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AWE ALDERMASTON

AN EVALUATION OF THE DEGREE TO WHICH POTENTIAL ACCIDENTS WITH OFF SITE RADIOLOGICAL CONSEQUENCES OCCURRING AT AWE ALDERMASTON ARE A MATERIAL CONSIDERATION IN DEFINING THE OVERALL FUTURE PATTERN OF DEVELOPMENT OF TADLEY

CONFIDENTIAL

SEPTEMBER 2015

WSP | PARSONS BRINCKERHOFF

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Bloor Homes

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1 INTRODUCTION

1.1.1 The Town of Tadley is located in Hampshire on the border with Berkshire. It lies immediately to the south of AWE Aldermaston. During the 1950s and 1960s, AWE Aldermaston became the area's largest employer and a large number of houses were built in Tadley to accommodate workers at the site. However, because Tadley is located entirely within the Detailed Emergency Planning Zone (DEPZ) for AWE Aldermaston, it is difficult to obtain planning permission for new residential developments in the town, with implications also for other non-residential, e.g. retail and amenity, developments. In this note, I argue that the individual and societal radiological risks to residents of Tadley, while real, are so small that they should not be regarded as a significant factor when considering whether residential developments should be permitted. Furthermore, I also argue that a reasonable programme of such developments, provided that it does not grossly increase the overall population of Tadley and provided that some other practical considerations (such as maintenance of ready access of the emergency services to the AWE Aldermaston site) are addressed, should not adversely affect the off-site emergency plan that has to be put in place for AWE Aldermaston. This plan has to be reviewed and updated every three years and it should be straightforward to adapt it to a structured programme of developments in Tadley, rather than regarding the current plan as a straightjacket that severely constrains the potential for giving planning permission for residential and other developments within the DEPZ.

1.1.2 In this Technical Note, I first describe the regulatory framework within which developments in the vicinity of nuclear licensed sites are permitted (Section 2). I then estimate individual and societal risks to residents of Tadley from the site and show them to be small (Section 3). This naturally leads on to a discussion of the off-site emergency plan and its role in mitigating these, already small, risks, as well as the extent to which that plan might be adversely affected by a less restrictive approach to the granting of planning permission for developments within the current DEPZ (Section 4). Detailed conclusions from this review, supportive of the overall views that I have expressed in this introduction, are provided in Section 5, and references cited in the review are listed in Section 6.

2 REGULATORY CONTEXT

2.1.1 In broad terms, the two relevant considerations are those relating to controls on developments in the vicinity of nuclear licensed sites and those related to the development and maintenance of off-site emergency plans. Of course, these two considerations are interrelated, in that controls on development, imposed for whatever purpose, are a factor in determining the numbers and characteristics of individuals to whom the off-site emergency plan applies, while the requirements of the off-site emergency plan need to be taken into account as a material consideration when determining the acceptability of proposed developments. Nevertheless, historically these two topics have been handled somewhat differently, so it is convenient to present them separately.

2.2 DEMOGRAPHIC CONSIDERATIONS

2.2.1 In the UK, controls on residential and other developments in the vicinity of nuclear installations have always been closely related to the policy position that has been adopted relating to the siting of those installations. Furthermore, the guidance on siting was largely developed in respect to nuclear power stations and has been applied by extension to control developments in the vicinity of other types of nuclear installation, such as AWE Aldermaston.

2.2.2 Relevant documents giving details of the development of policy on the siting of nuclear installations in the UK comprise Marley and Fry (1955), Farmer (1960), Charlesworth and Gronow (1967), Gronow (1969; 1978) and Tildsley (1985). However, the most recent government statement of that policy as it relates to developments in the vicinity of existing nuclear power stations is that given by Mr Michael Spicer, Secretary of State for Energy (Hansard, 1988) and reproduced by Highton and Senior (2008). This statement is given in full below.

2.2.3 'Mr Michael Spicer: ...Once a site has been accepted for a nuclear station, arrangements are made to ensure that residential and industrial developments are so controlled that the general characteristics of the site are preserved, and therefore local authorities consult the inspectorate with regard to any proposed development which might lead to an increase in population close to the site and on large developments further from the site. Limiting criteria based upon population distribution are used only for guidance and the inspectorate would not necessarily insist on rigid adherence to them. Other unquantifiable factors are also taken into account.

2.2.4 The limiting criteria are in the form of cumulative weighted populations out to various distances all around the site and in any 30 degree sector. To assess a site against the criteria at a certain distance, the population for a given band distance is multiplied by the appropriate weighting factor and the values up to the distance being evaluated are added together.'

2.2.5 It is important to note that this statement is primarily a description of the then current practice by the Nuclear Installations Inspectorate rather than a direction to the Inspectorate.

2.2.6 Subsequently, the quantitative approach used to assess the significance of changes in population in the vicinity of a nuclear installation has been set out in detail by Highton and Senior (2008) and Highton (2008). However, it is important to emphasise that the Office for Nuclear Regulation (ONR) no longer adopts this quantitative approach to evaluating the significance of individual developments and would not conduct a demographic analysis for individual planning cases. Instead, ONR has advised that 'After receiving a request for consultation on a planning application, where the proposed development lies within a consultation zone around a nuclear licensed site, ONR would consider the following questions: a) Does the proposed development represent an external hazard to a nuclear installation; and b) Could the proposed development be accommodated within the Local Authority off-site emergency planning arrangements.' (Randles, 2014).

2.2.7 If ONR had significant health and safety concerns on either count then it would advise against the development. However, if ONR was satisfied that the proposed development could be accommodated within the Local Authority off-site emergency planning arrangements and that it posed no external hazard to the installation, then ONR would have no grounds to advise against (Randles, 2014).

