



Nuclear Generation Limited

Safety and Assurance Division

REPPIR Report of Assessment for Sizewell B

Originated by:	Phil Perry Emergency Preparedness Engineer	Date: March 2017
Reviewed by:	Josh Tarling Emergency Planning Group	Date: April 2017
Approved by:	Paul Morton Station Director	Date: April 2017

Revision	Amendment	Impact level	Date
007	3 Year review of HIRE. Inclusion of Dry Fuel Store AR 1030213, EC 338898	Minor	21/04/2017

© 2017 Published in the United Kingdom by EDF Energy Nuclear Generation Ltd.
All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, including photocopying and recording, without the written permission of the copyright holder, EDF Energy Nuclear Generation Ltd, application for which should be addressed to the publisher. Such written permission must also be obtained before any part of this publication is stored in a retrieval system of any nature. Requests for copies of this document should be referred to Sizewell Document Centre, EDF Energy Nuclear Generation Ltd, Sizewell B Power Station, Leiston, IP16 4UR (Tel: 01728 653233) The electronic copy is the current issue and printing renders this document uncontrolled. Controlled copy-holders will continue to receive updates as usual.

LIMITATION OF LIABILITY – Whilst EDF Energy Nuclear Generation Ltd believes that the information given in this document is correct at the date of publication it does not guarantee that this is so, nor that the information is suitable for any particular purpose. Users must therefore satisfy themselves as to the suitability of the information for the purpose for which they require it and must make all checks they deem necessary to verify the accuracy thereof. EDF Energy Nuclear Generation Ltd shall not be liable for any loss or damage (except for death or personal injury caused by negligence) arising from any use to which the information is put.

Verification Certificate

Document Title:	Radiation (Emergency Preparedness and Public Information) Regulations: Report of Assessment for Sizewell B Power Station
Author:	Phil Perry
Section / Group:	Quality Management Group
Electronically approved for issue	
Date:	March 2017
Verifiers:	
Principal Verifier:	Josh Tarling
Section / Group:	Emergency Planning Group, HS&E
Electronically approved for issue	
Date:	April 2017
Procedure used:	
Verification Statement <i>{if required outline the extent of verification here and use a separate page if necessary}</i> :	
Approver:	Paul Morton
Section/Group:	Station Director
Electronically approved for issue	
Date:	April 2017

Sizewell B Power Station**Document Number: SZB/TZR/015****Radiation (Emergency Preparedness and Public Information) Regulations:
Report of Assessment for Sizewell B Power Station****Register of Review and Amendment**

Issue No.	Performed by	Amendment/Review and Brief Reason
001		Revision cancelled
002		Updated
003		Revision cancelled
004		Updated for three-yearly review.
005		Revision cancelled
006	Phil Perry	Change of title to RoA. Incorporation of significant additional information. Alignment of contents with REPIR Schedule 5 to facilitate assessment. AR 885329
007	Phil Perry	3 year review of HIRE. Inclusion of Dry Fuel Store following update to Station Safety Report (EC338898 SS1 rev 2)

Contents

1	Purpose.....	8
2	Background.....	8
3	Schedule 5 Requirements.....	11
3.1	a) the name and address of the operator.....	11
Figure 1:	Plan of Sizewell B Site.....	16
Figure 2:	Map of the Environs of Sizewell B.....	17
Figure 3:	Diagram of Primary Circuit.....	19
Figure 4:	Diagram of Fuel Route Showing Fuel Storage Pond.....	20
4	Definitions.....	29
5	References.....	31
Appendix A	Additional Information on the Assessment of the Reference Accident for Sizewell B	32
Appendix B	An explanation of how the design basis is defined for Sizewell B through application of the UK approach to licensing.....	45
Appendix C-E	Section 3.14 - Redacted Information.....	49

Sizewell B Power Station

Radiation (Emergency Preparedness and Public Information) Regulations: Report of Assessment for Sizewell B Power Station

Preface

The nuclear industry in the UK has a long history of safe operation. The safety standards used in the design, construction, operation and maintenance of nuclear installations reduce to a very low level the risk of accidents that could have a consequence for the general public. Nonetheless, prudence requires the preparation of plans for dealing with such events. The Nuclear Installations Act, controls the activities on civil nuclear installations in the UK, and requires, under the license granted, that adequate emergency arrangements are in place.

The UK, as a member state of the EU, introduces legislation to implement Council Directives. To implement the articles on intervention in case of radiation emergency in Council Directive 96/29/Euratom on the basic Safety Standards Directive for the protection of the health of workers and the general public against the dangers arising from ionising radiation (the BSS96 Directive) the Radiation (Emergency Preparedness and Public Information) REPPIR 2001 and Ionising Radiation Regulations 1999 have been made under the HSWA 1974 (except REPPIR Regulation 17 which is made under the European Communities Act 1972).

Emergency Preparedness for accidents that may affect members of the public involves many external organisations, such as the local authorities and emergency services. The REPPIR regulations have been developed alongside two other pieces of legislation, the Control of Major Accident Hazards Regulations and the Pipeline Safety Regulations. It is considered beneficial to responding organisations if legislative requirements for emergency preparedness, which affect them, are similar for different industries. Also some operators are active in more than one of these major hazard sectors.

The introduction of REPPIR did not replace the requirements of the Nuclear Installations Act, but consolidated and enhanced the approaches taken to emergency planning for accidents at Sizewell B Power Station.

The principal hazard to the public from most accidents at nuclear power stations will be the release of materials that emit ionising radiation. The risk to people and the health effects from exposure to ionising radiation have been the subject of intensive study and research for many decades. The results of this work have been used by the International Commission on Radiological Protection [ICRP] to make recommendations on the principles to be adopted for protection against ionising radiation and a system of dose limitation, both for people exposed to radiation at work and for members of the public in the event of accidents.

Everyone is exposed continuously to natural sources of radiation. Many people receive additional low doses of radiation from artificial sources such as medical X-rays. The principle harmful effect of small doses of radiation is to increase the probability of cancer induction in later years, but very high doses can lead to other serious illnesses in the short term. Although a direct relationship between radiation dose and harmful effects has been observed only in people exposed to relatively high doses of radiation, for the purposes of radiological protection it is assumed that any dose of radiation, however small, carries with it some risk to health. In making its recommendation on annual limits of radiation dose to workers and members of the public, the ICRP has used this cautious assumption.

Public Health England - Centre for Radiation, Chemical and Environmental Hazards [PHE-CRCE], an independent statutory body within the UK, has specified Emergency Reference Levels [ERL] using the ICRP recommendations on intervention. ERLs are levels of radiation dose to the public which would justify introducing a given countermeasure to stop people receiving such a radiation dose. The application of the various countermeasures - evacuation, sheltering and the issue of stable iodine tablets and the control of foodstuffs and water supplies - are based on these ERLs. The PHE-CRCE has balanced the risk from the potential radiation exposures and those that may be associated with the implementation of any of these countermeasures.

In the event of an emergency, current legislation requires the following five aspects to be included in the emergency response:

- a) The control of the accident at the site
- b) The assessment of the actual and potential accident consequences and alerting the relevant authorities and the public
- c) Introduction of countermeasures to mitigate the consequences as regards [i] individuals who could be affected in the short term and [ii] longer-term effects such as the contamination of food supplies, land and adjoining waters
- d) Information to the public affected or likely to be affected by the event
- e) The return to normal conditions

The Emergency Plan in place for Sizewell B Power Station is currently approved as adequate to deal with the items above. The Emergency Plan is based on fault study analysis and is drawn up against a reference accident for the site. The first concern is always to avoid any exposure to the public to radiation and therefore to rectify the fault before there is any danger to the public outside the site. Nevertheless, as soon as the fault occurs, the question of emergency action has to be considered and pre-determined actions, which might eventually lead to notification of off site agencies and the public, would begin. Emergency actions to protect the public may therefore be initiated in circumstances where the accident does not develop to a stage that has significant off site consequences.

Currently the emergency actions are based on (a) releases from a Reference Accident and (b) the principle of extendibility for releases beyond the design basis accidents.

- a) The releases from a Reference Accident are used to define a zone closely surrounding the installation within which arrangements to protect the public by introducing countermeasures are planned in detail.
- b) Emergency Plans need to be capable of responding to accidents which, although extremely unlikely, could have consequences beyond the boundaries of the area identified in (a) above, i.e. extendibility. The measures that are required to extend the detailed arrangements can not be precisely planned because the nature and potential of accidents can vary, for example according to weather conditions, when the exact response would be based on an assessment made at the time. The response may make use of local and national plans prepared to deal with a wide range of emergencies.

In an emergency, those who normally provide services/carry out protective functions for the public will continue to do so but in a co-ordinated manner which has been carefully planned and rehearsed. A considerable number of different authorities will be engaged, each applying its expertise to the situation as it develops. This off site emergency response depends on:

- a) Co-ordination, both locally and nationally, between centres dealing with public protection and information and those dealing with the incident on the site and:
- b) In particular both a local and national facility for co-ordinating information and making public the best assessments that can be made.

The national response for dealing with a nuclear accident follows the key principles applied by Government in responding to any civil emergency. Firstly, the initial response should be at a local level where control of an accident and its most immediate effects can be dealt with effectively. Secondly, there should be a single lead department to coordinate the Government's response at the national level. For nuclear emergency planning, the lead department is the Department of Energy and Climate Change (DECC), with the Scottish Government carrying out this function in response nuclear sites located within Scotland.

1 Purpose

As a nuclear licensed site, Sizewell B is required to “make and implement” adequate emergency arrangements (Licence Condition 11). The site also falls under the Radiation Emergency Preparedness and Public Information Regulations (REPPiR) which among other things require site operators to prepare and submit a “Report of Assessment” to enable the Office for Nuclear Regulation (ONR), the UK nuclear regulator, to determine the area to be covered within the local authority’s offsite plan for the site. Hazard Identification and Risk Evaluation is a key part of this determination.

The Report of Assessment for Sizewell B was last submitted to ONR in 2011. Under the regulations the operator is required to review the position every 3 years and if appropriate confirm that no change has occurred which affects their previous assessment. If a “material change” has occurred the operator must prepare a revised assessment.

There has been no “material change” to EDF Energy’s assessment of the previously assessed hazards and risk from this power station. However there have been changes to the neighbouring installation Sizewell A which have resulted in the assessment for Sizewell B assuming greater importance for the site as a whole.

This report goes beyond the minimum regulatory requirements laid down in the relevant REPPiR regulations and guidance and provides comprehensive information written in a style that is intended to be accessible to a lay reader. A more detailed technical report on the assessment of fault sequences, the content of which is classified, has also been provided to ONR.

It is important to be clear over the extent of current nuclear emergency planning at Sizewell. Although the focus is frequently the so-called Detailed Emergency Planning Zone (DEPZ), this is only one element within the offsite plans. The DEPZ is the area where the most urgent countermeasures (such as sheltering, evacuation and potassium iodate tablet issue) could be justified after an accident. Plans for other less urgent but equally important reassurance and protective measures (such as food restrictions) extend beyond the DEPZ and will continue to do so. Furthermore, it has long been a principle in UK nuclear emergency planning that these detailed plans should provide a basis for a wider response, calling on more general contingency arrangements and other resources where necessary. This is the principle of “extendibility”.

2 Background

Sizewell B’s emergency plans, including the previous detailed emergency planning zone (DEPZ) of 2.4km have existed since the commissioning of the Sizewell A power station in 1965. The scale of offsite planning at Sizewell was initially determined by:

the characteristics of what was called at the time the “maximum credible accident” for the design of Magnox reactor used at Sizewell, together with the local geographical features of the site (roads, habitations, etc.).

Together these factors led to plans that currently extend to around 40km and contain a smaller zone of radius 2.4km (in the Operators’ Plan) centred on Sizewell A called the DEPZ. This smaller zone was set so that it contained the areas where the most urgent countermeasures might be justified in the event of the Reference Accident for Sizewell A. When the DEPZ was originally defined it did not include any part of Leiston, the nearest town.

The plans for other, less urgent, protective actions were developed to a distance of around 40km and covered the monitoring of the environment, with a particular emphasis on foodstuffs, so that, if necessary, less urgent and potentially longer term health protection countermeasures could be imposed.

The offsite emergency arrangements were reviewed as part of the planning and licensing of Sizewell B in the 1980s. The safety characteristics for this more modern design of nuclear power station were such that the worst reasonably foreseeable accident for Sizewell B was less severe in terms of offsite releases of radioactivity than was the equivalent accident for the existing, much older, Sizewell A. As a result, the Reference Accident for Sizewell B was smaller than for Sizewell A so that the extent of both the DEPZ and the wider planning area were unaffected by the addition of the newer station. The DEPZ therefore remained at 2.4km radius and the wider planning area for longer term countermeasures at around 40km.

The evidence from ONR's predecessor as nuclear safety regulator, the Nuclear Installations Inspectorate (NII), which substantiated this conclusion (as well as evidence from the future licensee for the new power station) was heavily scrutinised during the Sizewell B public inquiry. The approach to identifying the Reference Accident is summarised in the following extract from the UK nuclear safety regulator's evidence [Ref. 1] to that Inquiry:

"The NII requires the CEGB¹ (Licensee) to draw up its plans to respond to the design basis accident (DBA) which would give the largest off-site release of radioactive materials. This is called the Reference Accident".

The same arguments on the approach to nuclear emergency planning were then examined in even greater depth during the Hinkley Point C Public Inquiry, which took place in 1988-89. (The Hinkley Point C proposal involved building a replica of Sizewell B design alongside an existing Magnox station and the Inquiry was held in the aftermath of the 1986 accident at Chernobyl.) The basis for emergency planning put forward by both licensee and the UK's national safety regulator was again confirmed as sound.

