ODPM BUILDING REGULATIONS (SANITATION) FRAMEWORK

IMPROVING THE FLOOD RESILIENCE OF BUILDINGS THROUGH IMPROVED MATERIALS, METHODS AND DETAILS

WORK PACKAGE 3 – HEALTH & SAFETY

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IMPROVING THE FLOOD RESILIENCE OF BUILDINGS THROUGH IMPROVED MATERIALS, METHODS AND DETAILS

REPORT WP3 HEALTH AND SAFETY

Report No.: WP3

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Contract No.: CI 71/8/5

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CONTENTS

APPENDICES

1. INTRODUCTION

1.1 This project, which investigates improvements into methods of mitigating the effects of flooding upon buildings, is divided into a number of Work Packages, as listed below:

WP1	Establish steering group and project start up
WP2	Review existing information and experience
WP3	Consider health and safety implications
WP4	Define draft procedure
WP5	Conduct laboratory testing
WP6	Conduct field trials
WP7	Revise draft procedure
WP8	Produce regulatory impact assessment
WP9	Produce guidance document
WP10	Publish guidance

1.2 Waterman Burrow Crocker (WBC) are responsible for this Work Package (WP3), which has been independently reviewed by Malcolm Bell of Leeds Metropolitan University.

1.3 The Scope of this report is an investigation into the health and safety (H&S) factors that will feed into relevant parts (e.g. C, G and H) of the Building Regulations with respect to flooding. It will also define the boundary conditions for the subsequent laboratory testing carried out in Work Package 5.

1.4 The format of this report examines risks to safety and health due to flooding in the UK, and proposes changes to the Approved Documents to the Building Regulations in order to minimize the risks identified. It then identifies research that needs to be carried out to enable clear guidance to be provided for the proposed changes in the Approved Documents. Finally, it recommends other mitigation, which cannot be addressed by changes to the Approved Documents.

2. BACKGROUND

2.1 There are a number of mechanisms that can cause flooding, as shown in table 1. Additional details about the causes of flooding are given in CIRIA Guide C624 1) and in the WP2 report.

Table 1: Categories of flood mechanisms

Category	Mechanism
Coastal, tidal and estuarial flooding	High tides, storm surges and wave action
Fluvial flooding	Flow exceeds capacity of watercourses, normally caused by extreme rainfall or snow melt.
Pluvial flooding	Lack of drainage capacity and/or flood relief path
Groundwater flooding	Raised groundwater
Flooding from overland flow	Water flowing over the ground, before entering a watercourse or drainage system
Flooding from artificial drainage systems	Blocked or overloaded culverts, drains, sewers or channels. Failure of pumping systems.
Flooding from infrastructure failure	Failure of water retaining system or water main.

2.2 The Foresight report on future flooding2) demonstrates that the UK must either invest in more sustainable approaches to flood and coastal management or learn to live with increased flooding.

2.3 Flooding of a property has very significant effects upon the building owner, and more particularly, for building occupiers. These effects include:

Before flooding

- anxiety, especially where there has been previous experience of flooding

During flooding

- physical hazards, such as drowning and structural collapse
- medical, such as heart attack
- psychological, such as anxiety
- cold, wet and exposure
- pathogens in flood water

After flooding

- pathogens in mud and building fabric
- moulds and spores
- exposure to disinfection chemicals

- electric shocks
- stress
- depression
- disruption of normal lifestyle
- infestation.

2.3 The extent of some of these effects can be dealt with by flood resilient construction (eg. reduction of physical hazards), whereas others can be mitigated to some extent by the preparedness of the occupants.

2.4 The literature sources show a paucity of data on health effects of flooding, which was remarked upon by the World Health Organization 3) in their 2002 meeting to discuss floods and confirmed by Hajat et al 4) and Few et al 5).

2.5 However, the literature, including Samwinga et al 6) , CIRIA Guide C624 1) and Tapsell et al 7) , all confirms that mental health effects are perhaps the most significant result of flooding. This is confirmed by the evidence from the floods in Lewes, Sussex in 2000 reported in the WHO meeting 3) which demonstrated that there were very few physical health effects but that mental health effects, such as anxiety and depression, were very significant and persistent.