2.3 OFF SITE EMERGENCY PLANNING

2.3.1 The development and implementation of an off-site emergency plan is a requirement under the Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPIR). REPPIR requires nuclear operators and local authorities to make and implement arrangements to ensure that the members of the public are properly informed and prepared in advance about what to do in the unlikely event of a radiation emergency occurring and provided with information if an emergency actually occurs. In respect of AWE Aldermaston, West Berkshire Council has the duty under REPPIR to prepare, revise, test and implement an off-site emergency plan (the on-site plan being the responsibility of AWE Aldermaston). The off-site plan is required to bring together the emergency arrangements of all the off-site agencies with a role to play in the intervention and mitigation of an emergency occurring at AWE Aldermaston, and to prepare arrangements to supply information to members of the public in the event of a radiation emergency actually occurring.

2.3.2 Currently the emergency arrangements required under REPPIR are based on (a) reference accidents and (b) the principle of extendibility. The reference accident helps define a Detailed Emergency Planning Zone (DEPZ), identified by the operator within which arrangements to protect the public by introducing countermeasures are planned in detail. For practical reasons the DEPZ can extend further to avoid, for example, splitting streets in half if one part of a street is inside the DEPZ while the other part is outside. The DEPZ corresponds to a zone in which the effective dose to an individual from the reference accident could exceed 5 mSv. In the case of AWE Aldermaston, calculations show that, on this basis, the DEPZ should have a radius of about 2 km (see Section 3 for details). However, for historical reasons and for the convenience of including all of Tadley within the DEPZ, the radius of the DEPZ is cautiously set to 3 km (see further the discussion in Section 3).

2.3.3 The reference accident is the worst reasonably foreseeable accident with radiological consequences against which it is considered reasonable to prepare detailed emergency plans. For emergency planning purposes the reference accident assumes that, during a release, a pathway occurs that allows radioactive material to escape uncontrolled into the environment.

2.3.4 Extendibility means that emergency plans need to be capable of responding to accidents, which, although extremely unlikely, could have significant radiological consequences beyond the boundaries of the DEPZ. The measures that are required to extend the detailed arrangements cannot be precisely planned because the nature and potential of accidents can vary. 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.

2.3.5 The current off-site emergency plan for AWE Aldermaston is set out in West Berkshire Council (2011). This plan was applicable through to November 2014 and discussions are ongoing as to its revision (Richardson, 2015a). However, the following description and discussion is based on the 2011 version of the plan. The associated REPPIR leaflet was last printed in 2013 (West Berkshire Council and AWE, 2013) and will be updated in accord with the revised off-site emergency plan, if this proves to be necessary (Richardson, 2015b).

2.3.6 Although West Berkshire Council is the Local Authority (LA) with overall responsibility for the development of the off-site emergency plan, it consults with a substantial number of other bodies who would have key roles in the implementation of the plan in the event of an accident with off-site radiological consequences. In particular, the most recent plan (West Berkshire Council, 2011) was prepared by the Off Site Plan Working Group, chaired by West Berkshire Council and consisting of Emergency Planning Officers and professionals drawn from the other organisations that are also copy holders of the plan. These include Basingstoke and Deane Borough Council.

2.3.7 In the event of an incident at AWE Aldermaston requiring implementation of the plan, co-ordination of the response would be the responsibility of Thames Valley Police in the first instance. However, they would transfer responsibility to other organisations in the later (recovery) stages of the incident.

3 POTENTIAL ACCIDENTS AT AWE ALDERMASTON WITH OFF SITE RADIOLOGICAL CONSEQUENCES

3.1 TYPES OF POTENTIAL ACCIDENTS

3.1.1 Potential accidents at the AWE Aldermaston site are discussed in the AWE Aldermaston Hazard Identification and Risk Evaluation (HIRE) together with the associated Report of Assessment (RoA) (AWE, 2011a; 2011b; see also AWE, 2012). In turn, these reports are reviewed by the Health & Safety Executive, Office for Nuclear Regulation (HSE, 2012). More recent data on potential accidents on the AWE Aldermaston Site are given in the REPPIR Report of Assessment for the AWE Aldermaston Site of November 2014 (AWE, 2014).

3.1.2 The HSE review (HSE, 2012) states that there are many facilities at the two AWE sites (Aldermaston and Burghfield) that handle a range of radioactive, explosive and chemical materials, which pose varying degrees of risk. The radioactive materials held and used at the premises include plutonium, uranium and tritium (see also AWE, 2014, Section 6 and Annex 1 of West Berkshire Council, 2011). These materials are held in sufficient quantities that the requirements of the Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPIR) apply and make a HIRE assessment required. There are other sources of radioactivity on the site. These are substantially less significant than those present in the main materials and are used for safety checks and normal industrial purposes (e.g. sources for radiography and in level gauges). These are well controlled, pose no threat to the public, and have no potential to give rise to a radiation emergency (AWE, 2012, paragraph 6.7 and AWE, 2014, paragraph 6.7).

It should also be noted that the off-site emergency plan (West Berkshire Council, 2011, paragraph 2.5.2) states that:

a. An explosion resulting in a nuclear yield is not possible by virtue of the safety features in the design of the weapon;

b. A reactor accident with off-site consequences is also not possible, as the site does not have an operating nuclear reactor with a significant core inventory of fission products;

c. The ‘Herald’ nuclear reactor at AWE Aldermaston was closed in the 1980s and its nuclear fuel removed from the site.

3.1.3 Operations at AWE are undertaken on a batch production basis, almost wholly during standard daytime working hours, with nuclear production materials stored securely overnight within the nuclear facilities. The AWE sites do not have a nuclear power plant (see above), nor do they hold stored nuclear fuel requiring decay heat removal. There are no bulk quantities of highly active liquors, irradiated reactor fuel or large quantities of high-level waste stored on either of the two sites (HSE, 2012). As HSE (2012) states, these considerations restrict the possibility of, and potential dose consequences arising from, a reasonably foreseeable radiation emergency at either site.

3.1.4 More specifically, AWE (2012, paragraphs 9.2 and 9.3 and 2014, paragraphs 9.2 and 9.3) provides a concise statement of the types of accidents that could give rise to significant off-site radiological impacts. That statement in AWE (2014) is reproduced in full below.