The REPPIR Regulations did not exist at the time of these events. Instead emergency plans were governed (a) by a requirement on the operator under the Nuclear Installations Act (enforced through Licence Condition 11) and (b) through the Ionising Radiations Regulations, which include a requirement for contingency arrangements to be established for "reasonably foreseeable" radiation accidents.

When the REPPIR regulations came into force in 2001 they were not only intended to apply to licensed sites but covered any site or operation that could give rise to a "radiation emergency". Indeed, when REPPIR was introduced, the Health & Safety Executive's guide [Ref. 2] to the new regulations stated:

"REPPIR does not replace the existing nuclear site licence conditions, but for operators of nuclear licensed sites, compliance with these conditions (i.e. Site Licence Conditions) should satisfy equivalent provisions in REPPIR"

Since 2001 the two licensees for the A and B power stations at Sizewell have therefore provided submissions to the nuclear safety regulator drawing on the work that was carried out to satisfy that same regulator under their existing Site Licence Conditions. This led to the Report of Assessment and Hazard Identification and Risk Evaluation for Sizewell A that was provided in accordance with the new REPPIR regulations continuing to provide the basis on which the extent of the DEPZ and

¹ CEGB is the Central Electricity Generation Board which was at the time the licensed operator

the wider offsite planning for the Sizewell site were determined. This was a consequence of the worst “reasonably foreseeable radiation emergency”² (i.e. the Reference Accident) for the A station having more extensive potential offsite impacts than would arise from any reasonably foreseeable radiation emergencies that could occur at the more modern B station.

In October 2011 the Magnox A Licensee notified ONR in their REPPiR submission that the shutdown and decommissioning of both reactors had substantially reduced the hazard potential from that site. So, with the A station Reference Accident (on which the current Sizewell emergency planning areas are currently based) no longer relevant, there is a need to reappraise what is the worst reasonably foreseeable radiation emergency for the site and hence what scale of offsite planning remains appropriate.

Following the serious Fukushima accident in 2011, the Government asked ONR’s Chief Nuclear Inspector to report to it on the lessons for the UK. Two substantial reports [Refs. 3 & 4] were published. ONR’s Chief Inspector also led the International Atomic Energy Agency’s team that visited Japan after the accident – a visit that led to a further authoritative report [Ref. 5]. In common with other UK operators, EDF Energy has itself initiated work to examine and address the lessons from Fukushima. Where relevant, this report also refers to these Fukushima reports and the conclusions within them relevant to the identification of the Reference Accident for Sizewell B.

In August 2013 ONR published a new Technical Assessment Guide [Ref. 6] to aid its inspectors when reviewing submissions under REPPiR. EDF Energy has also taken note of this new document, and this is identified in Appendix A.

In April 2014 ONR made their determination of their new REPPiR Offsite Emergency Planning Area for the Sizewell Sites – an area of between 3 and 5km from the centre of the B Station, and bounded by postcodes. This was followed by Suffolk County Council, in consultation with Public Health England, revising the area in which urgent countermeasures (sheltering and taking potassium iodate tablets) were required to 1km from the B Station.

² The phrase “reasonably foreseeable” is the one used in the REPPiR Regulations. In normal English usage this phrase might convey an event that is quite likely to happen. However, in the context of nuclear emergency planning, the term signifies events that may be foreseeable but are actually extremely unlikely ever to occur during the lifetime of the power station. For example, the assessed frequency of the two candidate Reference Accidents described in this report is around 1 chance in 300,000 per year

3 Schedule 5 Requirements

This section of the RoA provides the information required by Schedule 5 of REPPiR. Each element of Schedule 5 is listed, with Sizewell B specifics provided. This format has been used in order to allow rapid identification of each element in Schedule 5.

3.1 a) the name and address of the operator

EDF Energy Nuclear Generation Ltd.
Barnett Way
Barnwood
Gloucester
Gloucestershire
GL4 3RS

3.1.1 b) the postal address of the premises where the radioactive substance will be processed, manufactured, used or stored, or where the facilities for processing, manufacture, use or storage exist...

EDF Energy Nuclear Generation Ltd.
Sizewell B Power Station
Leiston
Suffolk
IP16 4UR

3.1.2 c) the date on which it is anticipated that the work with ionising radiation will commence, or if it has already commenced, a statement to that effect

Work with ionising radiation has already commenced at Sizewell B. The Power Station has been operational since 1995, and underwent commissioning prior to that date.

3.1.3 d) a general description of the premises or place including the geographical location, meteorological, geological, hydrographic conditions and, where material, the history of the premises...

Geographical location

The following information is provided from the Station Safety Report [Ref. 7] Sizewell B Power Station is located on the Suffolk coast, some 35 km north-east of Ipswich. It lies immediately to the north of the Magnox A station which is in turn just to the north of the hamlet of Sizewell near Leiston. The site is within the Leiston parish of Suffolk Coastal District Council and is administered also by Suffolk County Council.

The reactor building is approximately on Ordnance Survey Grid Reference TM475635.

To the east of the site is a series of stable sand ridges known as the Bent Hills which slope down to and run parallel to the seashore which at this point runs due north-south. The Bent Hills are some 100 m wide and have been remodelled and extended to form a continuous sea defence embankment 10 m high along the eastern site boundary. The land immediately to the north of the site is marshy and low lying, similar to the extreme northern part of the site. Further north the land is wooded, beyond which it adjoins the Minsmere Bird Sanctuary. The land lying immediately to the west of the site is marshy and low lying but farther west the land is agricultural or wooded and gently rises to approximately +15 m OD. To the south is Sizewell A power station, the hamlet of Sizewell and beyond is Cliff House Caravan Site and Sizewell Hall.

Meteorology

The UK Meteorological Office has produced a climate summary [Ref. 8] of Eastern England, an area including Suffolk where Sizewell B power station is located. This area has a common climate due to its eastern location in the UK, and its relatively low-lying geography.

The Met Office identifies mean annual temperature over the region varying from 9 °C to 10.5 °C. January and February are the coldest months with mean daily minimum temperatures across the region close to 1 °C (1.5 °C or more near the coast). Mean daily maximum temperatures range from 5 °C to 8 °C during the winter and from 19 °C to 22.5 °C in the summer.

Sea temperatures off the coast of eastern England are reported by the Met Office to vary from 5-6 °C in February and early March to 15-16 °C in August. The temperature is governed by the influx of warm water associated with the Gulf Stream. The number of days of frost is variable across the region although in East Anglia in particular, as the land is fairly flat, the main influence is proximity to the coast. The Met Office identify the average number of days a year with air frost to range from about 30 at the coast where Sizewell B is located, to about 55 well inland.

Low cloud from the North Sea can affect the coast especially in spring and summer. Across the region, annual average sunshine hours are around 1550 hours in eastern Suffolk according to the Met Office.

There is a much more even distribution of rainfall throughout the year in Eastern England than in most other parts of the UK. This is mainly due to a combination of the 'rain-shadow' effect for winter Atlantic depressions produced by the high ground to the west and a higher frequency of convective rainfall in summer. Across most of the region there are, on average, about 30 rain days (rainfall greater than 1 mm) in winter (December to February) and less than 25 days in summer (June to August) as identified by the Met Office. The number of thunderstorms in a year can make a significant contribution to the total annual rainfall. They can occur at any time of year but are more frequent during the summer months. Over East Anglia, the average number of days of thunder per year is about 15 although there is considerable variability from year to year.

Met Office statistics show the average number of days with snow falling each year ranges from under 20 in the south-east of the area to over 30 on higher ground, while the average number of days with snow lying is less, varying from about 7 to 20.

Eastern England is one of the more sheltered parts of the UK, since the windiest areas are to the north and west, closer to the track of Atlantic storms. The strongest winds are associated with the passage of deep depressions across or close to the UK. The frequency of depressions is greatest during the winter months so this is when the strongest winds normally occur.

In coastal areas sea breezes are an important feature of the weather in late spring and summer when the land is warming up and the sea still relatively cool. These start at the coast and then progress inland bringing a drop in temperature. The inland penetration is dependent on the temperature difference land to sea and the strength of convective activity. The Met Office data shows much of East Anglia and Lincolnshire has no more than 2 days of gale each year, but exposed coasts average about 5 gales each year.

Geology - stratigraphy

The solid geology stratigraphy of the Sizewell site is tabulated below:

Stratum	Elevation m (OD)
Crag Deposits	+6.5 to -10.2
London Clay	-41.2 to -48.0
Lower London Tertiaries (Reading, Woolwich and Thanet Beds)	-55.0 to -61.0
Upper Chalk	-77.5 to -83.2

The Upper Chalk has been proven to a level of about -150 m OD.

Over the northern part of the site the Crag Deposits are overlain by weak alluvial clays and peats up to about 7 m thick and a layer of sand fill generally between four and seven metres thick. It is in this area that elevations of the top of the Crag as low as the limiting value quoted above (-10.2 m OD) are encountered.

Major unconformities exist between the Crag Deposits and the London Clay and between the Lower London Tertiaries and the Chalk. The sequence between the Upper Chalk and the pre-Permian basement under the site is not known with precision. However, information from deep boreholes at Harwich and Lowestoft together with limited geophysical data, indicate a regional trend leading to the conclusion that the pre-Permian rocks at Sizewell are at about -400 m OD. A large number of on-site geotechnical investigations have confirmed and refined the anticipated sequence to a maximum borehole depth slightly in excess of 150 m.

This information is based on the Sizewell B Station Safety Report [Ref. 7], and greater detail on the stratigraphy is available in this document.

Geology - site structure

There is no evidence from any of the boreholes of any tectonic deformation within the Sizewell site. Minor displacement features have been observed in boreholes at the extreme north-east corner of the site, but they do not pass downwards into the underlying Chalk. Hence, they are not the direct result of tectonic displacement. The top of the Chalk is found at a stratigraphic horizon anticipated from previous knowledge and the bases of the Crag and the Palaeocene deposits are encountered at levels more or less to be expected from the known shapes of these surfaces. The base of the Crag shows an average dip of about 1 in 70 towards the south-east.

Geology - regional structure

The tectonic map of Great Britain shows the structure of East Anglia generally to be cratonic (platform) cover over folded pre-Permian rocks. In the latest published information, Sizewell is located inside the eastern edge of the East Anglian Massif, a stable structural platform during the Mesozoic-Tertiary period. The present dip of the strata in this part of East Anglia is mainly the result of differential subsidence in the North Sea Basin producing, during the Tertiary period, a gentle tilting of the East Anglian Massif towards the east while, to the south, the London Basin subsided. Tilting continued through the Quaternary as demonstrated by the present-day differences in elevation between similar age horizons in the Crag.

Hydrographic conditions

The site is situated on a plateau at +6.4 m OD and is equipped with its own storm water drainage system. The sea is to the east and to the north and west are areas of low lying marshland containing a Site of Special Scientific Interest and a number of other locations where statutory environmental designations apply. This marshland is about 5 m below site level and the surface drainage flows northwards through a system of ditches before reaching the sea at Minsmere Sluice. The water level in these ditches is only a little above mean sea level and not thought to be in direct hydraulic contact with the Crag aquifer. There is no flooding hazard to the site from this low lying marshland nor are there any major water retaining structures inland of the site whose collapse could result in a similar hazard.

Apart from superficial deposits (weak clay and peat) and fill on the northern end, the site consists of the permeable sands of the Crag Deposits. This aquifer is underlain by the aquiclude of the London Clay which effectively isolates it from the underlying Chalk. Water levels within the aquifer are just above mean sea level (+0.5 to +1.0 m OD) and on the site show an average fluctuation of about 0.25 m throughout the tidal cycle although this effect is considerably reduced towards the western side of the site. Data obtained from pumping tests, site investigation work and water level monitoring suggest a gentle local groundwater gradient across the site from the south towards the marshland to the north and west with an upward gradient within the marshy area probably reflecting evaporation losses. Water levels in the Chalk aquifer are artesian at a level close to +6.0 m OD confirming the efficient separation of the Chalk and Crag aquifers by the low permeability layers of the Lower London Tertiaries and the London Clay. Within the Crag aquifer the hydrogeological map of southern East Anglia indicates regional groundwater gradients rising gently to the west at a rate of about one metre per kilometre.

During the construction of the works for the B station, a diaphragm wall was constructed around the deep excavation for the foundations of the principal buildings. The wall extended down through the Crag Deposits to form a watertight seal with the London Clay. De-watering took place within the area bounded by this diaphragm wall so that the building foundations could be constructed under dry conditions. The provision of the diaphragm wall limited the possibility of any settlement beneath the A station and reduces pumping costs during de-watering. It also avoided unconfined de-watering of the surrounding area, thus preventing the drying up of local wells and water courses (used for irrigation) as well as preventing damage to the local ecology and avoiding possible saline pollution of the adjacent marshland. The diaphragm wall was breached prior to completion of Sizewell B so that ground water levels could equalise inside and outside the diaphragm wall.

On evidence of hydrographic surveys carried out over a period in excess of 150 years, Sizewell is situated on one of the most stable sections of the East Anglian coast. The main shoreline monitoring and response arrangements are accomplished via the Sizewell Shoreline Management Steering Group.

Further information on hydrographic conditions can be found in the Sizewell B Station Safety Report [Ref. 7].

3.1.4 e) in the case of an assessment by an operator, a description of any radioactive substance on the premises which is likely to exceed any quantity or mass specified in Schedule 2 or Schedule 3, as the case may be, which description shall where practicable include details of the radionuclides present and their likely maximum quantities

The greater part of the radioactive substances present on site is contained in the irradiated nuclear fuel. In its unirradiated state (i.e. as brought onto site) the fuel contains very little radioactivity. However, exposure to the nuclear chain reaction and the radioactive decay of the products of that chain reaction causes the fuel to become highly radioactive. The radioactivity of fuel increases with irradiation in the reactor but decays when removed from the reactor.