3. SAFETY

3.1 Drowning

3.1.1 The draft "Flood Risks to People" 8) data shown in Box 1 shows that even fairly small flow velocities can sweep people off their feet or sweep vehicles into the flow. Once in the water, the velocity will hamper swimming, exacerbated if heavy clothing is worn, and may result in drowning. Debris in the water increases the danger to persons.

3.1.2 Flood water is generally murky and so deep pools and stream channels cannot be seen and this has resulted in fatalities where people have unknowingly walked into deep or fast flowing water.

3.1.3 Drowning can occur within buildings, particularly cellars and basements, or where occupants are asleep, infirm or very young. Flooding can occur very quickly, with little or no warning given.

3.2 Structural damage and collapse

3.2.1 Structural damage or collapse of a building or part of a building can result in death and injury; either by falling onto a person, trapping them underwater or causing a person to fall from a place of safety.

3.2.2 Structural collapse of buildings or parts of buildings can be caused by uneven pressures on different sides of a structural element. Free-standing walls and fences are particularly vulnerable. Additional information is given in the WP 2 report.

3.2.3 Hydrodynamic effects (ie. the effect of the velocity of the water and waves) add to the static forces. Silt suspended in the water increases its density and increases pressures. Floating debris will also locally increase the forces on a structure. This is illustrated in Box 2, taken from "Flood Risks to People" 8).

3.2.4 The effect of flotation on a structure may reduce its effective strength, especially where its stability relies upon its weight. Flotation forces may even be so large that the structure moves, with the potential of overturning when it comes to rest or inflicting damage upon external objects.

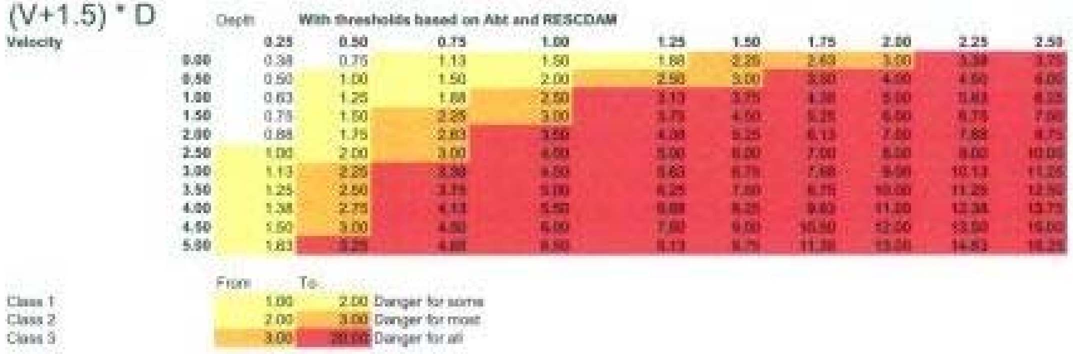
3.2.5 Fast flowing water, particularly silt laden water, can cause erosion of common building materials, eg. mortar, which in turn may lead to failure of a structural element.

3.2.6 Prolonged immersion in water can soften building materials, which may lead to failure of large components.

3.2.7 Erosion of the ground can lead to undermining of the building or its foundations, with a risk of collapse.

3.2.8 Buildings are normally designed for hydrostatic pressures only. The other factors described above are not normally taken into account in structural calculations and reduce the factor of safety against failure.

Table 7.4 Hazard classification table with thresholds based on Abt and RESCDAM data combined