3.1.5 'The majority of identified potential faults will not result in any release of particulate radioactivity to the open environment, by virtue of the prevention, mitigation and protection provisions installed and maintained in each facility. For a significant release of radioactivity from a nuclear facility to be possible it is necessary for an initiating event to propagate and overcome all the barriers between the hazardous radioactive materials present inside the facility and the outside environment, or for these all to fail at the time of demand. These barriers have been designed to accommodate the form of the material itself, any cladding and all the containments. The physical boundary of the facility forms part of the containment system as well. Given that all of these barriers are breached, then some radioactivity could be transported out of the facility and be dispersed into the atmosphere. For many postulated accident scenarios this would be through a designed and authorised discharge point, so mitigation by appropriate filters would minimise the particulate release.

3.1.6 The most likely scenario in a facility which could have the potential to affect areas beyond the AWE, Aldermaston site boundary is a major fire. Such a fire might be caused by a seismic event or other significant insult to a facility or group of facilities. Only a major fire or fires (initiated as a result of a significant seismic event) engulfing a whole building or entire compartments within a building where significant quantities of radioactive material were present would have the potential to cause a radiological hazard to the public outside the site. The nature of fire accidents falls within the concept of accidents currently considered to be "reasonably foreseeable".'

3.1.7 Paragraph 9.4 of AWE (2014) adds that 'It is not reasonably foreseeable that the consequences of potential unauthorised behaviour of employees or the public would extend beyond the consequences of the accident scenarios assessed by AWE under regulation 4 of REPPIR.'

3.1.8 With respect to the pathways of significance in respect of such accidents, the HSE (2012) comments that AWE has concluded that direct inhalation of contaminants within a radiation plume is the dominant contribution. Other pathways, including ingestion and exposure by absorption through the skin, are generally considered negligible by comparison.

3.2 FREQUENCIES OF POTENTIAL ACCIDENTS

3.2.1 For its 2011 REPPIR submission, AWE Aldermaston adopted a reference accident approach to bounding the area that may be affected by a reasonably foreseeable radiation emergency. In this context, AWE adopted a definition of 'reasonably foreseeable' to include all fault sequences for which the associated dose has a return frequency of at least one in one hundred thousand per annum (HSE, 2012). AWE also examined fault sequences with a frequency of as low as one in a million per annum to establish whether there would be any stepped increases in dose consequences with the inclusion of these less frequent events. Within its HIRE, AWE also considered some even less frequent fault sequences with off-site consequences, but considered that these are not reasonably foreseeable for the purposes of detailed planning of the emergency response. However, such fault sequences are taken into account when considering the extendibility of the emergency plans.

3.2.2 In general, the frequency of accidents decreases as their severity increases. Therefore, the reference accident can be taken as exhibiting a frequency of around one in ten thousand per annum (the maximum return frequency for initiating seismic events, see Section 3.3) to one in one hundred thousand per annum.

3.3 RADIOLOGICAL CONSEQUENCES OF POTENTIAL ACCIDENTS

3.3.1 AWE categorises individual facilities according to the radiological hazard with which they are associated. Category 5 is defined as 'facilities or operations which are capable of yielding a significant off-site hazard at a level at which countermeasures (such as sheltering or evacuation) would be required...'. The term 'significant off-site hazard' is defined in the RoA (AWE, 2011b) as 'an off-site whole body effective dose ≥ 5 mSv at the nearest site boundary' (HSE, 2012).

3.3.2 More broadly, the Off-site Emergency Plan for AWE Aldermaston (West Berkshire Council, 2011, paragraph 2.6.4) states that accidents at the site should not exceed Level 5 on the International Nuclear Event Scale (INES) (see http://www-ns.iaea.org/tech-areas/emergency/ines.asp). Thus, it is determined that serious (Level 6) and major (Level 7) accidents (as can occur at nuclear power stations) cannot occur at AWE Aldermaston. Both the Chernobyl and Fukushima accidents have been classified as Level 7 events.

3.3.3 For each individual facility, the approach adopted in the HIRE is to initially assess the associated fault sequences to establish whether their off-site dose consequences are above the 5 mSv threshold. They are then screened by frequency to establish whether the events are reasonably foreseeable (i.e. have a probability of occurrence of more than one in one hundred thousand per annum). The reference accident for each facility corresponds to the reasonably foreseeable fault sequence that leads to the largest off-site dose consequence (HSE, 2012).

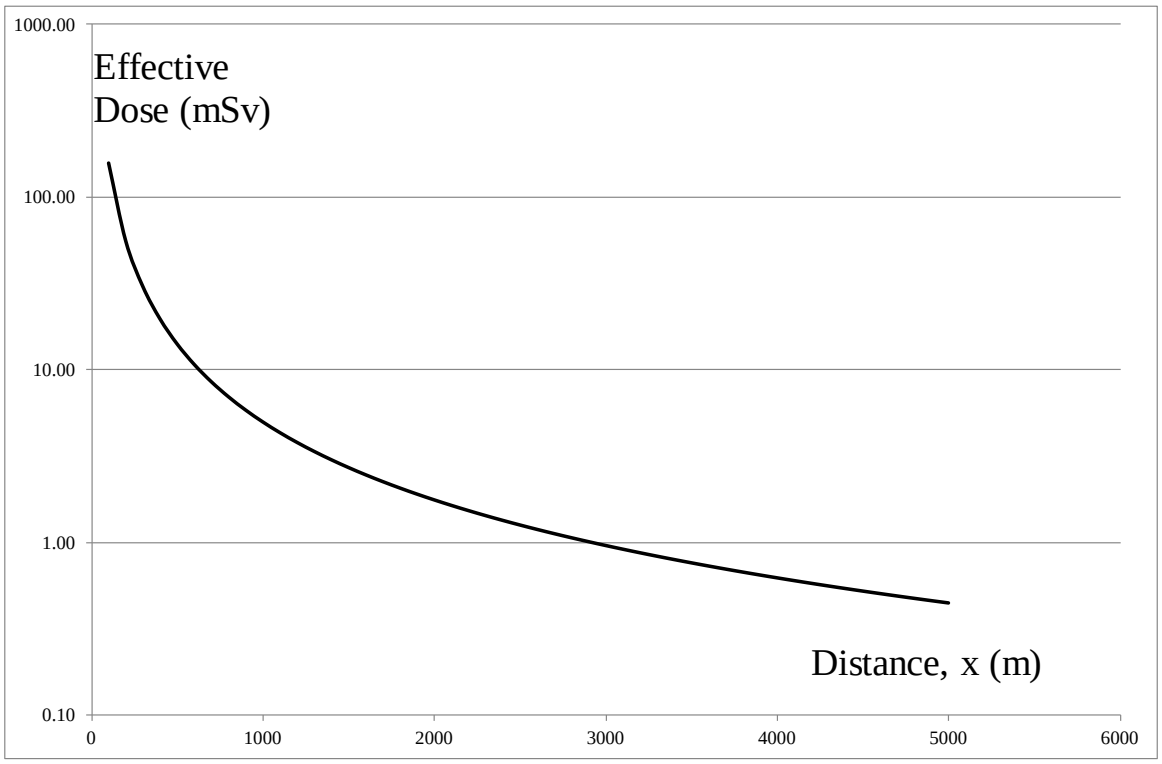
3.3.4 Four facilities on the AWE Aldermaston site were assessed as having the potential to result in off-site doses of more than 5 mSv and a bounding 5 mSv circular dose contour, centred on the facility concerned, was established based on the reference accident for that facility. The largest such dose contour had a radius of 1,035 m and the next largest had a radius of 950 m. The 5 mSv dose contours for the other two facilities were considerably smaller (HSE, 2012).