After the fuel, the most significant activity inventory will be in the Reactor Pressure Vessel and associated core structure and components. Radioactivity is present in these structures by activation of the structural materials. Structures that contain sufficient radioactivity to exceed the levels specified in Schedule 2 of the Regulations include:

- primary circuit pipe work
- reactor pressure vessel and internal reactor structures
- primary circuit supporting systems

This activity is fixed in the structures and there is no plausible mechanism for this activity to be released to the environment, even in the case of a severe accident.

There is other radioactive material on site although the quantities are very much less than is present in the reactor fuel. Potentially important material is shown below;

- the reactor primary circuit coolant water
- the fuel storage pond water
- solid radioactive waste
- liquid radioactive waste

3.1.5 f) in the case of an assessment by a carrier, a description of any radioactive substance which is likely to exceed any quantity or mass specified in Schedule 4 or Schedule 3, as the case may be, which description shall where practicable include details of the radionuclides present and their likely maximum quantities

Applicable to carriers of radioactive materials only.

3.1.6 g) ...a plan of the premises in question and a map of the environs to a scale large enough to enable the premises and any features which could affect the general risk in an emergency to be identified

Figure 1 provides a plan of the site, while Figure 2 shows Sizewell B Power Station in its local context on an Ordnance Survey map as outlined in the Sizewell B Operator's Emergency Plan [Ref. 9].

Figure 1: Plan of Sizewell B Site

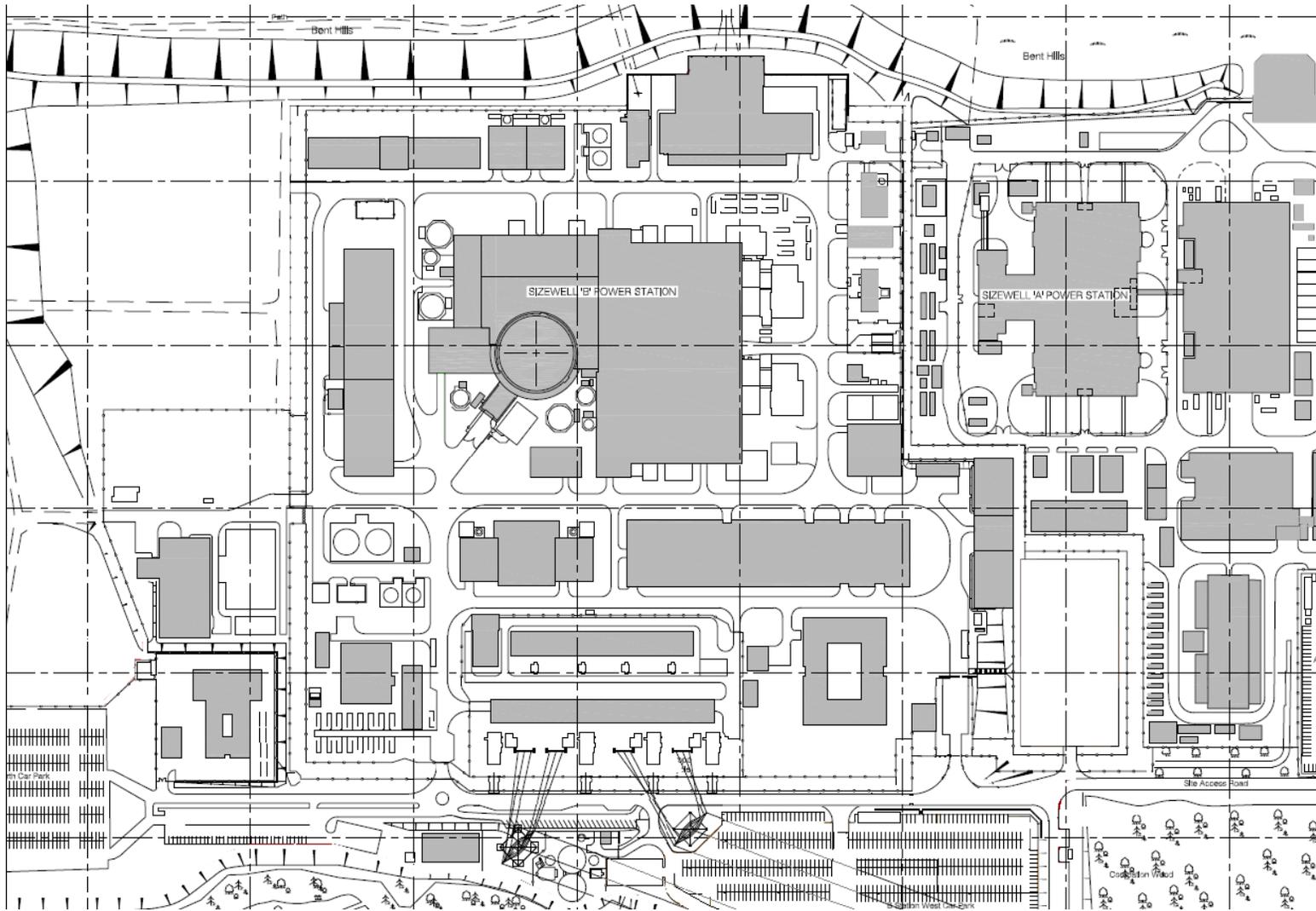
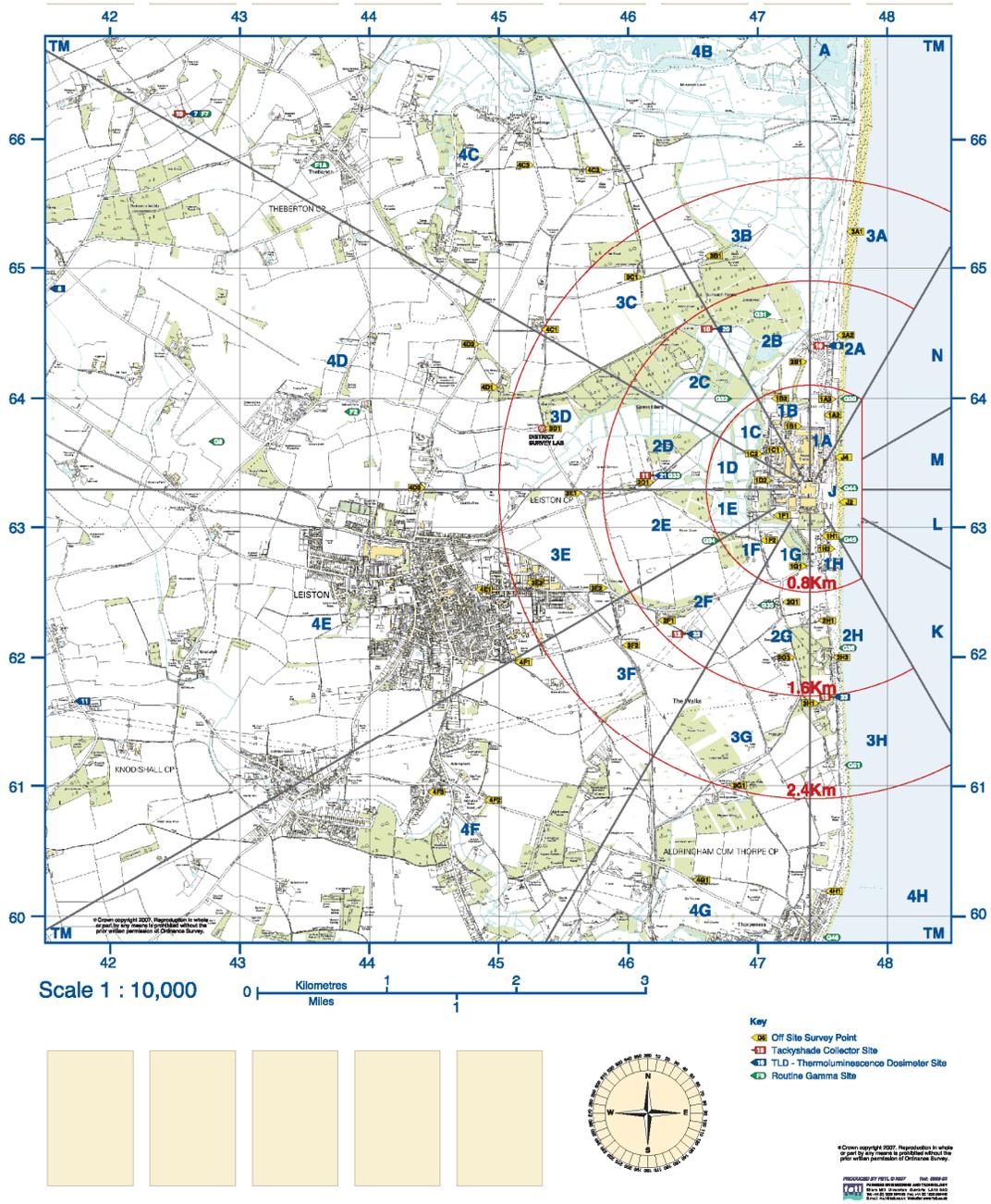


Figure 2: Map of the Environs of Sizewell B³



³ Taken from [Ref. 9]

3.1.7 h) a diagram and description of any single plant or enclosed system containing more than the quantity or mass of any radioactive substance specified in Schedule 2 or Schedule 3, as the case may be...

The principal plant and enclosed systems are:

- the reactor primary circuit coolant water
- the fuel storage pond water

Primary Circuit [Ref. 10]

The main functions of the reactor coolant system and its pressure-retaining boundary are to:

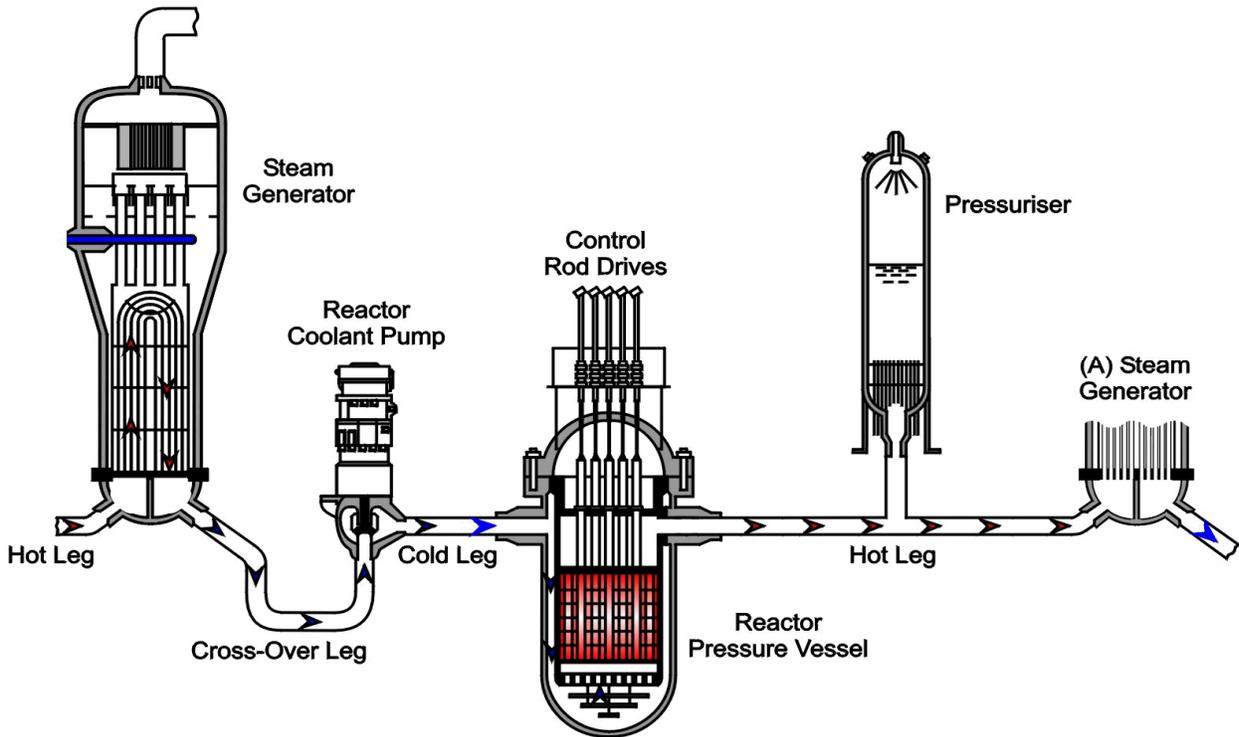
- Keep fuel covered and cooled by transferring heat from the reactor core to the steam generators.
- Limit leakage of coolant and radioactivity by containing the reactor coolant under operating conditions.
- Control the pressure of the reactor coolant and accommodate coolant volume changes generated by temperature changes (expansion and contraction).

In the Sizewell B design, the reactor vessel, pressuriser and steam generators are constructed of carbon steel of controlled composition and manufacture. The surfaces in contact with reactor coolant are lined with stainless steel to provide corrosion protection. The coolant pump bowls and interconnecting pipes are constructed of stainless steel.

It can be seen in Figure 3 that the steam generator is positioned above the reactor, this is to minimise the pipework lengths and to ensure that coolant flow will be maintained by natural circulation in the event of the failure of the reactor coolant pumps.

After installation, before commissioning and at prescribed intervals during operational life the whole pressure boundary is subjected to pressure tests and inspection of welds. All components are provided with externally mounted thermal insulation constructed of layered stainless steel sheet and spacers. This is demountable at welds to allow in-service inspection.

The reactor coolant (light water) normally operates at approximately 293°C and 155 bar(a) pressure on the cold legs. The temperature rise through the core is approximately 32°C. The flow rate through each coolant loop is 4,800 kg/sec.