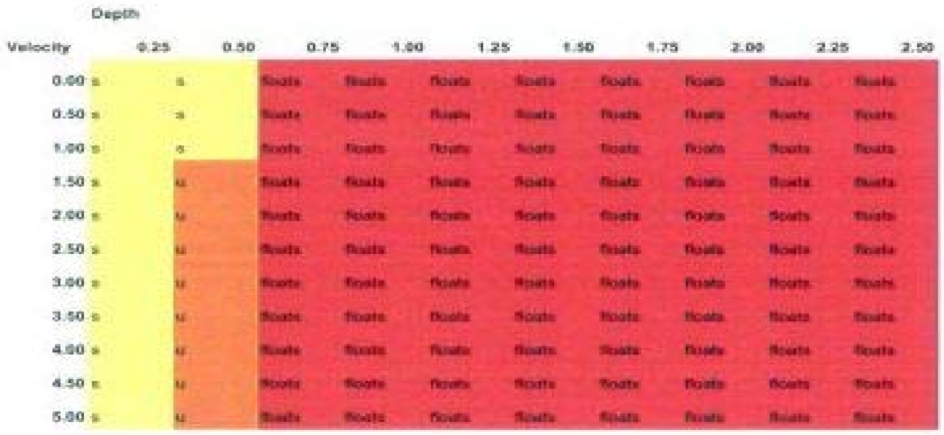
(V+1.5) * D

With thresholds based on Abt and RESCDAM

Velocity \ Depth	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
0.00	0.38	0.75	1.13	1.50	1.88	2.25	2.63	3.00	3.38	3.75
0.50	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
1.00	0.63	1.25	1.88	2.50	3.13	3.75	4.38	5.00	5.63	6.25
1.50	0.75	1.50	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50
2.00	0.88	1.75	2.63	3.50	4.38	5.25	6.13	7.00	7.88	8.75
2.50	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
3.00	1.13	2.25	3.38	4.50	5.63	6.75	7.88	9.00	10.13	11.25
3.50	1.25	2.50	3.75	5.00	6.25	7.50	8.75	10.00	11.25	12.50
4.00	1.38	2.75	4.13	5.50	6.88	8.25	9.63	11.00	12.38	13.75
4.50	1.50	3.00	4.50	6.00	7.50	9.00	10.50	12.00	13.50	15.00
5.00	1.63	3.25	4.88	6.50	8.13	9.75	11.38	13.00	14.63	16.25

	From	To	
Class 1	1.00	2.00	Danger for some
Class 2	2.00	3.00	Danger for most
Class 3	3.00	20.00	Danger for all

Table 7.8 Flood hazard matrix for saloon car (Peuguot 307)

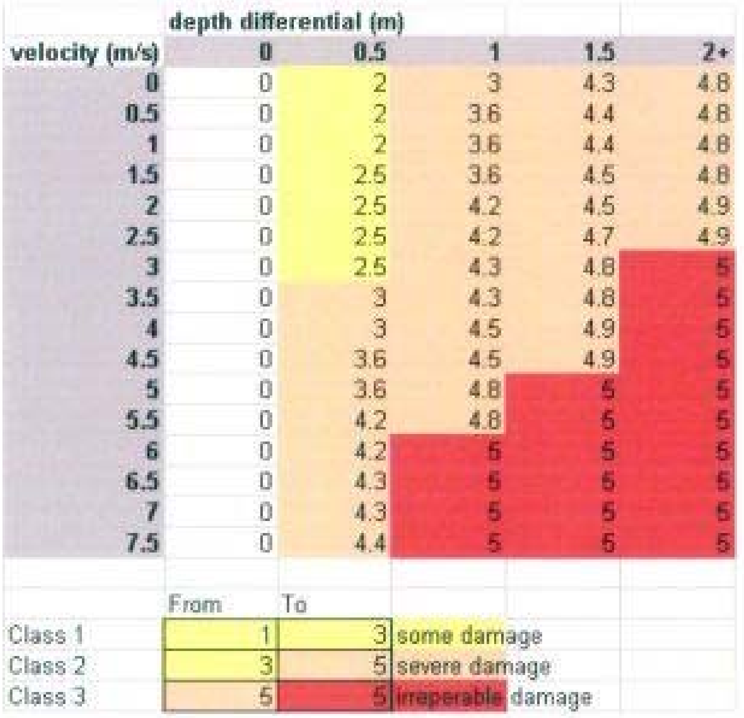


Velocity \ Depth	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
0.00	s	s	floats	floats	floats	floats	floats	floats	floats	floats
0.50	s	s	floats	floats	floats	floats	floats	floats	floats	floats
1.00	s	s	floats	floats	floats	floats	floats	floats	floats	floats
1.50	s	u	floats	floats	floats	floats	floats	floats	floats	floats
2.00	s	u	floats	floats	floats	floats	floats	floats	floats	floats
2.50	s	u	floats	floats	floats	floats	floats	floats	floats	floats
3.00	s	u	floats	floats	floats	floats	floats	floats	floats	floats
3.50	s	u	floats	floats	floats	floats	floats	floats	floats	floats
4.00	s	u	floats	floats	floats	floats	floats	floats	floats	floats
4.50	s	u	floats	floats	floats	floats	floats	floats	floats	floats
5.00	s	u	floats	floats	floats	floats	floats	floats	floats	floats