3.3.5 In order to account for common cause effects from extreme external events, the HIRE also presents an analysis that combines dose estimates from individual facilities. This relates to reasonably foreseeable fault sequences initiated by a seismic event (based on a return frequency of less than one in ten thousand years), which leads to radionuclide releases from two facilities, due to the common cause. For each pair of facilities, the most adverse wind direction was assumed and the dose contour was conservatively increased to account for the distance between the facilities and the nominal centre of the site. This gave an overall bounding 5 mSv off-site circular dose contour at 2,125 m from the AWE Aldermaston centre location (HSE, 2012), i.e. substantially less than the 3 km radius of the DEPZ (note that this value for the radius has been in use for a substantial period and is not based on the reasonably foreseeable accidents currently envisaged in assessments by AWE Aldermaston and accepted as appropriate by the ONR). More recently, AWE (2014) reports that '[t]he bounding reference accident for the AWE Aldermaston Site is a seismic event leading to consequential fires causing simultaneous loss of containment in multiple facilities with an unfavourable wind direction that would cause cumulative doses from two separate facilities' (AWE, 2014, paragraph 15.2). For such an accident '[t]he maximum foreseeable radiation dose that could potentially be received by a member of the public at the site boundary has been assessed by AWE as 16.9 milliSieverts [mSv].' (AWE, 2014, paragraph 15.3). Furthermore, 'AWE's assessments have concluded that the area in which a member of the public might potentially receive a radiation dose of up to 5 milliSieverts [mSv] as a result of a reasonably foreseeable radiation emergency at AWE Aldermaston is bounded by a distance of 1.925 kilometres from the centre of the existing DEPZ for the Aldermaston Site (National Grid Reference SU 595 635). These dose assessments include contributions from plume inhalation, and the inhalation of re-suspended radioactive material over the year following the release. Contributions from irradiation from the passing plume or from deposited material have been assessed as negligible and are not included in this assessment.' (AWE, 2014, paragraph 14.2). Note that the 5 mSv dose contour has decreased slightly from 2125 m to 1925 m in the 2014 assessment and that the centre of this circular dose contour is now assigned a precise geographical location.

3.3.6 AWE also considered the dose consequences from a number of severe infrequent fault sequences involving extreme external events that were not considered to be reasonably foreseeable. These led to a range of 5 mSv dose contours both within and beyond the current Detailed Emergency Planning Zone (DEPZ) which is circular with a cautiously defined radius of 3 km, with its origin at the site centre. On the basis of the 2011 HIRE (AWE, 2011a; 2011b), the HSE (2012) recommended that the ONR Emergency Arrangements Team should advise the Local Authority to adopt a circular DEPZ with a minimum radius of 2.125 km, with its origin at the site centre. However, subsequently, ONR discussed in detail with West Berkshire Council the consideration that a circular area of 2.125 km radius from the centre of the site would present a situation in which the technical basis for the DEPZ would cut through Tadley. This would present a significant issue in terms of delivery of the REPPIR emergency plan. Therefore, in terms of emergency planning and to ensure the protection of public and society in the event of radiation emergency, ONR considers it to be appropriate to set the DEPZ for AWE Aldermaston nuclear licensed site as a circular area of a distance of 3 km from the centre of the site (ONR, 2013), i.e. the value currently adopted in the off-site emergency plan (West Berkshire Council, 2011). However, the size of the DEPZ is a matter that is currently being reviewed in the context of updating the off-site emergency plan (Richardson, 2015a).

3.3.7 In interpreting this information relating to the 5 mSv dose contours, it is relevant to note the dose decreases according to a power law, $E = A/x^n$, where E (mSv) is the effective dose, A is a coefficient that depends upon the characteristics of the release, x (m) is the downwind distance and n is a coefficient that typically has a value of approximately 1.5 (Highton, 2008; Highton and Senior, 2008). Thus, for example, if the 5 mSv dose contour is at 1,000 m from the source, the 2.5 mSv dose contour will be at a distance x (m) given by $x = 1{,}000\times(5.0/2.5)^{1/n}$. For n = 1.5, this gives the 2.5 mSv contour at 1,590 m. More generally, the fall-off in dose with distance is as shown in Figure 3.1, normalised to 5 mSv at a distance of 1,000 m.