Figure 3: Diagram of Primary Circuit

Fuel Storage Pond[Ref. 11]

The Pressurised Water Reactor (PWR), unlike some existing UK Advanced Gas-cooled Reactors (AGRs), cannot be refuelled whilst at power, and must be shut down at regular intervals to remove the used fuel and replace some of it with new fuel. This means that periodically (typically once per 18 months), depending on the fuel added at the last outage, the reactor must be shutdown and access gained to the reactor core in order to renew fuel. Normally around 40 percent of the core is replaced, ~80 fuel assemblies, and the remainder are reshuffled to give the desired neutron flux pattern. Part of this process will also involve the shuffling of other in-core components such as the Rod Cluster Control Assemblies (RCCAs).

During this refuelling window the opportunity is taken to carry out extensive maintenance and testing programmes on all areas of plant that are either inaccessible or in service during normal operational periods.

The Fuel Building contains the stainless steel lined Fuel Storage Pond within which are racks for holding both new and irradiated fuel. Adjacent to the fuel storage pond and separated from it by dam gates, is the fuel transfer canal and two bays for preparation and filling of irradiated fuel transport flasks. The ponds are kept filled with borated water.

Also within the fuel building are facilities for the receipt and inspection of new fuel and the loading bay for the road transport vehicles.

Fuel is always handled under borated water. This removes the decay heat from irradiated fuel and provides an effective and inexpensive radiation shield. The boric acid in the water ensures the fuel assemblies cannot become critical in any circumstances.

Dry Fuel Storage

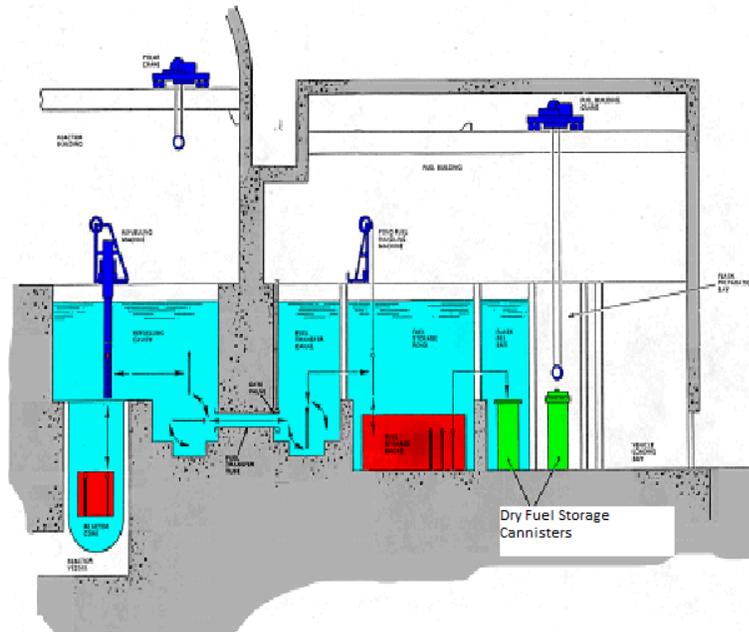
As more fuel is removed from the core and placed into wet storage, the number of spent fuel assemblies begins to fill the Fuel Storage Pond and reaches the limit of available storage space in the pit.

After several years of cooling in the Fuel Storage Pond, the Spent Nuclear Fuel can be safely moved to above-ground storage casks (Dry Storage)

Spent Fuel Assemblies produce Heat and Radiation. It takes several years of storage under water to reduce their heat and radiation levels to where they can be moved into dry storage, where they are air cooled.

At this point assemblies are removed from the ponds and placed into specially designed storage canisters, which are then sealed. Each canister can hold up to 24 assemblies. The fuel canister is then stored in an additional shielded container within a specifically designed dry fuel storage facility on Site.

Figure 4: Diagram of Fuel Route Showing Fuel Storage Pond and Dry Fuel Storage Canisters



3.1.8 i) those factors which could precipitate a major release of any radioactive substance and the measures to be taken to prevent or control such release and information showing the maximum quantity of radioactive substance which, in the event of a major failure of containment, would be released to the atmosphere including, in respect of premises, the identification of plant and other activities anywhere on the premises which could precipitate such release

The Sizewell B Pressurised Water Reactor was built with a containment building. The design intent of this structure is to contain accidental release of radioactive material from the reactor. As a consequence, the chances of an extreme release affecting the public is extremely low as the probability of the failure of containment is vanishingly small. As with all emergency planning, it is however prudent to consider extended release scenarios. The releases described below and used in the analysis of the Sizewell B Reference Accident are Reasonably Foreseeable releases which involve the breach of systems that are designed to contain radioactive material (ie containment), however it should be noted that the Primary Containment of the PWR at Sizewell B is designed such that its failure is not reasonably foreseeable.

Systematic analysis has identified that various internal and external initiating events at Sizewell B could result in a radiation accident leading to a release of radioactivity and a potential radiation emergency. The safety analysis approach used in this context involves detailed analysis of potential faults and their consequences in order to demonstrate that the risks to the public from accidental releases of radioactivity from the power station are As Low As Reasonably Practicable (ALARP), and to give assurance that the plant protection and safeguard systems have achieved their design objectives of minimising the occurrence of faults and mitigating their consequences.

In the early stages of the design of Sizewell B, certain faults were identified as those against which the plant needed to be designed. These were the faults which the design needed to be shown to be capable of withstanding without the consequences being unacceptable. These design basis faults are defined as those faults or fault sequences which originate from faults in the fault schedule and which can be tolerated by the plant design without exceeding the safety limits.

These design basis faults were classified in the following groups:

- a. Loss of Coolant Accidents (LOCA) affecting the primary circuit during power operation and at shutdown and which may result in fuel damage;
- c. Faults where the primary circuit is initially intact during power operation and at shutdown and which may result in fuel damage;
- d. Faults in interfacing systems in the Auxiliary Building during power operation and at shutdown;
- e. Faults during fuel handling operations and irradiated fuel storage;
- f. Faults affecting the radioactive waste treatment plant.

In order to examine the distribution of risk for these faults, design basis assessment levels were defined which comprise three dose bands that relate the consequences of the release, specifically the dose to an individual, to the frequency of occurrence.

The safety analysis demonstrated that there are fault sequences from these groups that contribute to the frequency totals in each of the three design basis assessment levels.

It is considered that faults corresponding to a reasonably foreseeable radiation emergency are those contributing to these dose bands and that the upper limit for the magnitude of the release associated with a reasonably foreseeable radiation emergency is represented by those faults contributing to the design basis dose band defined by the uppermost value of individual dose (called dose band 3). Further information on the Design Basis approach can be found in Appendix B.

The maximum quantity of radioactive substance which, in the event of a major failure of the systems containing that radioactivity, would be released to the atmosphere are identified in a redacted appendix to this report and in an additional report provided to ONR.

The plant from which these release could reasonably foreseeably occur are those identified under Schedule 3 in Section 3.1.4 and described in Section 3.1.7.

3.1.9 j) those factors which could precipitate a smaller but continuing release of any radioactive substance and the measures to be taken to control such releases to atmosphere

These are a subset of the factors identified in paragraph i) above.

3.1.10 k) those factors which could give rise to an incident involving the initiation of an unintended self-sustaining nuclear chain reaction or the loss of control of an intended self-sustaining nuclear chain reaction and, in either case, the measures to be taken to prevent or control any such incident

The following is based on an identified reference to the Station Safety Report [Ref. 12].

Nuclear fuel is handled and stored outside the reactor, primarily in the Fuel Storage Pond. The design of the equipment and plant used for these operations includes engineered controls to ensure that a self-sustaining chain reaction (criticality) will not occur. These design features include: physical separation of the fuel assemblies and the incorporation of neutron absorber materials (poisons) in the storage racks; additional Solid Absorber Assemblies inserted into some of the stored assemblies and equipment design which physically prevents the handling of multiple assemblies at any time. In addition, soluble neutron absorber is added to the pond water to further reduce the possibility of a chain reaction.

In addition to engineered safety features, the operational rules for handling and storage of fuel include further criticality controls. These include strict controls on the presence of water or other moderating materials in areas where fuel is handled outside of the pond.

All fuel handling and storage outside the reactor is covered by criticality safety cases. These consider all normal operations and also all credible (design basis) accidents and hazards and require that a large margin is maintained to criticality at all times. The reactivity of the fuel is assessed using extremely pessimistic calculational methods and assumptions. In all cases, the fuel has been shown to remain safely sub-critical by the required margin. This ensures that the risk from criticality is negligible.

The safety case has also demonstrated that failure of some or all of the operational controls would not reasonably be expected to lead to criticality outside the fuel storage ponds. Within the ponds, an additional safety feature is the shielding provided by the pond water and concrete walls. This would ensure that, in the hypothetical event of a criticality occurring in the ponds, no-one on-site could receive a dose higher than the 20 mSv limit. Doses off-site would be close to zero.

3.1.11 I) information concerning the management systems and staffing arrangements by which the radioactive substance is controlled and by which the procedures are controlled

All designs for, and modifications of, nuclear plant are subjected to detailed safety reviews of the engineered systems and the operating/ maintenance procedures. When relevant this extends to reviewing changes to organisational structures and resources. Independent expertise is used to check major changes within the process of achieving safety, major changes are also scrutinised by the Nuclear Safety Committee (NSC).

The Site licence requires that the responsibilities of each member of the Sizewell B management team are defined within a quality assurance programme for matters that affect nuclear safety. The structure of the management team and the responsibilities of its members are summarised below.

The Sizewell B, Station Director is responsible for the safe operation of Sizewell B. This includes an overall responsibility for ensuring that adequate numbers of staff are present on Site to operate the reactor and ancillary plant in a safe manner, carry out the initial response to an emergency and that these staff are suitably qualified and experienced. Beneath the Station Director the Plant Manager has delegated responsibility for the operation of the station. Sizewell B is organised into 12 departments: Operations, Outage, Maintenance, Technical and Safety, Continuous Improvement, Finance, Human Resources, Work Management, Security, Supply Chain, System Health and Training. The Operations Manager is responsible to the Sizewell B Station Director for the safe operation and maintenance of the reactor and all associated plant, including the un-irradiated fuel store and the fuel discharge route. Thus, the greater part of the responsibility for controlling radioactive substances rests with the Operations Manager. During refuelling periods the Outage Manager is responsible for the planning and coordination of outage activities; however plant operation remains the responsibility of Operations even when the reactor is shutdown. The Operations Manager is supported in this respect by the Technical and Safety Manager, who is responsible to the Sizewell B, Station Director in his own right for providing nuclear safety assessments, monitoring and advice on radiation protection, quality assurance programme and industrial safety. The Maintenance Manager, System Health Manager and Work Management Manager are responsible to the Sizewell B, Station Director and Plant Manager in their own right for ensuring that adequate maintenance and repairs are carried out on plant and equipment. Thus keeping the safety systems in good working order, so that they will perform when demanded with the required integrity. The Continuous Improvement Manager is responsible for ensuring the station continually evaluates its performance, bench marks against industry world leaders and strives for improvement. The Training Manager ensures that all personnel are sufficiently and suitably qualified to carry out their roles competently and proficiently. The Supply Chain, HR and Finance Managers are responsible for providing general support services to the operation of the Site in the area of business management.

Additional services for the Station are provided by the Central Technical Organisation (CTO) including Asset Management, Central Engineering Support, Design Authority, Lifetime and Fleet Programmes, Projects and Supply Chain. Finance and Human Resources support services are provided. Technical and Safety provide Environmental Regulation and Oversight, Nuclear Fuel and Liabilities and Nuclear Inspection and Oversight (NIO).

Staffing

Each department has a team of personnel, all of whom are suitably qualified and experienced for the work which they are expected to perform. The minimum required manning levels are fully documented in the departmental instructions.

A continuous shift system is operated at Sizewell B which ensures that there are adequate staff resources available at all times to operate the Site safely and to deal with any emergency situation which might arise. The level of staffing has been underwritten by a human factors assessment, which was undertaken as part of the probabilistic safety assessment.

Procedures

It is a requirement of the Nuclear Site Licence that adequate quality assurance arrangements are made and implemented for all matters that may affect safety. These arrangements are specified in the top tier of a multi-tiered system, and define the requirements for procedures and instructions across the Site. The lower levels are described below.

The top tier requirements for procedures and instructions are further developed on a departmental or system basis. Each system or department leader is responsible for the preparation and issue of sufficient instructions to enable work to be carried out to maintain safety is adequately controlled.

Conditions for the safe operation of the plant, and the work needed to maintain the plant in a safe and reliable condition, are specified in a range of documents and arrangements.

Regulatory Control

The Nuclear Industry is regulated by the Office for Nuclear Regulation (ONR) which has at least one inspector assigned for each licensed Site. These inspectors have the right to inspect any equipment or procedure at short notice and the right to require the Company to provide information. The ONR can direct the shutdown of any process that it considers unsafe.

The ONR require that the safety of plant and operations is considered in a systematic manner at all stages from planning, building, operating and decommissioning and that the safety case is subject to both continuous review and formal periodic review.

Any significant changes in procedures, plant or management structure has to be approved by the ONR before the event, in accordance with nuclear Site licence arrangements.

Emergency Organisation

Sizewell B has on-Site emergency arrangements that ensure that suitably qualified and experienced people are available at all times to respond to any events that cause the reactors or other equipment to deviate from their normal operating conditions. The provision of emergency arrangements can further mitigate the probability of a major release of radioactivity to the environment. Should a release of radioactivity occur, the off-Site emergency arrangements are focused on implementing countermeasures to prevent the exposure of the public to radiation.

The local Fire and Ambulance services form part of the integrated response to a site emergency. Mitigation actions carried out by the fire service would include fire fighting, search and rescue and support to teams carrying out tasks in breathing apparatus. In providing assistance it is expected that emergency exposures may be required for Fire service intervention staff because of the proximity or duration of tasks to sources of radiation. Due to the nature of their role, it is not expected that emergency exposures would be required for Police personnel.

