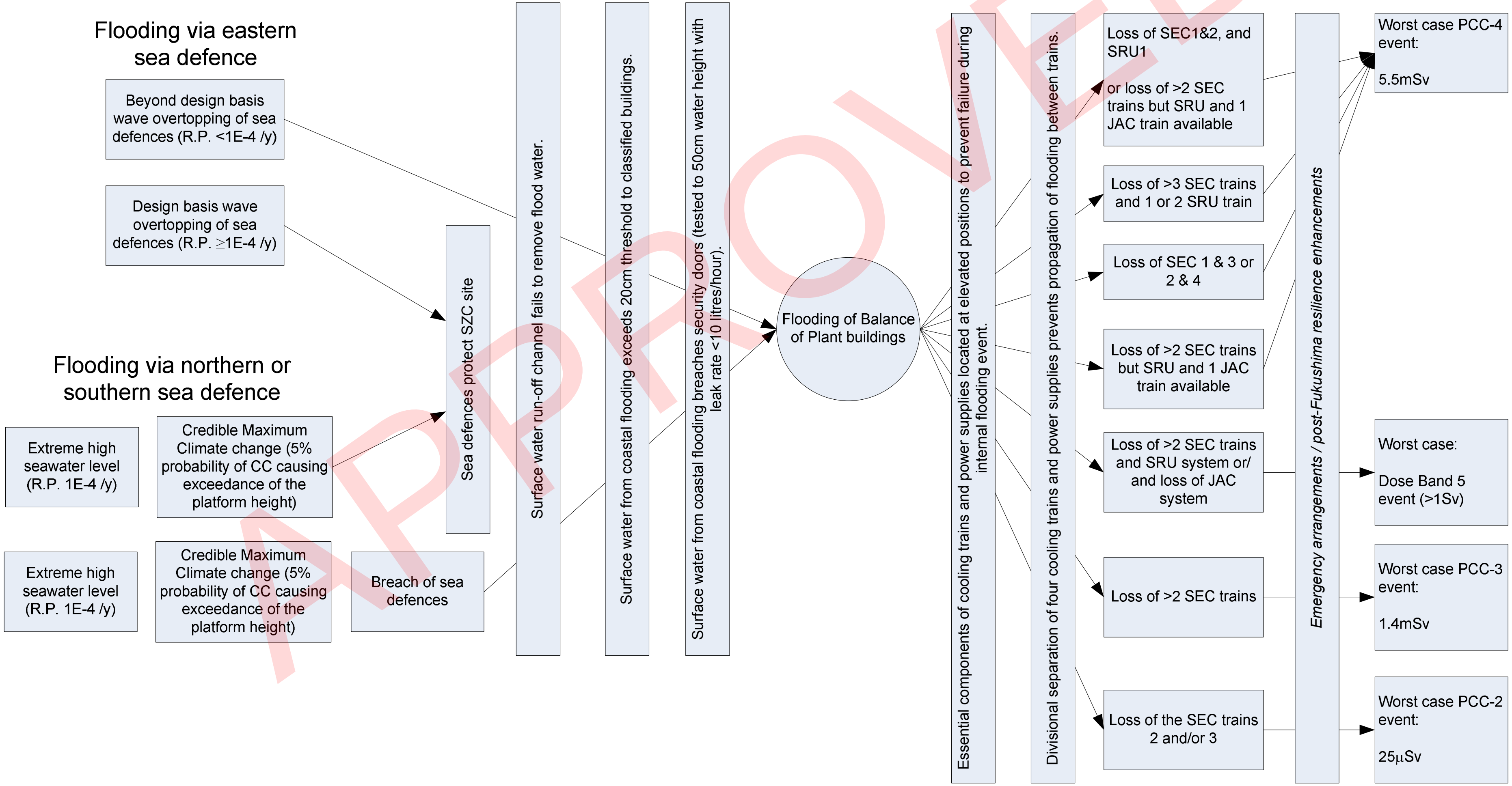
In terms of the parameters of coastal flooding and their defence, the following table provides an outline summary and comparison of HPC & SZC:

Parameter	Protection mechanism at HPC	Protection mechanism at SZC
Extreme still sea water level (10,000 year Return Period)	Platform height	Platform height
Climate change (reasonably foreseeable)	Platform height	Platform height
Surge	Platform height	Platform height
Extreme waves	Platform height	Sea defences
Tsunami	Platform height	Platform height with negligible claim on Sea defences
Seiche	Platform height	N/A

Table 11: Comparison of coastal flooding protection at HPC & SZC

APPENDIX A BOW TIE DRAWINGS

Option 2: 7.3mOD platform height



Flooding via eastern sea defence

Beyond design basis wave overtopping of sea defences (R.P. <1E-4 /y)

Design basis wave overtopping of sea defences (R.P. ≥1E-4 /y)

Flooding via northern or southern sea defence

Extreme high seawater level (R.P. 1E-4 /y)

Credible Maximum Climate change (5% probability of CC causing exceedance of the platform height)

Extreme high seawater level (R.P. 1E-4 /y)

Credible Maximum Climate change (5% probability of CC causing exceedance of the platform height)

Breach of sea defences

Sea defences protect SZC site

Surface water run-off channel fails to remove flood water.

Surface water from coastal flooding exceeds 20cm threshold to classified buildings.

Surface water from coastal flooding breaches security doors (tested to 50cm water height with leak rate <10 litres/hour).

Flooding of Balance of Plant buildings

Essential components of cooling trains and power supplies located at elevated positions to prevent failure during internal flooding event.