Figure 3-1 Variations of Effective Dose with Distance Downwind



3.3.8 Typically, the southern boundary of the AWE Aldermaston site, which is its distance of closest approach to Tadley is about 800 to 1,000 m from the centre of the DEPZ. Along this boundary, the effective dose from a reference accident is assessed as 16.9 mSv. The Town of Tadley lies mainly between this distance and the boundary of the DEPZ at 3,000 m from its centre. Applying the $1/x^n$ relationship described above, this results in an effective dose of about 4 to 6 mSv at 2,000 m from the centre of the DEPZ and about 2 to 3 mSv at 3,000 m. These results are in line with the recommendation described in paragraph 3.3.6, that the DEPZ should have a radius of 2,125 m, bearing in mind that the distance to the 5 mSv contour has recently been reduced from 2,125 m to 1,925 m (see paragraph 3.3.5).

3.3.9 For severe infrequent fault sequences (with a probability of occurrence extending to below one in one million per year), the 5 mSv dose contours were both within and beyond the current DEPZ with a radius of 3,000 m. Taking the 5 mSv contour typically to be at 3,000 m, worst case accidents, occurring with an annual probability of no more than about one tenth of that of the bounding reference accident, would typically result in a radiological impact no more than about a factor of two larger.

3.3.10 As the report on the Public Inquiry relating to the Boundary Hall development emphasised (Ware, 2011, paragraph 289), doses of this magnitude would only be received if the wind was blowing towards Tadley at the time of release. Furthermore, sheltering (which is the recommended emergency response, as discussed in Section 4) would substantially mitigate these doses and staying indoors, with the doors and windows closed, has been assessed to remove almost all the risk (Ware, 2011, paragraph 291). Similarly, AWE (2012, paragraph 15.5) comments that, in the event of a major release of radioactive material from the site, the dose to the public would be reduced by the imposition of appropriate countermeasures that could include the issue of instructions to the public to shelter (which reduces cloud inhalation and irradiation doses) and subsequently to evacuate (which prevents further exposure from resuspension of deposited material by moving the public from the affected area to facilitate recovery and remediation, as appropriate).

3.4 COMPARISON OF RISKS FROM POTENTIAL ACCIDENTS WITH THOSE OF EVERYDAY LIFE

3.4.1 Based on the analysis presented in Section 3.3, it is determined that bounding reference accidents giving an effective dose of 2 to 17 mSv to residents of Tadley located 800 m to 3,000 m from the centre of the AWE Aldermaston site could occur with a probability ranging from one in ten thousand ($1\ 10^{-4}$) per year down to one in one hundred thousand per year ($1\ 10^{-5}$) per year. Here, the convenient notation is used that 10^n means 10×10...×10, where n is the number of factors of ten. Similarly, 10^{-n} means 1/(10×10...×10).

3.4.2 For more extreme accidents, effective doses could range up to about a factor of two larger than for the bounding reference accident, but the likely frequency of such accidents would be no more than $1\ 10^{-5}$ per year and could be as low as $1\ 10^{-6}$ per year.

3.4.3 These effective doses are relatively low and are within the range that the linear dose response with no threshold (LNT) model generally applied in radiological protection (ICRP, 2007). That model assigns detriment-adjusted risk coefficients of $5.5\ 10^{-5}$ per mSv for cancer and $2.0\ 10^{-6}$ per mSv for heritable effects in the whole population (including infants, children and adults). Thus, the overall risk is $5.7\ 10^{-5}$ per mSv, which may be thought of as equivalent to the risk of death arising from the irradiation. Thus, for a bounding reference accident giving rise to an effective dose of 2 to 17 mSv, the risk conditional on that accident occurring is in the range $1.1\ 10^{-4}$ to $1.0\ 10^{-3}$, i.e. between about one in nine thousand and one in one thousand. Furthermore, as the annual probability of such an accident occurring is less than one in ten thousand, the annual risk of death from accidents up to and including the bounding reference accident in size is no more than about one in ten million (accidents substantially smaller than the bounding reference accident would not have significant off-site consequences).

3.4.4 For accidents, larger than the bounding reference accident, the effective dose could be doubled, corresponding to a conditional risk of between 2.3 10^{-4} and 1.9 10^{-3}. However, the annual probability of such an accident is no more than about one in one hundred thousand, so the annual risk of death is no more than one in fifty million.

3.4.5 The above risks make no allowance for the probability that the wind is blowing towards Tadley or of mitigation of the effective dose through sheltering.

3.4.6 Thus, overall, the annual probability of death for an individual living in Tadley due to an accident at AWE Aldermaston with significant off-site radiological consequences is assessed as less than one in ten million, and could be substantially less if the probability that the wind is blowing towards Tadley and mitigation of the effective dose through sheltering were taken into account.

3.4.7 For comparison, the HSE in its report Reducing Risks, Protecting People (HSE, 2001) has given annual risks of death from various causes. These include 1 in 16,800 from all forms of road accident, 1 in 29,000 from lung cancer caused by the radioactive gas radon in dwellings, 1 in 510,000 from a gas incident (fire, explosion or carbon monoxide poisoning) and 1 in 18,700,000 from lightning. From this comparison, it is clear that the annual probability of death for an individual living in Tadley due to an accident at AWE Aldermaston is likely to be similar to or less than the annual probability of being killed by being struck by lightning.

3.4.8 It is also relevant to note that, when assessing the significance of individual risks the HSE (2001) comments that it 'believes that an individual risk of death of one in a million per annum for both workers and the public corresponds to a very low level of risk and should be used as a guideline for the boundary between the broadly acceptable and tolerable regions. As is very apparent from Tables 1-4 at Appendix 4 [of HSE, 2001], we live in an environment of appreciable risks of various kinds which contribute to a background level of risk – typically a risk of death of one in a hundred per year averaged over a lifetime. A residual risk of one in a million per year is extremely small when compared to this background level of risk. Indeed many activities which people are prepared to accept in their daily lives for the benefits they bring, for example, using gas and electricity, or engaging in air travel, entail or exceed such levels of residual risk.'

3.4.9 Thus, the annual probability of death for an individual living in Tadley due to an accident at AWE Aldermaston is at least an order of magnitude below the boundary of the tolerable region, i.e. it is well within the region where the risk would be judged broadly acceptable. This conforms with the judgement of the Secretary of State in respect to the Boundary Hall development close to the southern boundary of the AWE Aldermaston site. In paragraphs 21 to 23 of his judgement, he concludes as set out below.