The emergency plans, both on-Site and off-Site, for Sizewell B are approved by the ONR and exercised regularly. Consultation and development of best practice in emergency planning for nuclear Sites is discussed at consultation meetings involving key stakeholders. The DECC-led Nuclear Emergency Planning Development Committee (NEPDC) provides national guidance and

co-ordination, and the Nuclear Emergency Arrangements Forum (NEAF) is a forum for operators to share practices. Locally the Emergency Planning Consultative Committee (EPCC) meets regularly to coordinate local plans, to allow consultation on changes, and acts as a focal point for planning issues.

3.1.12 m) ...information about the size and distribution of the population in the vicinity of premises to which the report relates

The following information is taken from Suffolk County Council's Sizewell Offsite Emergency Plan [Ref. 13]:

Distance	Total Permanent population	Total Private Properties	Transient Population	Commercial Properties
Within 1km	23	12	290 - 370	4
1 - 2km	96	47	500 - 650	6
2 - 3km	2,962	1,245	150	121
3 - 4km	4,334	1,858	Small numbers	22
4 - 5km	203	98	Nil	nil

A full breakdown on a sector by sector basis is available in the Suffolk Offsite Plan.

3.1.13 n) an assessment of the area which is likely to be affected by the dispersal of any radioactive substance as a result of any radiation emergency and the period of time over which such dispersal is likely to take place

The selection of the worst reasonably foreseeable accident for Sizewell B has been reviewed to provide the additional information requested by ONR. The review has considered:

- Previous REPIR submissions for the station
- The evidence presented by ONR and the licensee at the time of the licensing of Sizewell B
- Developments within the safety case for Sizewell B
- The insights from Fukushima as recorded in the reports by ONR to Government, and
- The suggestions for ONR's assessors within the Technical Assessment Guide published in August 2013

Greater detail on this review is provided in Appendix A.

Two candidate fault sequences with similar scales of potential offsite radiological consequences were identified from among the many faults analysed within the extensive safety case for Sizewell B. Of these the fault sequence which is shown to lead to the largest offsite contour applying the REPIR effective dose criteria has been proposed as the Reference Accident for Sizewell B. This fault involves a major leak from a system containing reactor coolant, following a reactor shutdown, and the release of all radioactivity within the primary coolant in the space of one hour.

The distance to which the REPPiR 5mSv effective dose criterion could be exceeded in the event this accident occurred is estimated to be around 230 metres taking account of additional dose from ingestion in the first 24 hours. The distances to an equivalent dose of 15mSv to the lens of the eye and an equivalent dose of 50mSv to the skin have been determined to be less than this value.

In the event that either of these candidate accidents occurred it would be necessary to assess whether urgent countermeasures were needed to protect the public. Urgent countermeasures such as sheltering, potassium iodate tablets, and evacuation are used to reduce exposure to airborne radioactive materials and should be introduced quickly for maximum effect. The Emergency Reference Levels (ERLs) provide guidance as to what level of dose saving is sufficient to justify the use of each of these countermeasures.

An assessment has therefore been made of the maximum distance to which the lower ERL of dose for sheltering or stable iodine tablet issue could be exceeded in the event either of these two faults were ever to occur. For the fault sequence "Code 3A" the maximum distance is estimated to be around 320 metres (lower ERL for sheltering). For fault sequence "BLDBF-6" the maximum distance is slightly larger at around 527 metres (lower ERL for stable iodine tablet issue). The difference between the two candidate faults is a result of the different proportions of particular radioactive materials within the release.

Less urgent countermeasures, such as restrictions on locally produced foodstuffs, could be required to a greater distance. EDF Energy suggests this aspect of responding to a radiation emergency should also be taken into account within ONR's determination of the scale of offsite plans required under REPPiR.

These results confirm the evidence presented at the time of licensing which concluded that a 1km offsite DEPZ for urgent countermeasures together with the existing scale of offsite plans governing food restrictions and longer term actions would bound all reasonably foreseeable releases for the Sizewell B design of PWR.

3.1.14 o) an assessment of the likely exposures to ionising radiation of any person or class of persons as a result of any radiation emergency...

In line with the assessment summarised in Section 3.1.13 above, two tables are provided below which show effective doses versus distance for the 2 candidate fault sequences.

These tables do not include any contribution from ingestion in the first 24 hours. When this exposure pathway is included the estimated distance to an effective dose of 5mSv to an infant increases to 234 m for "Code 3A" and to 210 m for "BLDBF-6". For both identified faults the distances to an equivalent dose of 15mSv to the lens of the eye and an equivalent dose of 50mSv to the skin have been determined to be less than these values.

Table 1: REPPIR 5mSv Dose Contour – Effective Dose versus Downwind Distance for DBF 3A

Downwind Distance (m)	Effective Dose (mSv)		
	Adult	Child	Infant
50	24.9	31.5	36.2
100	18.6	23.6	27.3
150	5.8	7.4	8.6
200	3.7	4.8	5.5
250	3.0	3.8	4.5
300	2.5	3.2	3.7
350	2.1	2.7	3.1
400	1.8	2.3	2.7
450	1.5	2.0	2.3
500	1.3	1.7	2.0
Interpolated Distance to 5 mSv (m)	169	195	226

Table 2: REPPIR 5mSv Dose Contour – Effective Dose versus Downwind Distance for BLDBF-6

Downwind Distance (m)	Effective Dose (mSv)		
	Adult	Child	Infant
50	4.9	8.0	10.4
100	3.1	5.1	6.6
150	2.2	3.6	4.7
200	1.7	2.7	3.5
250	1.3	2.1	2.8
300	1.1	1.7	2.2
350	0.9	1.4	1.9
400	0.8	1.2	1.6
450	0.7	1.1	1.4
500	0.6	0.9	1.2
Interpolated Distance to 5 mSv (m)	<50	104	141

3.1.15 p) an assessment of the necessity for an emergency plan to be prepared by the operator...

As a result of the assessments carried out by EDF Energy, and reported in sections 3.1.13 and 3.1.14 above, it is apparent that the Reference Accident (the reasonably foreseeable accident with the largest consequences offsite) would result in an effective dose of 5mSv in a 12 month period, and would therefore be classed as a Radiation Emergency under the REPPiR regulations. As a result of this definition, an Operator's Emergency Plan is required under REPPiR. Notwithstanding this assessment, EDF Energy is also required under the Site Licence to prepare an Operator's Plan.

4 Definitions

AGR	Advanced Gas-cooled Reactor
ALARP	As Low As Reasonably Practicable
BLDBF	Bounding Limiting Design Basis Fault
CTO	Chief Technical Officer
DBF	Design Basis Fault
DECC	Department of Energy and Climate Change
DEPZ	Detailed Emergency Planning Zone
EPCC	Emergency Planning Consultative Committee
ERL	Emergency Reference Level
HIRE	Hazard Identification & Risk Evaluation
HS&E	Health Safety & Environment
HSWA	Health & Safety at Work Act 1974
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
LDBF	Limiting Design Basis Fault
LOCA	Loss of Coolant Accident
NEAF	Nuclear Emergency Arrangements Forum
NEPDC	Nuclear Emergency Planning Delivery Committee
NEPLG	Nuclear Emergency Planning Liaison Group
NIO	Nuclear Inspection and Oversight
NSC	Nuclear Safety Committee
OD	Ordnance Datum
ONR	Office for Nuclear Regulation

PHE-CRCE	Public Health England – Centre for Radiological and Chemical Hazards
PSR	Periodic Safety Review
PWR	Pressurised Water Reactor
RCCA	Rod Cluster Control Assembly
REPIIR	Radiation (Emergency Preparedness and Public Information) Regulations 2001
RoA	Report of Assessment
SAP	Safety Assessment Principles
SZB	Sizewell B
TAG	Technical Assessment Guide
WENRA	Western European Nuclear Regulators' Association

5 References

- 1 Sizewell B Public Inquiry: Para 42.21 of Inspector's Report
- 2 ISBN 978 0 7176 2240 5 A guide to the Radiation (Emergency Preparedness and Public Information) Regulations 2001 – Guidance on Regulations. Health & Safety Executive. 2002.
- 3 Japanese earthquake and tsunami: Implications for the UK Nuclear Industry by HM Chief Inspector of Nuclear Installations – Interim Report (May 2011).
- 4 Japanese earthquake and tsunami: Implications for the UK Nuclear Industry by HM Chief Inspector of Nuclear Installations – Final Report (September 2011)
- 5 IAEA International Fact Finding Expert Mission of the Fukushima Dai-ichi NPP Accident following the Great East Japan Earthquake and Tsunami. June 2011.
- 6 T/AST/082 – Issue 1 Technical Assessment Guide: The Technical Assessment of REPPIR Submissions
- 7 SXB-IP-772001-514. Issue 100. Sizewell B Station Safety Report. April 2009.
- 8 <http://www.metoffice.gov.uk/climate/uk/ee/print.html> viewed 13/09/2013
- 9 SZB EM HBK SEC 1 Sizewell B Emergency Plan. 2010.
- 10 SZB/TRNG/SWB/100/1002C. 'Systems for Technicians – Primary Circuit'. Nov 2008. Revision 001
- 11 SZB/TRNG/SWB/504/002 Rev 00. 'PWR Appreciation Course for Managers and Engineers – Refuelling and Fuel Route.
- 12 SXB-IP-772001-715, Issue 109, Station Safety Report, Identified Reference 13.3(2), Description of Criticality Assessment of the Fuel Route, Aug 2012.
- 13 **Sizewell Off Site Plan - Issue 3.5. 28 Feb 2017.** Suffolk County Council.

Appendix A Additional Information on the Assessment of the Reference Accident for Sizewell B

REPPIR requires operators to assess whether it is “reasonably foreseeable” that their installation could cause a “radiation emergency” and, if it could, to identify the maximum extent of the offsite area within which the public could be affected.

A “radiation emergency” is defined in REPPIR as an event which could cause a member of the public to receive an effective radiation dose exceeding 5 millisieverts (5mSv)⁴ over a period of one year as a consequence of the event. The REPPIR regulations stipulate that no account should be taken in the assessment of any potential dose reduction from countermeasures during the first 24 hours of the radiation emergency.

The stages of this re-examination of the position for Sizewell B are therefore:

1. To consider what potential radiation emergencies are “reasonably foreseeable” for Sizewell B and to identify the one with greatest potential offsite consequences. This is the event termed the “Reference Accident”. This part of the assessment is covered in Section 4.1.
 - a. The starting point in Section 4.1.1 is the conclusion from the previous REPPIR assessment. The position for potential radiation emergencies from fault sequences arising from equipment failures and from the impact of both internal hazards (e.g. a fire) and external hazards (e.g. an earthquake) are summarised.
 - b. In Section 4.1.2 potentially significant changes since the previous submissions that could conceivably affect the selection of Reference Accident for Sizewell B are considered. These include:
 - The impact of Periodic Safety Reviews of Sizewell B (these are carried out every 10 years under Site Licence Condition 15) and any other relevant developments in Sizewell B’s safety case over the intervening period since the last REPPIR submission.
 - The insights from the reports following the Fukushima accident in 2011, particularly those submitted to UK Government by ONR’s Chief Inspector.
 - ONR’s new Technical Assessment Guide published in August 2013
 - c. Section 4.1.2 sets out the conclusion of the first stage of this report and identifies “candidate” Reference Accidents for Sizewell B
2. The second stage of the assessment in Section 4.2 summarises the results of an evaluation of the potential offsite area within which effective doses could reach the REPPIR 5mSv/ year level for these “candidate” Reference Accidents. This information is used to substantiate the choice of Reference Accident from the “candidate” fault sequences considered.
 - a. Doses are evaluated using the conditions stipulated within REPPIR.

⁴ A dose of 5mSv in one year is around twice the average dose that is received in one year by people living in the UK due to exposure to natural and man-made (mainly medical) sources.

- b. In addition EDF Energy has confirmed that the critical dose for implementing urgent countermeasures would not extend further than area delineated by the REPPIR defined effective dose of 5mSv in a year.
- c. EDF Energy has then evaluated the distance to which food restrictions could be justified as this is relevant to the scale of wider offsite plans
- d. The conclusion of Section 4.2 is the identification of the appropriate Reference Accident under REPPIR for Sizewell B

Assessment

Stage 1: What is the worst “reasonably foreseeable radiation emergency” for Sizewell B?

The Health & Safety Executive (HSE) Guidance⁵ for REPPIR states at para 114:

“Some of the requirements of REPPIR are already covered by existing nuclear site licence conditions under NIA65. These include requirements relating to hazard identification and risk evaluation (covered by the safety case). In such cases, requirements complied with under nuclear site licence conditions should satisfy equivalent requirements in REPPIR.”

Under Site Licence Condition 14 a nuclear licensee is required to produce safety cases covering all aspects and phases of the operation of the site. The safety case documentation for Sizewell B produced to meet Licence condition 14 is extremely comprehensive and includes within it an assessment of many thousands of identified fault sequences covering a very wide spectrum of both likelihood and potential radiological consequence. The safety case for Sizewell B is a “live” body of work and is updated as and when modifications are made to the station or as the result of other developments or periodic reviews.

The assessment within this report follows HSE’s REPPIR Guidance quoted above by drawing on this comprehensive safety case material so as to satisfy the REPPIR requirement for hazard identification and risk evaluation.

The Sizewell B safety case divides fault sequences into those within and those outside (or beyond) the design basis. What these terms mean within the UK regulatory system and how the UK approach to using these concepts differs significantly from that applied in most other countries is explained in Appendix B.