Note; s= stable, u= unstable

Box 1. Hazard classification of floodwater on people and vehicles

Defra/Environment Agency
Draft R&D Output. Flood Risks to People
Phase 2 Project Record



	depth differential (m)				
velocity (m/s)	**0**	**0.5**	**1**	**1.5**	**2+**
0	0	2	3	4.3	4.8
0.5	0	2	3.6	4.4	4.8
1	0	2	3.6	4.4	4.8
1.5	0	2.5	3.6	4.5	4.8
2	0	2.5	4.2	4.5	4.9
2.5	0	2.5	4.2	4.7	4.9
3	0	2.5	4.3	4.8	5
3.5	0	3	4.3	4.8	5
4	0	3	4.5	4.9	5
4.5	0	3.6	4.5	4.9	5
5	0	3.6	4.8	5	5
5.5	0	4.2	4.8	5	5
6	0	4.2	5	5	5
6.5	0	4.3	5	5	5
7	0	4.3	5	5	5
7.5	0	4.4	5	5	5

	From	To	
Class 1	1	3	some damage
Class 2	3	5	severe damage
Class 3	5	5	irreperable damage

Figure 7.7 Flood risk to buildings matrix

Box 2. Flood risk to buildings matrix

Defra/Environment Agency
Draft R&D Output. Flood Risks to People
Phase 2 Project Record

3.3 Debris

3.3.1 Where flooding is prolonged, the ground will be softened, making trees more liable to be felled, eg. by water or strong winds. Falling trees can cause injury or death, either directly or indirectly by causing structural damage.

3.3.2 Debris in flood water can cause direct injury to people or cause impact damage to structures, as shown by the increase in hazards in Box 3, taken from “Flood Risks to People” 8). In addition, debris can block water paths, increasing flooding. News footage of Boscastle dramatically demonstrated cars being swept along in the flood waters, hitting buildings and becoming jammed below a bridge.