3.4.10 '21. [The] Secretary of State agrees … that, with the exception of those general LP policies dealing with pollution and environmental well-being, the application accords with the development plan including the site being identified in a saved LP policy for the type of development currently proposed (IR395). Furthermore, the site is in a sustainable location, the proposal would make good use of the land in both visual and sustainability terms and would provide planning benefits (IR396) including the provision of affordable housing and the replacement of community facilities...'

3.4.11 '22. Against these benefits, the Secretary of State agrees with the Inspector (IR398) that the sole objection relates to the potential effect on human health of a materially harmful radiation dose. However, while he does not seek to minimise the potential impact of any individual dose, the Secretary of State considers that this should be placed in the context of the probability of such a dose arising which, while unquantified, has been described as 'extremely remote' ... Added to this, he has taken account of the fact that there is no evidence that the Off Site Plan for dealing with such emergencies would fail; and he is satisfied that the intensification of population density is not, in itself, a reason to refuse planning permission.

3.4.12 '23. The Secretary of State considers that these factors temper the weight to be attached to the risk of a materially harmful radiation dose relative to the benefits of the proposed scheme. No activity can ever be regarded as being risk free, each case has to be considered on its own merits, and the Secretary of State concludes that the potential benefits of this scheme, coupled with the fact that is generally in accordance with the development plan, outweigh the real, but very small, risks attached.'

3.4.13 Subsequent to the judgement by the Secretary of State, the probabilities of accidents with off-site radiological consequences occurring and the effective doses associated with such accidents have become better quantified than was the case at the time of the Boundary Hall Inquiry, so any concern as to the unquantified probability of the doses arising has been significantly mitigated.

3.4.14 Notwithstanding the low annual risks incurred by residents of Tadley due to accidents at AWE Aldermaston, it is of interest to set the assessed effective doses in context. These effective doses are from 2 to 17 mSv for the bounding reference accident and up to about double this for a worst-case accident. As the average annual effective dose in the UK, mainly from naturally occurring radioactivity, is around 2.7 mSv, the effective dose from the bounding reference accident corresponds to no more than a few years of normal exposure. Comparisons can also be made with medical exposures. For example, a Computed Tomography (CT) scan of the chest typically delivers 6.6 mSv and a whole-body CT scan typically delivers 10 mSv. There are also considerable regional variations in natural background, with the average annual radon dose to the people of Cornwall being 7.8 mSv, compared with a UK-wide average value of 1.3 mSv (http://www.hpa.org.uk/Topics/Radiation/UnderstandingRadiation/, downloaded 10 February 2014).

3.4.15 Thus, the radiological impact of the bounding reference accident, if it was to occur, on a resident of Tadley would be:

a. similar to the radiological impact due to exposure to background radiation for a few years in a typical location in the UK;

b. similar to the regional variations in the annual exposure to natural background in the UK;

c. similar to the exposure incurred as a result of a single medical CT examination.

3.4.16 This is not to argue that such exposures are of no importance. Indeed substantial efforts are being made to reduce high regional exposures to radon and the use of CT scanning in medicine is subject to a requirement for justification and optimisation on a case-by-case basis. However, it does show that the radiation doses that would be likely to arise if a major accident occurred at the AWE Aldermaston site are within the range commonly experienced by members of the public in the course of their everyday life.

3.4.17 However, as well as considering individual risk, it is appropriate to consider the overall health impact of a major accident at AWE Aldermaston. At the present time, the overall population of Tadley is about 14,000 (rounded sum of values for the Baughurst and Tadley North, Tadley Central and Tadley South Wards at the 2011 census, taken from http://www.basingstoke.gov.uk/, accessed 17 July 2015). If an accident of the size of the bounding reference accident were to occur and the wind was blowing towards Tadley, a substantial fraction of this population would receive effective doses in the range 2 to 17 mSv. Not all of the population of 14,000 would receive a significant dose, as the plume would not spread sufficiently laterally to encompass all of these three wards. To illustrate the potential overall health impact of such an accident in the absence of sheltering, it is reasonable to assume that about 7,000 people might receive an average effective dose of about 10 mSv, corresponding to a risk of death of around $5.7\ 10^{-4}$. Thus, in the absence of sheltering, about four deaths would be projected to occur as a result of such an accident. These would arise over several decades and would not be detectable against the general mortality of the population over that period. Nevertheless, this number of projected deaths emphasises why it is important to have an appropriate off-site emergency plan in place.

4 REQUIREMENTS ON THE OFF SITE EMERGENCY PLAN

4.1.1 As demonstrated in Section 3, there is a remote possibility (with a probability of one in ten thousand per year or less) that a major accident could occur at AWE Aldermaston that would result in a few (about four) deaths of residents of Tadley spread over several decades following the accident, but only if no efforts were made to mitigate the effects of the accident. In practice, sheltering indoors with the doors and windows shut for the duration of the period of release of radioactivity from the AWE Aldermaston site would almost entirely eliminate the risk. This is because the main radiological risk from such an accident arises from the inhalation of aerosol particles incorporating plutonium or enriched uranium. On a timescale of a few hours, sheltering, with control of the building ventilation, will maintain indoor radioactive aerosol concentrations at much lower values than those existing outdoors. However, when the radioactive plume has dispersed, which will occur within about an hour of the cessation of the release, it will be appropriate to restore free ventilation between the indoor and outdoor environments, to ensure that any small amount of radioactive aerosol that has penetrated the building envelope exchanges with, and is diluted in, outdoor air. In the longer-term, there will be some exposure from aerosol particles that have been deposited on surfaces, but this will generally be of limited radiological significance compared with the radiological impact of direct inhalation from the dispersing plume, unless mitigated by sheltering.

4.1.2 Because of the above considerations, the off-site emergency plan lays considerable emphasis on warning and informing the potentially exposed population within the DEPZ, and advising them to shelter. Specifically, residents within the DEPZ are in receipt of a REPPIR leaflet. This leaflet is updated by AWE (in consultation with the partner agencies) on a three yearly basis. The most recent issue was published in 2013 (West Berkshire Council and AWE, 2013) and an update is scheduled for 2016 (see Richardson, 2015b). It contains details of the hazards that may give rise to an incident and what to do should an incident occur.