Stage 1 of this reassessment identifies 2 fault sequences which are considered to be “candidates” for selection as the worst reasonably foreseeable radiation emergency for Sizewell B – i.e. the Reference Accident.

Summary of Previous REPPIR Assessment for Sizewell B

In previous REPPIR submissions for Sizewell B the worst reasonably foreseeable radiation emergency (or Reference Accident) was the most severe design basis fault sequence identified within the safety case submitted under the Site Licence. As explained earlier, this is the approach that was examined and endorsed during the two public inquiries of the 1980s and is the approach

⁵ A guide to the Radiation (Emergency Preparedness and Public Information) Regulations 2001 – Guidance on Regulations. Health & Safety Executive ISBN 978 0 7176 2240 5. 2002.

to defining the Reference Accident that is described within the 2011 reports⁶ to the UK Government from ONR that examine the lessons from Fukushima.

The justification for this approach comes from the UK licensing regime which requires the designer to take into account all those fault sequences that are reasonably foreseeable and provide mitigation for them to ensure that their offsite consequences are limited in scale and duration. It is not reasonable to impose requirements on the communities around nuclear power stations through the imposition of detailed emergency planning zones where those zones are determined by accidents so unlikely that they do not need to be taken into account within the design of the power station. Instead the detailed offsite planning is determined by the accidents identified within the safety case that lie within the design basis of the installation and are reasonably foreseeable. The UK principle of extendibility ensures that these detailed emergency plans also provide a basis for a larger scale response in the very remote event that was ever to be needed. This longstanding approach stems from the way the UK licensing system defines the design basis faults to be addressed. As Appendix B explains, this UK approach interprets the design basis concept differently from most other countries.

The safety case assessment for Sizewell B includes faults originating from equipment failures, faults or unavailability as well as from both internal and external hazards. Examples of internal hazards are fires and/or flooding arising from equipment faults, while external hazards include events originating from outside the site like earthquakes, extreme weather or aircraft crash. The design basis for these hazards is set at a level of severity consistent with a return frequency of once in 10,000 years. The power station is required to be designed so that it is robust against this level of hazard. This approach means that the offsite releases from hazards are by design constrained so they remain within the range of releases achieved for design basis faults that could result from equipment failure or faults.

There has been no specific consideration in previous REPIR submissions of the potential for radiation emergencies to originate from security incidents. The new ONR Technical Assessment Guide (TAG) suggests this potential cause of radiation emergency should be more explicitly considered in the submission and this guidance has been followed in this document. Although the conclusions of this assessment are provided, it should be noted that it is not possible to publish the detailed analysis due to its sensitivity.

The conclusion in previous REPIR submissions was that no Sizewell B design basis fault from either plant failures or hazards would give to a release exceeding the maximum permissible for "Dose Band 3" within EDF Energy's design safety criteria. As explained in Annex A, this is a scale of release that might be just large enough to warrant the evacuation of a member of the public who was present at the site fence during the accident and is a scale of release that would be likely to lead to a requirement for offsite sheltering and food restrictions within a limited offsite area.

The objective in previous submissions was to confirm that the Sizewell A REPIR release remained at that time appropriate for determining the scale of offsite emergency plans for the Sizewell site because it was significantly larger than the Reference Accident for the more modern B station. On this basis it was considered appropriate in previous REPIR submissions for Sizewell B to submit a bounding release equivalent to a hypothetical accident with consequences at the upper limit of "Dose Band 3" (in the knowledge that the REPIR 5mSv effective dose contour would not actually be determined by this release but by the A station Reference Accident).

⁶ Japanese earthquake and tsunami: Implications for the UK Nuclear Industry by HM Chief Inspector of Nuclear Installations – Interim Report (May 2011) and Final Report (September 2011)

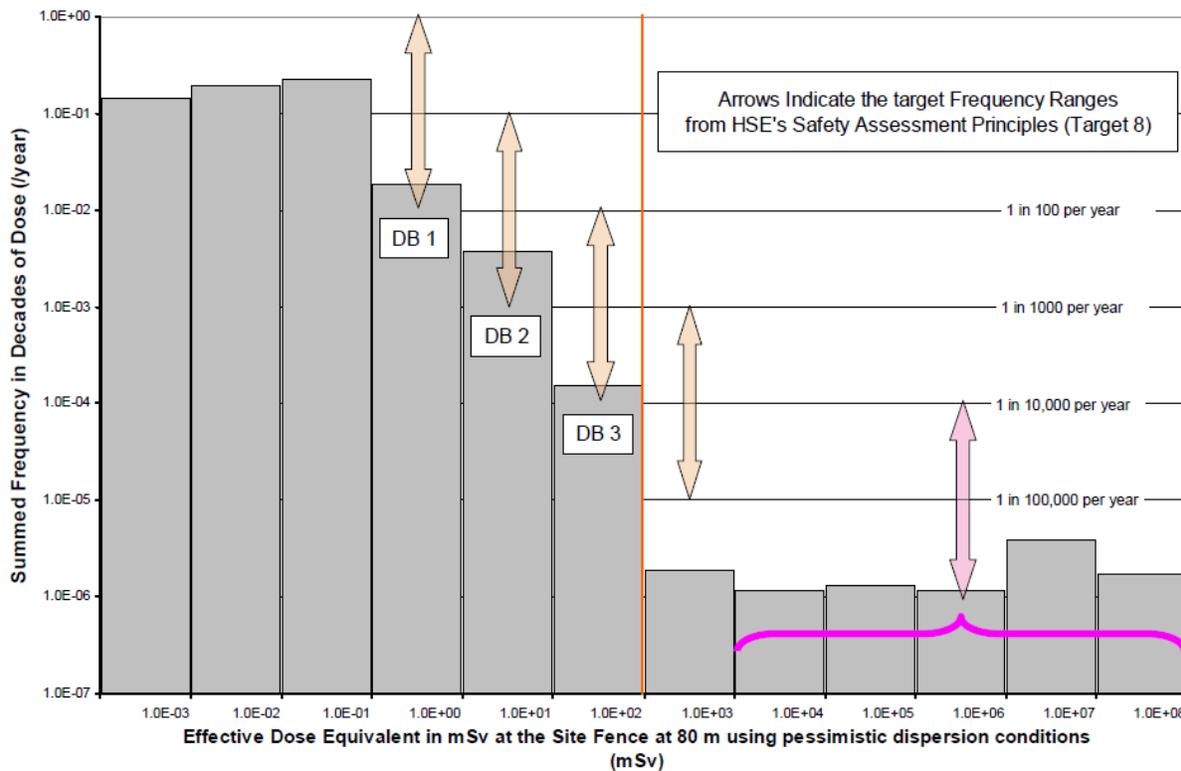
In this report the specific release, as evaluated in the safety case for the identified Sizewell B Reference Accident, is used.

Developments since the previous REPIR submission

Periodic Safety Review (PSR) and other safety case changes

The current assessment of Sizewell B potential fault sequences and their offsite releases is illustrated in the figure below. It should be noted that this figure is a log-log plot. This means that each scale division along either the vertical or the horizontal axis of the graph represents an increase (or decrease) of “times 10”.

The Figure shows the likelihood of an accident at Sizewell B occurring and leading to a release within a particular “dose band” (i.e. a range of severity in terms of the potential offsite radiation dose). The graph is the result of analysing many thousands of potential fault sequences covering a very wide range of likelihood and potential scale of radioactivity release and allocating each fault sequence to a “dose band”. The height of each of the grey bars in the figure represents the combined frequency of every fault sequence that could lead to a scale of release in that particular “dose band”.



Within the figure above are shown the 3 “dose bands” used in the assessment for Sizewell B. The design criteria set for Sizewell B was that no design basis fault sequence should lead to a release larger than the top of Dose Band 3 (DB 3 in Fig.1). The design aim was also to reduce the likelihood of very large scale releases of radioactivity (from fault sequences falling outside the design basis) to less than one chance in one million per year. (This is written as 10⁻⁶ or 1.0E-06 per year.) These design targets were largely achieved.

It can be seen from the figure that the likelihood (frequency) of accidents occurring that could lead to even larger offsite releases drops sharply for all the dose bands above Dose Band 3. This is a result of the measures taken in the design to avoid “cliff-edge” effects through ensuring that the frequency of beyond design basis faults with the potential to give rise to larger releases than would be “permitted” within the design basis have extremely low probabilities of ever occurring.

Also shown in the figure above are the targets which ONR asks its inspectors to use when assessing the acceptability of a design for licensing in the UK. The double-headed arrows show the range in “acceptable” frequency for various accident dose bands between the “Basic Safety Limit” and the “Basic Safety Objective”. It can be seen that the Sizewell B design meets and in some cases goes better than these ONR criteria.

The table below identifies the individual fault sequences and the Bounding Limiting Design Basis Fault (BLDBF) sequences responsible for the largest releases within Dose Band 3. It should be noted that, among these, the fault Coded “3A” in the table below is the individual fault sequence assessed to have the highest frequency at $2.8E-06/y^7$ or 1 chance in 300,000 per year. The BLDBF with the assessed highest frequency is BLDBF-6. A BLDBF actually represents a number (typically more than 10) of individual fault sequences all of which could result in a similar offsite release. In the case of BLDBF-6 all the individual fault sequences represented by it together have a combined frequency of $2.5E-06$ or 1 chance in 400,000 per year.

Code	Description	Freq. (/year)	Dose (ERL)	Notes
Individual fault sequences				
3A	Loss of coolant following shutdown bypassing containment	2.8E-06	0.45	Candidate for Reasonably Foreseeable Accident
7C(DNB)	Leak of coolant bypassing containment	1.6E-10	0.40	Low frequency - 1 hour release so bounded by 3A
6A	Loss of coolant following shutdown bypassing containment	1.2E-06	0.34	Bounded by 3A
Bounding Faults (i.e. representing many individual fault sequences)				
BLDBF-2	Large Loss of Coolant Accident (LOCA); iodine filters not working	1.2E-06	0.53	Bounded by BLDBF-6
BLDBF-4	Medium LOCA; iodine filters not working	1.9E-06	0.60	Bounded by BLDBF-6
BLDBF-6	Intermediate LOCA; Fuel Failures, iodine filters not working	2.5E-06	0.64	Candidate for Reasonably Foreseeable Accident
BLDBF-9	Intermediate / Small LOCA; No Fuel Failures Degraded reactor building isolation	2.3E-05	0.40	Candidate for Reasonably Foreseeable Accident

⁷ “2.8E-06/y” is scientific notation meaning 2.8×10^{-6} per year or chances of 2.8 in a million per year

Code	Description	Freq. (/year)	Dose (ERL)	Notes
BLDBF-2	Large / Medium / Intermediate LOCA at Intermediate Shutdown, Fuel Failures; iodine filters not working	3.6E-06	0.43	Candidate for Reasonably Foreseeable Accident
BLDBF-4 (DNB)	Major depressurisation in secondary circuit with fuel failures; (assumes no circuit activity retained)	3.6E-06	0.44	Candidate for Reasonably Foreseeable Accident
BLDBF-10(ii)	Fire involving radioactive materials	1.0E-08	0.44	Very Low frequency - Conservative assessment
BLDBF-11(i)	Fire involving radioactive materials	1.0E-08	0.44	Very Low frequency - Conservative assessment

The data in this table are extracted from a supporting technical report with the fault descriptions simplified to enable the information to be published in the public domain. The radiation doses are expressed as fractions of the lower Emergency Reference Level (ERL) of dose for evacuation⁸. The descriptions of the individual accidents have been simplified to enable this information to be shared publicly.

The frequency of accidents that could give rise to greater offsite consequences than the worst design basis faults listed above has also been examined. This showed that in the dose bands covering beyond design basis fault sequences there is no single fault sequence at or above a frequency of 1E-07 or 1 chance in 10 million per year and most fault sequences are significantly less likely even than this. At ONR's request EDF Energy has also confirmed that there is no dominant initiating event or hazard which would make a group of similar beyond design basis fault sequences a potential candidate for consideration as Reference Accident.

The conclusion from this is that there are no accidents whose assessed likelihood is sufficient for them to be considered as "reasonably foreseeable" and whose consequences lie in the bands of release that extend beyond the scale of the most severe design basis faults. This means that the Reference Accident (or worst reasonably foreseeable accident) lies within Dose Band 3 of Figure 1. The 5 "candidate" individual or bounding limiting design basis fault sequences are therefore those identified within the Table above. Of these 5 candidates the two largest offsite releases are:

- The **individual fault sequence** due to a loss of coolant following shutdown bypassing the primary containment (Code 3A in the Table)
- The **bounding fault sequence** involving an intermediate loss of coolant accident; fuel failures, with iodine filters not working (Code BLDBF-6 in the Table). It should be noted that this bounding sequence actually represents a number of individual faults (typically more than 10) which could give rise to similar offsite consequences.

⁸ ERLs are strictly the levels of dose averted for which a particular countermeasure, such as evacuation, is judged to be worthwhile. Therefore, if the total dose from an accident is less than the ERL for evacuation, implementation of that countermeasure is unlikely to be justified.

Either of these could be chosen as the Reference Accident given that each is larger than all other releases within Dose Band 3.

The analysis above is based on the UK approach to identifying and assessing the design basis faults for Sizewell B. The next Section examines whether there is any reason to change this UK approach as a result of the lessons from Fukushima.

The lessons from Fukushima

There are many lessons from this serious event. This section of the report considers whether the occurrence of the Fukushima accident in Japan calls into question the approach to fault analysis utilised both in UK nuclear licensing and within previous REPPiR submissions in a way that could affect the selection of the Reference Accident for Sizewell B.