Divisional separation of four cooling trains and power supplies prevents propagation of flooding between trains.

Loss of SEC1&2, and SRU1

or loss of >2 SEC trains but SRU and 1 JAC train available

Loss of >3 SEC trains and 1 or 2 SRU train

Loss of SEC 1 & 3 or 2 & 4

Loss of >2 SEC trains but SRU and 1 JAC train available

Loss of >2 SEC trains and SRU system or/ and loss of JAC system

Loss of >2 SEC trains

Loss of the SEC trains 2 and/or 3

Emergency arrangements / post-Fukushima resilience enhancements

Worst case PCC-4 event:

5.5mSv

Worst case:

Dose Band 5 event (>1Sv)

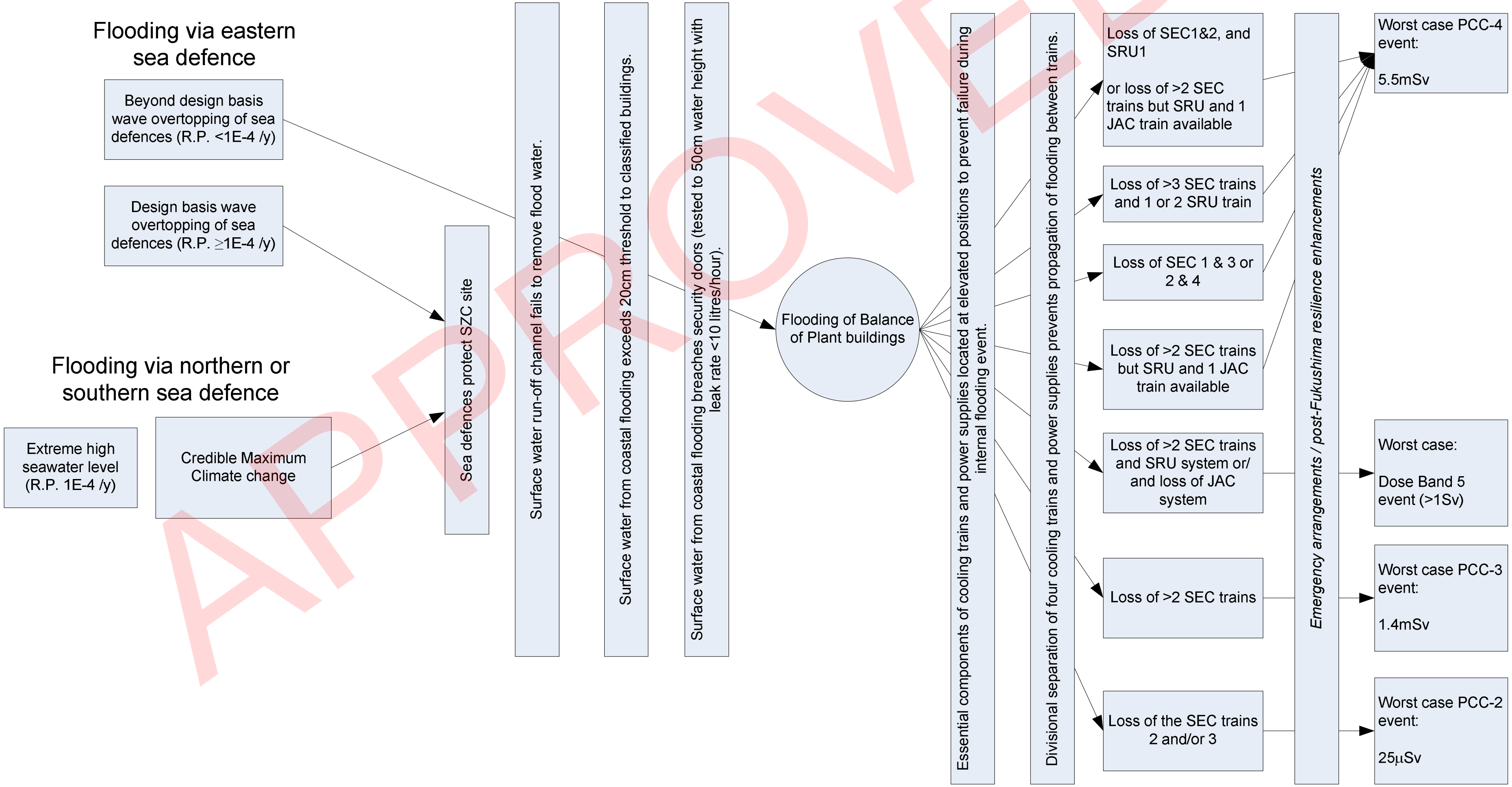
Worst case PCC-3 event:

1.4mSv

Worst case PCC-2 event:

25µSv

Option 3: 8.8mOD platform height



Flooding via eastern sea defence

Beyond design basis wave overtopping of sea defences (R.P. <1E-4 /y)

Design basis wave overtopping of sea defences (R.P. ≥1E-4 /y)

Flooding via northern or southern sea defence

Extreme high seawater level (R.P. 1E-4 /y)

Credible Maximum Climate change

Sea defences protect SZC site

Surface water run-off channel fails to remove flood water.

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Loss of >2 SEC trains and SRU system or/ and loss of JAC system

Loss of >2 SEC trains

Loss of the SEC trains 2 and/or 3

Emergency arrangements / post-Fukushima resilience enhancements

Worst case PCC-4 event:

5.5mSv

Worst case:

Dose Band 5 event (>1Sv)

Worst case PCC-3 event:

1.4mSv

Worst case PCC-2 event:

25µSv