4.1.3 When an incident had caused, or might cause, an off-site emergency, the following warning and informing actions would take place (West Berkshire Council, 2011, Annex 12).

a. AWE would initiate the automatic telephone alerting system to households around the site. By this method, members of the public would be advised to go inside and stay inside the nearest suitable building and to tune into the radio and television to hear public service broadcasts.

b. Information and warnings about the emergency would be broadcast on TV, local and national radio and the Internet, as appropriate. West Berkshire Council has a dedicated webpage ready to be activated should there be an incident.

c. Other activities, such as loud hailers may be employed to ensure messages are going out. The emergency plan states that all means necessary will be employed to get the messages across.

4.1.4 Specifically, the current issue of the REPPIR leaflet states the following.

‘If there were a radiation emergency that could affect the public, you may be advised to take shelter indoors until checks were made to ensure it is safe. You would be alerted either by:

→ •Telephone - The telephone alerting system would phone you with a pre-recorded message advising you what action to take. (It should be noted that this system only works with standard ‘landline’ telephones and not with mobile phones)

→ Via the media – You may hear an alert on the local radio or TV'

4.1.5 Self-evacuation is strongly advised against in the REPPIR leaflet. This point is also emphasised in the off-site emergency plan, where the following statement is made (West Berkshire Council, 2011, Section 5.5).

'The possibility of self-evacuation by members of the public at any time cannot be ignored. The impact of which may cause disruption to the response and may make the situation worse should radioactive particles be resuspended. Case studies show that there is greater risk of accidents during such self-evacuation than a situation of shelter and controlled evacuation if needed.

Public Information and local control will be needed to reduce the risk of this taking place.'

4.1.6 Persons attempting to return to the sheltering area from outside during this initial phase of the accident would be sent by the police to reception/rest centres where they would be looked after, and get help and information (REPPIR leaflet, page 10).

4.1.7 In the longer-term, countermeasures other than sheltering might be initiated. These are set out in Section 5.2 of the off-site emergency plan (West Berkshire Council, 2011) and their key aspects are summarised in Table 4.1, below.

Table 4-1 Countermeasure Options

COUNTERMEASURE	DESCRIPTION	POTENTIAL SCENARIOS/AREAS FOR WHICH THIS COUNTERMEASURE MAY BE IMPLEMENTED	PROCESS
Sheltering	Going and staying inside buildings or other structures with doors and windows closed	Automatic countermeasure in downwind sectors of the DEPZ; exceptionally may be extended across a wider area.	Automated telephone alerting system plus other measures, as described in the text.
Immediate evacuation	Evacuation of people without any delay to remove them from an immediate threat to their safety	Potentially required in non-radiological scenarios, but not for radiological scenarios (where immediate self-evacuation is advised against).	Not implemented.
Priority evacuation	Evacuation of priority groups (e.g. vulnerable people), which may require extra resource and logistical planning	May be required in the hours and days following declaration of a radiation emergency in downwind sectors of the DEPZ following an initial period of sheltering.	The Local Authorities, Health and other agencies will identify vulnerable people in the area affected. Contact will be made with the clients or carers and, thereafter, the necessary support will be arranged. This may be in the form of extracting the vulnerable to suitable locations or providing help in their own homes.
Non-urgent evacuation	Evacuation of other members of the public who do not require special resources or support to evacuate.	May be required in the days following declaration of a radiation emergency in downwind sectors of the DEPZ following an initial period of sheltering.	
Subsequent evacuation	Displacement of members of the public from their homes and businesses to facilitate longer-term recovery and remediation of affected areas	May be required in the days and weeks following a radiation emergency where areas are found to have been contaminated with radioactive or other hazardous materials.	May be necessary if people take cover in buildings such as factories, offices and other work places. These sheltering areas may not be suitable in terms of providing support for the people there for any length of time due to lack of facilities, food and bedding. This will need to be considered at an early stage depending on the zones affected. Other subsequent evacuation of the public from their homes may be necessary to facilitate recovery. The process for subsequent evacuation will be communicated via the media to those affected.
Restrictions on food and water consumption	Early advice not to eat certain foodstuffs or to drink water from boreholes in a potentially contaminated area to minimise the uptake of radioactive	May be implemented on a precautionary basis in the early phase of the response to a radiation emergency. Intervention levels for implementing this countermeasure are	

	materials in a radiation emergency	flexible and would be scenario-dependent.	
Restrictions on food production	Advice or specific restrictions on food producers not to produce food sourced from a potentially contaminated area to minimise the potential uptake of radioactive materials following a radiation emergency	May be required following a radiation emergency where areas are found to have been contaminated with radioactive or other hazardous materials. Intervention levels for implementing this countermeasure are flexible and would be scenario-dependent.	Trading Standards, Animal Health and the Food Standards Agency would review the actions and advice required.
Restrictions to transport movements	Restricting road, rail and other transport movements in and around the area allows emergency vehicles access and reduces the risk of resuspension of radioactive particles	May be required to facilitate response and recovery.	Any decision to close footpaths should be referred to the Councils' Rights of Way teams in order for them to identify what paths can be closed. Road closures would be handled by the Police, supported by Local Authorities and the Highways Agency.

4.1.8 In considering the impacts of proposed developments within the DEPZ on the off-site emergency plan, it needs to be kept in mind that all the provisions described above are already applied to the total population of Tadley (around 14,000 persons), which is considerably more than it would have applied to if the radius of the DEPZ had been set to a realistic value of 2.125 km or 1.925 km rather than the historical value of 3.0 km that has been adopted.