The occurrence of the serious accident at Fukushima in 2011 did lead *inter alia* to a review of the UK “design basis” approach to delivering safety as this was one of the issues ONR considered in their report to the UK Government. ONR’s conclusions on this aspect are given below:

On pages (v) and (vi) of the Executive Summary:

“The IAEA fact finding mission remarked on the inadequacies of the design basis for tsunamis (at Fukushima). Further, in their report to IAEA, the Japanese government openly acknowledges that the design for tsunami was inadequate and that there were deficiencies in the design basis for tsunamis. Our approach differs from the Japanese as we use a goal setting approach rather than a purely deterministic, prescriptive, methodology. It is clear that in the development of its Safety Assessment Principles (SAP), ONR Inspectors anticipated potential combinations of events, such as those that occurred at Fukushima 1, and the UK consequently has a robust, structured and comprehensive methodology for identifying design basis events.

Conclusion FR-1: Consideration of the accident at Fukushima against the ONR Safety Assessment Principles for design basis fault analysis and internal and external hazards has shown that the UK approach to identifying the design basis for nuclear facilities is sound for such initiating events.”

And at para 742 of the main report:

“The Japanese regulatory system has features that are fundamentally different to those in the UK, including a much more prescriptive approach, a different approach to design basis and periodic review of safety for older plant, and the regulator being part of a central government department. Having considered these differences and other matters, our view remains that the basic philosophy of nuclear safety regulation and the system of regulation in the UK is robust and the further information we have received about the facts surrounding the Fukushima accident reinforces this view. This view is endorsed by the conclusions of independent peer reviews of the UK regulatory system at the review meetings of the various international conventions as well as the two IAEA review missions. We therefore consider Conclusion IR-5 of our Interim Report remains valid:

Conclusion IR-5: Our considerations of the events in Japan, and the possible lessons for the UK, has not revealed any significant weaknesses in the UK nuclear licensing regime.

On this basis the Fukushima accident provides no reasons therefore to depart from the past approach to identifying the worst reasonably foreseeable radiation emergency for Sizewell B (and other licensed installations). That past approach is built on the licensing approach applied within the UK with its rigorous identification of the likelihood and consequences of potential design basis faults – an approach which ONR’s report to UK Government concluded remains sound in the light of Fukushima.

The new Technical Assessment Guide (TAG) issued by ONR

ONR's new Technical Assessment Guide (T/AST/082) has been published since the last Sizewell B REPPiR submission. This section of the report addresses some of the questions it suggests ONR assessors should consider when evaluating REPPiR submissions and their identification of the Reference Accident.

Identifying what is "reasonably foreseeable" (paras A18-A22 of TAG)

The safety case for Sizewell B uses a combination of deterministic and probabilistic approaches (as is recommended in ONR's Safety Assessment Principles (SAPs)⁹). This applies to the selection of initiating faults and the consideration of subsequent failures within fault sequence analysis. The extremely comprehensive safety case assessment for Sizewell B provides a sound basis for REPPiR; it examines many thousands of individual fault sequences (covering a range down to predicted frequencies far below the $10^{-6}/y$ (one chance in one million per year) figure quoted in the TAG).

Uncertainty in technical risk assessments (para A24 of TAG)

The safety cases on which the selection of the Reference Accident is based do address uncertainties. This is a requirement of the UK licensing approach. The approach generally is to use a conservative¹⁰ approach in situations where uncertainty makes it difficult to substantiate best estimate values. In such instances the safety case records that this has been done to prevent a misleading conclusion being taken. This is in line with the guidance given to ONR inspectors during their assessment of a license

"Cliff-edge" Effects (para A24 of TAG)

As explained in Annex A, the design criteria applied to Sizewell B resulted in an assessment of possible cliff-edge effects at the boundary of the design basis for the power station. ONR's SAPs also stipulate that ONR's own independent assessment of a licensee's safety case should include examination against this objective.

Figure 1 shows the impact of this approach. The effect is to require the designer to incorporate features which prevent a situation where there are accident sequences with predicted consequences significantly greater than those of the worst reasonably foreseeable radiation emergency at frequencies just below those of design basis faults. The sharp reduction in the frequency (likelihood) of releases leading to consequences above the maximum in Dose Band 3 is the result of this approach.

Reference Accident philosophy and common mode effects (paras A27-A30 of TAG)

This report has used the term "Reference Accident" to signify the "worst reasonably foreseeable radiation emergency" (as para A28). As suggested in para A29, the approach does include consideration of more than one "candidate" so as to ensure that the consequences of the accident chosen do bound those of all others that are reasonably foreseeable.

Common cause failures are an important consideration within Sizewell B's safety case. The design uses the principles of "diversity" (i.e. safety equipment that uses different principles, energy sources etc.) and "separation" (i.e. ensuring that where reliance is placed on redundant (duplicated, triplicated, etc.) safety systems, the relevant equipment, and its cabling, pipework, etc. is physically separated). In addition the analysis imposes a limit (the "common mode failure cut-

⁹ Safety Assessment Principles for Nuclear Facilities (Rev 1). Published by HSE.

¹⁰ In the context of a safety case a "conservative approach" means that the assumptions made in areas of uncertainty will tend to exaggerate the likelihood and/or the consequences of a fault

off”) on the level of reliability that can be claimed from providing safety through redundant systems utilising the same equipment.

Review of operations and safety case for potential radiation emergencies (paras A31-A32 of TAG)
Sizewell B does possess a “modern safety case” and, as referred to in this report, this has been subject to Periodic Safety Reviews that have updated the safety case as appropriate. This has been taken into account in this report.

The full range of potential accidents is examined within the safety case and the documentation of this has been submitted to ONR as required by the site licensing arrangements.

Unauthorised behaviour of employees or the public (paras A33-A34 of TAG)

EDF Energy interprets this part of the TAG to mean that it is necessary to consider the potential for sabotage or terrorism to lead to a radiation emergency. These risks are not explicitly assessed within the fault analysis referred to above but they are taken into account in other ways.

The key question is whether a security incident could occur that is sufficiently likely to be classed as “reasonably foreseeable” and which could lead to even more serious offsite consequences than the worst reasonably foreseeable radiation emergency derived from the safety case analysis?

Although a security incident presents a different type of initiator to equipment failures or faults, operator errors, or internal and external hazards, the issues that determine whether an offsite release could occur as a result, and, if it could, how big any release might be, are the same. For example, a release will not occur if at least one physical barrier to the release is maintained. This is as true of an event initiated by sabotage as it is of a fault sequence initiated by a major item of plant failing.

The approach taken to assessing this area was:

1. To take advice from those in the security services on the maximum scale of the threat
2. For those individuals with a knowledge of the security features provided at Sizewell B to consider this scale of threat and assess what scale of equipment damage or disabling could result
3. To consider what potential scale of radiological consequence could result from this degree of plant damage and compare this to the potential consequences from faults arising from other initiators that could involve a comparable degree of physical disruption and damage

EDF Energy has carried out this assessment by involving the small number of individuals who advise on these matters. For obvious reasons it is not possible to provide more details of this assessment publicly. The conclusion from this work was that there is no reasonably foreseeable security event at Sizewell B that could result in a greater offsite release than would arise from the most severe fault sequences already included within the design basis assessment of the plant.

4.1.2.3.7

Tailoring of the Operator’s Technical Assessments for HIRE Reports (para A35 of TAG)

A modern standard approach (taken from the Safety Case) has been applied to the analysis whose results are reported in this document.

4.1.2.3.8

Safety Measures that Reduce the Likelihood of Accidents and/or Radiological Consequences and Best Estimate Analysis (paras A36-A37 of TAG)

The TAG states that a suitable best estimate rather than conservative¹¹ approach should be undertaken where possible so as not to result in emergency planning whose extent is unwarranted. As explained within Annex A to this report, the Sizewell B safety case includes assessment of many thousands of individual fault sequences. It is not possible to apply best estimate methods to the assessment of either the likelihood or the radiological consequences of each of these faults.

As the Annex sets out, one of the techniques used to simplify assessment is the grouping together of those fault sequences that could result in similar offsite releases and then representing all these similar releases by a single bounding fault whose release is equivalent to the largest consequence fault within the group and whose likelihood is the summation of the likelihood all the individual faults it represents. This approach does lead to some conservatism but greatly reduces the amount of analysis.

A further technique for some similar faults is to oversimplify the range of potential sequences. An example is the analysis of potential faults which could occur during the movement of irradiated fuel. The consequences from such faults depend on both the degree of damage to the fuel and the location of the fuel along the fuel transfer route at the time of the damage. To simplify analysis and derive a bounding value of possible risk, it is assumed that the worst degree of damage occurs at the worst location even these two “worst case” conditions could not in practice occur together. The effect of these analytical approaches is that the scale and likelihood of the Reference Accident identified in this report is likely to be conservative. It is the Licensee’s view, however, that this conservatism should not in practice lead to disproportionately extensive planning.

The Identification of a Radiation Emergency (paras A38-A40 of TAG)

This analysis reported within this document does address the REPPiR 5mSv effective dose contour and examines the significance of faults with different release durations. No credit is taken for countermeasures – either within the first 24 hours, or beyond that period. All relevant REPPiR-defined assessment characteristics have been used.

Screening Analysis for Multi-Facility Sites (para A41 of TAG)

Sizewell B’s safety case covers all potential sources of radiation emergency on the site (including the reactor, the spent fuel facility, and the radwaste facilities). No screening analysis is therefore required.

Multiple Releases at a single site and Adjacent Nuclear Sites (paras A44-A45 of TAG)

At Sizewell B the fault analysis takes into account the potential effects of the neighbouring A station. Common cause failures are also covered in the safety case.

Addressing uncertainty (paras A45-A47 of TAG)

The safety case analysis has been used to evaluate both the source term (the amount of radioactivity released and the characteristics of how that release could take place) and the likelihood of fault sequences. As explained above certain simplifying assumptions or methodologies in the safety case will tend to lead to a larger release source term and release likelihood than would be derived on the basis of a purely best estimate approach (were that to be practicable). The probability that the 5mSv REPPiR effective dose contour is underestimated for the Reference Accident is, on this basis, assessed to be very low.

The UK criteria requiring that a “cliff-edge” effect beyond the design basis is prevented through design makes it unlikely that there are any reasonably foreseeable fault sequences that could give

¹¹ In the context of a safety case a “conservative approach” means that the assumptions made in areas of uncertainty will tend to exaggerate the likelihood and/or the consequences of a fault

rise to a significantly larger release than the Reference Accident. This has been confirmed by examining the potential fault sequences that contribute to releases up to around 10 times the Reference Accident release.

Determining the size of the Detailed Emergency Planning Zone (paras A48-A50)

This report does not present EDF Energy's view on where the centre of the DEPZ (or other offsite planning areas) should be located. At the Sizewell site this would depend on the assessment of reasonably foreseeable radiation emergencies for both the A and B sites. This matter can therefore best be determined by ONR.

EDF Energy's view is that the radius or, if not circular, the boundary of the offsite emergency planning area should reflect both the reassessed risk from the two nuclear installations and the local geographical factors at Sizewell.

As a result of changes in the safety case since Sizewell B was originally licensed (due to plant experience and operating regimes, changes in radiological assessments, etc.), both the assessed likelihood and potential scale of Sizewell B's Reference Accident has reduced somewhat. The A station risk has reduced substantially due to the station's shutdown and the progress on decommissioning. As a result there is therefore scope for ONR to consider whether a reduction in the scale of the current offsite plans is warranted.

EDF Energy's view is that the benefits of any reduction in the areas included within the offsite plan should be considered in terms of the potential to relax any local planning constraints that are no longer justified; ONR should also take into account the importance of communicating to the local community the fact that the level of risk from the nuclear installations at Sizewell has reduced. These benefits should then be weighed against the views of the local community on moving away from the offsite plans that may have become familiar to them over the nearly 50 years they have been in place at Sizewell.

Extendibility (paras A51-A54 of TAG)

Extendibility has long been a principle within UK nuclear emergency planning. To support this principle, the scope of detailed planning developed on the basis of the Reference Accident needs be sufficient to provide the basis from which a more extensive response could be implemented in the very remote event that this ever became necessary. The more extensive response would use the framework developed in the detailed planning but would also call on wider contingency planning and resources.

EDF Energy considers that detailed planning based on the Reference Accident proposed in this report should provide a sound basis from which a more extended response could be developed.

Generic HIRE Assessment (para A55 of TAG)

This report is intended to apply to Sizewell B and is not generic.

The Candidate Reference Accidents for Sizewell B

On the basis of the analysis reported above, the candidate fault sequences for selection as the REPPiR Reference Accident for Sizewell B are those plant faults within Dose Band 3 that result in the largest offsite release of radioactivity. Referring back to Section 4.1.2.1 those are:

- The **individual fault sequence** due to loss of coolant following shutdown bypassing containment (Code 3A in the Table)
- The **bounding fault sequence** involving an intermediate loss of coolant accident; fuel failures, with iodine filters not working (Code BLDBF-6 in the Table) NB This bounding sequence actually represents a number of individual faults (typically more than 10) which could give rise to similar offsite consequences.

It is not possible to judge which of these “candidate” Reference Accidents will result in the most extensive 5mSv effective dose contour without carrying out a specific assessment using the REPIR parameters. This assessment is reported in the Technical Report that supports this document with the results of the assessment summarised below.

Stage 2: Evaluation of the offsite consequences of the “candidate” Reference Accidents

This part of the report examines the offsite radiological consequences of the “candidate” Reference Accidents in terms both of the 5mSv REPIR effective dose contour and also the area within which the release could give rise to a need for short term or longer term countermeasures to be considered. EDF Energy believes this information is relevant to determining the areas within which members of the public would be affected and hence the areas to be covered by REPIR offsite plans and the provision of prior information on those plans.

The REPIR 5mSv Effective Dose Contour

Using the radiological consequences assumptions that are defined under REPIR, the maximum extent of the “5mSv in one year” effective dose contour for the critical age group is just over 230 metres downwind of the release point for the fault sequence “Code 3A” and 210 metres downwind for the fault sequence “BLDBF-6” (when contribution from ingestion in the first 24 hours is included).

Contours for equivalent doses

For both identified faults the maximum extent of the dose contours for an equivalent dose of 15mSv to the lens of the eye and an equivalent dose of 50mSv to the skin have been determined to be less than those of the 5mSv effective dose contours.

The Area Potentially Affected by Urgent Countermeasures

In the event that either of these candidate accidents occurred it would be necessary to assess whether urgent countermeasures were needed to protect the public. Urgent countermeasures such as sheltering, potassium iodate tablets, and evacuation are used to reduce exposure to airborne radioactive materials and should be introduced quickly for maximum effect. The Emergency Reference Levels (ERLs) provide guidance as to what level of dose saving is sufficient to justify the use of each of these countermeasures.

An assessment has therefore been made of the maximum distance to which the lower ERL of dose for sheltering or stable iodine tablet issue could be exceeded in the event either of these two faults were ever to occur. For the fault sequence “Code 3A” the maximum distance is estimated to be around 320 metres (lower ERL for sheltering). For fault sequence “BLDBF-6” the maximum distance is slightly larger at around 527 metres (lower ERL for stable iodine tablet issue). The difference between the two candidate faults is a result of the different proportions of particular radioactive materials within the release.

The Area Potentially Affected by Longer Term Countermeasures

In the event that either of these accidents occurred it would be necessary to consider what other longer term countermeasures could be justified. These would include the potential for restrictions over consumption of locally produced food and the need to relocate people from areas where, over a prolonged period of time, they might otherwise accumulate a significant radiation dose from deposited radioactivity.

For these accidents it would be the potential restrictions on locally produced food that would extend furthest. The European Community has agreed Community Food Intervention Levels (CFILs) that would be introduced in the event of an accident. EDF Energy has used these to determine the maximum extent to which it might be necessary to introduce restrictions on locally produced food.

Fault	Distance to which CFIL could apply (km) ¹²	
	Milk	Green Vegetables
Code 3A	11	36
BLDBF-6	24	26

Conclusion of Consequences Assessment

Although the offsite radiological consequences of the two candidate fault sequences are different in detail, these differences are not so great as to make one obviously more suitable for selection as the Reference Accident than the other. EDF Energy proposes the fault sequence Code 3A as Reference Accident on the grounds that it results in the largest distance for which the REPPiR 5mSv/y effective dose contour would be exceeded and is also a more rapid release. This was also the fault sequence described as the Reference Accident within the evidence presented to the Hinkley Point C Public Inquiry in 1989. The scale of release and other characteristics of this fault sequence make it an appropriate Reference Accident in particular for the development of urgent offsite countermeasures and assessing the areas where such protective actions could be justified. With the conservative assumptions EDF Energy has applied in its analysis, the Code 3A release would also lead to a somewhat greater area being affected by food restrictions.

¹² The distances in this table are likely to be overestimates because of the very cautious assumptions made.

Appendix B An explanation of how the design basis is defined for Sizewell B through application of the UK approach to licensing

This Appendix sets out why using the Sizewell B safety case and specifically the design basis and beyond design basis fault analysis provides a sound approach to determining the REPPiR “reasonably foreseeable” radiation emergency.

History

At the time of the Sizewell B and Hinkley Point C Public Inquiries during the 1980s the worst reasonably foreseeable radiation emergency (i.e. the Reference Accident) for the Sizewell B design was explained to be the design basis fault sequence with the greatest offsite impact. This was the evidence both of the future operator and its independent safety regulator (ONR’s predecessor, the NII).

Having examined the arguments presented together with evidence from organisations and individuals who challenged this idea, both these Inquiries supported the choice of Reference Accident and the approach to selecting it put forward by the NII and operator. The Hinkley Point C Inquiry also examined in some detail the legal meaning of the term “reasonably foreseeable” and concluded that the interpretation of it offered by both the operator, and by the UK nuclear safety regulator, was correct.

Subsequent REPPiR submissions for Sizewell B have maintained this approach and have linked the maximum reasonably foreseeable radiation emergency (the Reference Accident) to the design basis fault sequence identified within the safety case which could have the maximum offsite radiological impact. This approach is also the one described in ONR’s post-Fukushima reports to the UK Government¹³.

It is clearly important that there are no reasonably foreseeable fault sequences beyond the design basis that could have significantly greater offsite consequences. The section below explains why the analysis carried out for Sizewell B gives confidence in this respect over the selection of the Reference Accident. It also highlights some important differences between the UK approach to defining the range of design basis faults to be considered, and the use of the design basis concept applied in most other countries. This different UK approach is an important part of the justification of the Reference Accident choice for Sizewell B.

The Sizewell B Safety Case Analysis

The International Convention on Nuclear Safety¹⁴ states that the prime responsibility for the safety of a nuclear installation rests with the licence holder (Article 9). Unlike regulators in most other countries, ONR requires a nuclear plant licensee to set out why their design is acceptably safe and does not itself set out a list of prescriptive safety requirements which the licensee has to meet. UK licensees must assess their plant’s safety against criteria that they propose and do so in the knowledge that the safety cases they are required to produce will then be assessed by the independent regulator according to its own Safety Assessment Principles (SAPs).

¹³ Japanese earthquake and tsunami: Implications for the UK Nuclear Industry by HM Chief Inspector of Nuclear Installations – Interim Report (May 2011) and Final Report (September 2011)

¹⁴ The International Convention on Nuclear Safety established in 1994 through the UN International Atomic Energy Agency commits participating States to maintain a high level of safety by setting international nuclear safety benchmarks to which States subscribe.

The safety case for Sizewell B is therefore structured around the licensee's own criteria which are in turn based on the recommendations of the ICRP^{15,19} and have been found through experience to be broadly consistent with the principles employed by ONR in their own independent assessment of the plant's safety. The safety criteria were formulated to ensure that power stations which were designed so as to meet them could be constructed and operated nearer to urban areas than had previously been possible. Thus the "design basis" for the plant was linked to the Emergency Reference Levels (ERLs)¹⁶ for offsite countermeasures.

The approach taken is to divide possible fault sequences into those that are described as being within the "design basis" and those "beyond design basis". Design targets are set for each group of faults. Releases from faults within the design basis should not lead to radiological exposures at the site boundary exceeding the dose level defined within the ERLs that could justify the evacuation countermeasure. Faults which could lead to larger releases should be demonstrated to be extremely unlikely with a target for individual faults not to exceed frequencies above 10^{-7} per year (i.e. a chance of occurring of 1 in ten million). These are the beyond design basis faults.

It is important to note, however, that although the terms "design basis" and "beyond design basis" are used widely within the international nuclear community, their application within the UK as described above is different to the way these terms are used and understood in most other countries. This is explained further below.

Being able to distinguish between those fault sequences within and those beyond the design basis is important because it is neither sensible nor practicable to address every possible fault sequence at the design stage of a new nuclear power station.

In most countries (although not the UK) the design basis has, historically, been defined by the regulator. This is done through the regulator specifying a limited list of initiating events against which the plant must be adequately defended. The list of faults has developed from many years of experience and the philosophy is essentially that, provided the design can tolerate these faults, it will be acceptably safe overall. The design basis fault sequences are therefore defined by these initiating events and the protection designed against them.

The approach in the UK is rather different. In essence, it starts from the point that some fault sequences will be so improbable that the introduction of additional design measures to mitigate their consequences would not be justified. These fault sequences would then be "beyond the design basis". In the UK the fault sequences are not simply defined as single initiating events but are any sequence (i.e. combination of events) with a probability of greater than about 10^{-7} per year. This approach results in the UK design basis for Sizewell B including more complex multiple failure events that would not be addressed within the design basis approach adopted by most other regulatory systems.

It follows from this relatively simple philosophy that in the UK any fault sequence that is to be regarded as beyond the design basis must be shown to be so unlikely ever to occur that it can legitimately be excluded from the design basis in this way.

In addition it is necessary to show that for all the fault sequences that remain within the design basis that the level of radiological consequences is kept to an acceptable level by the design. In

¹⁵ International Commission for Radiation Protection

¹⁶ ERLs are strictly the levels of dose averted for which a particular countermeasure, such as evacuation, is judged to be worthwhile. Therefore, if the total dose from an accident is less than the ERL for evacuation, implementation of that countermeasure is unlikely to be justified.

addition, the scale of consequence that may be regarded as acceptable is dependent on the assessed likelihood of the fault. In the UK this means that many more individual fault sequences must be identified and assessed. It also means that the radiological consequences of these faults have to be shown not just to have been mitigated but to be kept to a level that is acceptable given the likelihood with which they are assessed to occur.

Even though the main thrust of the UK approach to beyond design basis fault sequences is to show them to be extremely improbable, this does not mean that the radiological consequences of these very low likelihood events are not considered within the safety case. Analysis of the potential impacts of beyond design basis fault sequences does form an important part of the assessment of Sizewell B as is explained below.

Objectives for Design Basis Fault Sequences

EDF Energy's criterion for all design basis fault sequences is to demonstrate that their consequences are limited and "acceptable" through the capability within the design to mitigate radioactive releases following their occurrence. This same approach is part of ONR's SAPs¹⁷ (see for example Target 4). The method adopted is to define 3 broad bands of radiological consequence and for each band to define the maximum acceptable frequency (i.e. likelihood) at which accidents in that dose band may occur. Under the UK approach many thousands of individual fault sequences were assessed for Sizewell B to show that the objectives of fault sequence frequency and offsite dose were met.

Within these criteria, the largest "acceptable" consequence for any design basis fault (i.e. the dose at the top end of dose band 3) is a dose that could just warrant the evacuation of the public on the assumption that the exposed individual was as close as they could be to the site. In the safety case this dose is calculated on the assumption that there is a person at the site fence throughout the release.

The philosophy underpinning this approach to safety is that so far as is reasonably practicable no design basis fault sequence should give rise to a release that could require a significant scale of urgent countermeasures to be triggered offsite. This design objective has been adopted in the UK since the mid 1970s and is now being adopted internationally under criteria developed within WENRA¹⁸ and adopted by the IAEA¹⁹ for new nuclear plants.

So as to make the task of analysing thousands of individual design basis fault (DBF) sequences manageable, fault sequences which could lead to a similar scale of radiological release are grouped together. All these DBFs are then represented by a single limiting design basis fault (LDBF) sequence whose release is similar to but bounds all those DBFs. The likelihood of this LDBF is then the sum of all those DBFs it represents. A further process of grouping combines LDBFs that have similar release characteristics into a smaller number of bounding LDBFs (BLDBFs).

Objectives for Beyond Design Basis Fault Sequences

As explained above, the first requirement under EDF Energy's approach to safety assessment of fault sequences beyond the design basis is to justify their exclusion from the design basis.

As explained above this is a consequence of the UK's "goal-setting" rather "prescriptive" regulatory approach. Under a prescriptive approach the design basis is defined by the regulator through a list

¹⁷ ONR's Safety Assessment Principles (Rev 1) are available through their website

¹⁸ WENRA is the Western European Nuclear Regulators Association.

¹⁹ IAEA is the UN's International Atomic Energy Agency.

of initiating faults developed over years of regulatory experience. Under this approach, if a fault is not on this defined list and is one for which the design provides less than effective mitigation, then that fault is regarded as being beyond the design basis. That is not the approach used in the UK.

When Sizewell B was licensed the differences between the UK “goal-setting” and US “prescriptive” type of regulatory approach were brought into sharp focus. The starting point for Sizewell B was a standard US PWR design that had been developed against the US prescriptive definition of design basis. Applying the UK approach led to a requirement to address within the design of Sizewell B additional fault sequences that were not explicitly identified under US regulation. These additional fault sequences then became part of the design basis for Sizewell B.

The UK approach to safety also imposed a further design objective for fault sequences that are to be justified as being beyond the design basis. This is the requirement to avoid a “cliff edge” effect (i.e. a design where accident sequences just outside the design basis could potentially lead to very much greater offsite consequences than for design basis accidents). This additional element within the UK approach ensures that fault sequences that could have much larger offsite impacts than those of the worst design basis fault will only arise at significantly lower levels of likelihood than the Reference Accident.

Summary of the UK design basis approach applied at Sizewell B

- Sizewell B’s fault analysis is extensive. Many thousands of fault sequences have been considered spanning the full range both of fault likelihood and level of consequence.
- The Safety Case for Sizewell B divides fault sequences between those within and those beyond the design basis.
- The plant is designed so as to limit the releases from design basis faults. In addition to setting a target for the maximum offsite consequence, the criteria also set targets which limit the allowable frequency (likelihood) of fault sequences within 3 defined bands of potential offsite radiation dose.
- Fault sequences beyond the design basis could have potentially more serious consequences than design basis faults. These fault sequences must be demonstrated to be so unlikely that further design measures to reduce their consequences would not be justified. As a result these faults cannot include accidents that are “reasonably foreseeable”.
- Additionally it must be shown that there is not a “cliff-edge” with much greater offsite consequences predicted to occur from faults whose likelihood would place them just beyond the design basis.
- This UK approach to defining the design basis for Sizewell B goes further than other countries. It involves the analysis of many more fault sequences and has resulted in Sizewell B’s design basis extending to cover a wider range of faults than would generally apply elsewhere to a similar nuclear facility.
- It is the rigour of this approach that is an important part of justifying the selection of Sizewell B’s worst design basis fault as the worst reasonably foreseeable radiation emergency (or Reference Accident) under REPPiR.

Appendix C-E Section 3.14 - Redacted Information

NOTE: These sections are Protectively Marked 'Official Sensitive. They are removed from the main report. The Document Reference is SZB/TZR/015/APP, It is not accessible within CDMS or AMS. For access to the document contact the SZB, DCC Team Leader or EPE.