4.1.9 A key consideration that could influence the off-site emergency plan is whether the population of Tadley might increase substantially in the future if a more relaxed attitude was taken to permitting developments within the DEPZ. However, even with less restrictive planning requirements, there is limited space within the DEPZ for additional developments. Beyond the DEPZ, the greatest growth in recent years has been in the Chineham Ward (7,005 in the 2001 census and 9,240 in the 2011 census) and in the Bramley and Sherfield Ward (4,940 in the 2001 census and 5,875 in the 2011 census, http://www.basingstoke.gov.uk/). Based on these figures, it is plausible to suggest that the population of Tadley within the DEPZ, as currently defined, might increase by no more than about 3,000, or about 20%. If the radius of the DEPZ was reduced to a realistic value of 2.125 or 1.925 km, then the population within the DEPZ would be expected to decrease rather than increase, even with less restrictive planning requirements.

4.1.10 If the population within the DEPZ was to increase somewhat, the main requirement placed on the off-site emergency plan would be to warn and inform this additional number of people. As to sheltering, it seems likely that new housing stock would have better control on ventilation and be more suitable for sheltering than some of the existing stock, so the gradual replacement of existing stock with new stock would tend to facilitate implementation of the off-site emergency plan, particularly if each proposed development was required to demonstrate that consideration in design had been given to key issues in off-site emergency planning (warning and informing; short-term and longer-term sheltering; urgent evacuation needs; impacts on the vulnerable; access and egress for emergency vehicles and those in the community).

4.1.11 In particular, individual developments and the pattern of development as a whole would need to ensure that the access for emergency services to the AWE Aldermaston site was not impaired. Indeed, in some contexts, such developments could contribute to improving access.

4.1.12 It is perhaps worth emphasising that the potential magnitude of accidents at AWE Aldermaston is such that there is not a requirement for the off-site emergency plan to be completely effective. If some individuals were to fail to shelter, the risks that they would be subject to in consequence would be comparable to those arising from exposure to natural background for a few years or from a single CT scan. The situation is different from that arising in some conventional accidents, e.g. gasholder explosions, where failure to evacuate the immediate area and/or shelter could result in an individual almost certainly suffering serious injury or death. It is also different from that arising around commercial nuclear power stations, where potential exposures to much higher radiation doses might lead to a requirement for immediate evacuation.

4.1.13 Thus whereas less-restricting planning control within the DEPZ might require some detailed changes to the off-site emergency plan, there is no reason to suppose that substantial qualitative changes would be required. Furthermore, with structured planning of developments and an existing requirement to update the off-site emergency plan every three years, it should be straightforward to ensure that minor alterations to the plan are integrated with the implementation of approved developments.

4.1.14 Finally, it is noted that the scale of developments that could occur in Tadley would not change the overall nature of the town. Thus, the general policy requirement 'that residential and industrial developments are so controlled that the general characteristics of the [nuclear licensed] site are preserved' (paragraph 2.2.3) should be readily satisfied.

5 CONCLUSIONS

5.1.1 In the past, the location of Tadley within the DEPZ of AWE Aldermaston has placed significant constraints on its development. However, the limited size of accidents with off-site radiological consequences that could occur at AWE Aldermaston (no more than Level 5 on the INES scale, see paragraph 3.3.2) means that effective doses to residents of Tadley from a bounding reference accident would be relatively low, i.e. in the range 2 to 17 mSv, even if they did not shelter, as they are advised to do under the off-site emergency plan. For worst case accidents, effective doses could be about a factor of two larger, but the frequency of such accidents would be about a factor of ten lower than for bounding reference accidents. These effective doses are similar in magnitude to those arising from natural background radiation or from a single CT scan (paragraph 3.4.15). This is not to argue that they are of no importance, but they are within the range commonly experienced by members of the public in the course of their everyday life (paragraph 3.4.16).

5.1.2 Furthermore, the frequencies of such accidents are low (below one in ten thousand per year for bounding reference accidents and below one in one hundred thousand per year for worst case accidents). This means that the annual risk of death from accidents up to and including the bounding reference accident in size is no more than about one in ten million. For larger accidents, the risk of death is no more than one in fifty million (paragraphs 3.24 and 3.25). These risks are those that would arise in the absence of sheltering, which would substantially mitigate the risks. Even without sheltering, the risks are similar to, or less than, those of being killed by being struck by lightning and are more than a factor of ten below the boundary of the broadly acceptable risk region, as defined by the HSE (paragraphs 3.4.7 to 3.4.9).

5.1.3 If a bounding reference accident was to occur with the wind blowing toward Tadley and mitigation of effective doses by sheltering was not taken into account, about four deaths are projected to occur as a result of the accident. These would arise over several decades and would not be detectable against the general mortality of the population over that period. Nevertheless, this number of projected deaths emphasises why it is important to have an appropriate off-site emergency plan in place (paragraph 3.4.17).

5.1.4 The off-site emergency plan properly emphasises warning and informing with a view to achieving short-term sheltering. Such sheltering would very substantially reduce the effective doses incurred by individuals present downwind of the accident. Such sheltering would only be required until the atmospheric release from AWE Aldermaston had ceased. This would typically be a few hours. Provision of such advice is largely automated and does not place a heavy load on the authorities.

5.1.5 It is possible that if less restrictive planning requirements were imposed within the DEPZ that Tadley could increase in population relatively rapidly. Nevertheless, there is limited space for development within the current DEPZ. Together with observations of the growth in population of Wards outside the DEPZ between 2001 and 2011, it seems unlikely that the population of Tadley would grow by more than about 3,000 or 20% of the current population (paragraph 4.1.8). In terms of sheltering, it seems likely that the new housing stock would have better control on ventilation and be more suitable for sheltering than some of the existing stock (paragraph 4.1.10). Overall, a growth in population of up to 20% might require some detailed changes to the off-site emergency plan, but there is no reason to suppose that substantial qualitative changes would be required. As the off-site emergency plan has to be revised every three years, it should be straightforward to integrate updates with the implementation of proposed residential and other developments (paragraph 4.1.13). However, it will be important to ensure that the design of these developments gives consideration to key issues in emergency planning (paragraph 4.1.10) and that access for emergency services to AWE Aldermaston is not impaired, or is enhanced (paragraph 4.1.11).

5.1.6 Even if there was a significant increase in the population of Tadley, it seems clear that it would still comply with the general requirement that the general characteristics of the area around a nuclear licensed site should be preserved (paragraph 4.1.14).

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