3.3.3 Debris and silt left after a flood can result in slips and trips.

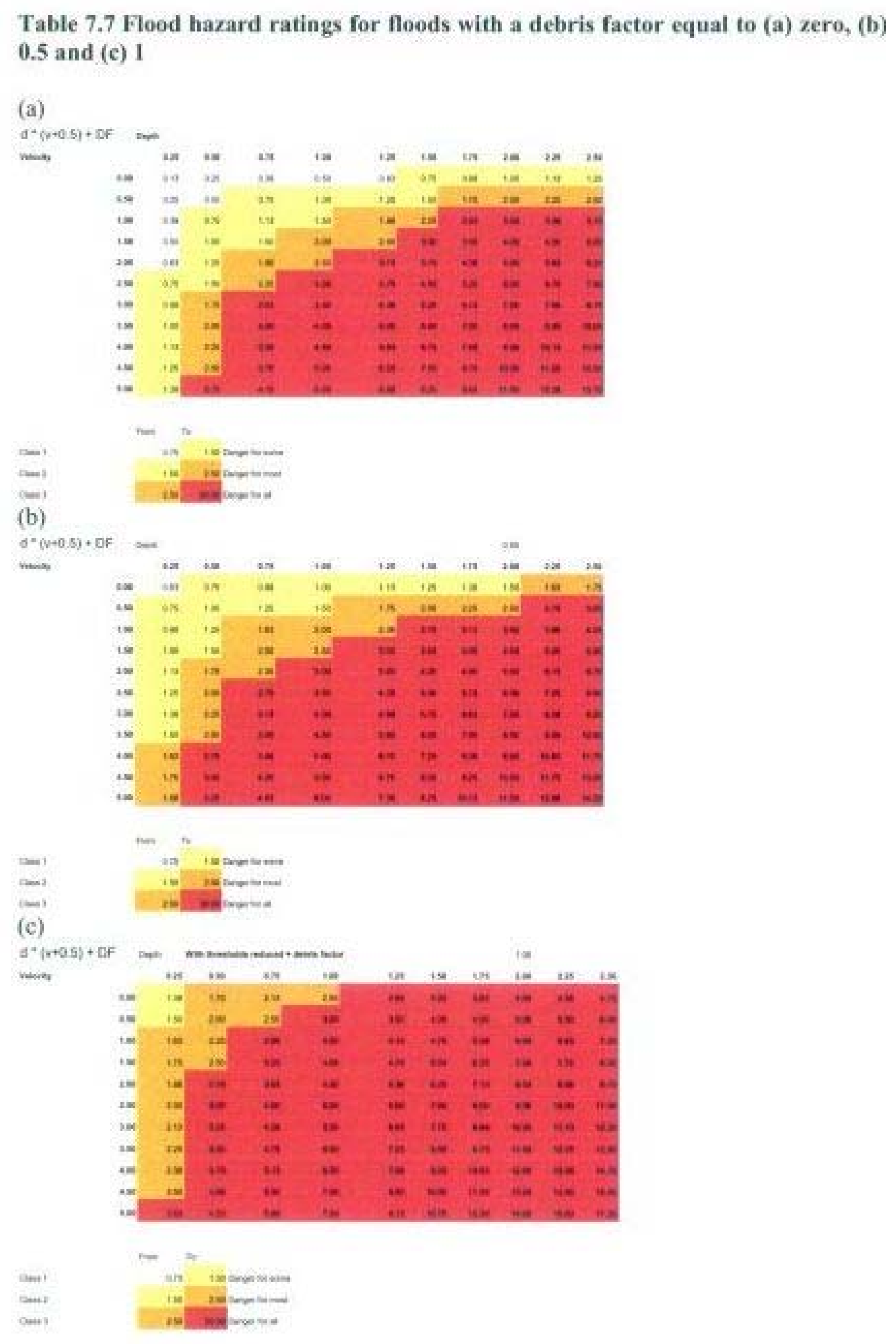


Table 7.7 Flood hazard ratings for floods with a debris factor equal to (a) zero, (b) 0.5 and (c) 1

(a)

d * (v+0.5) + DF

(b)

d * (v+0.5) + DF

(c)

d * (v+0.5) + DF

Box 3. Hazards to people from flood waters containing debris

Defra/Environment Agency
Draft R&D Output. Flood Risks to People
Phase 2 Project Record

3.4 Displaced access covers

3.4.1 The pressure of water escaping from surcharging drains and sewers often removes the covers. Although this is obvious when water is escaping, a displaced cover is a trip hazard and can cause traffic accidents.

3.5 Subsidence and landslips

3.5.1 Flood water, particularly if it is fast moving, can initiate land slips and subsidence. These can cause either direct injury or death, or indirect injury or death because of the adverse affects to buildings due to increased loads or reduced strength of foundations.

3.6 Evacuation

3.6.1 Our enquiries with emergency services show that they generally prefer people to remain in a place of safety within a flooded property, rather than risk safety during evacuation.

3.6.2 Where a situation arises that necessitates evacuation, there is a risk of injury during the evacuation process.

3.6.3 Extreme stress can lead to medical emergencies, such as heart attacks and premature births. These medical emergencies are exacerbated by the flooding, which disrupts emergency services and delays help. Flooding can affect electricity supplies and telephone cables, which can further hamper efforts to obtain a speedy response to the emergency.

3.7 Carbon monoxide poisoning

3.7.1 Ventilation blocked by floodwater, flood protection or silt and debris, or alternatively, the use of inappropriate heating equipment during an emergency, can result in carbon monoxide poisoning.

3.7.2 Carbon monoxide poisoning is also reported by Hajat et al 3) to have occurred whilst flooded basements were being pumped out (presumably using petrol-driven pumps).

3.8 Electrocution

3.8.1 Electrocution can occur when live power cables come into contact with flood water.

3.8.2 The risk of electrocution remains after flood waters have receded, where the electricity installation and building are still wet.

3.9 Explosion

3.9.1 Gas leakage due to pipe movement or fracture caused by flood water can result in explosions.

3.9.2 Fuel storage tanks (eg. heating oils) can float off their bases and sever connecting pipelines or overturn, spilling their contents. Alternatively, if prevented from floating, storage tanks may be crushed by the external water pressure and rupture, also leading to fuel spillage.

3.9.3 Flooding of bunded storage areas would result in previous spillage being released into the flood water.

3.10 Temperature

3.10.1 Being cold and wet can result in hypothermia, particularly where the power in the dwelling cannot be used either because of the wet or because power supplies have been severed. Hypothermia is a severe condition. Immersion in water is an even more serious situation, with survival times being extremely low, even at relatively warm temperatures, as indicated in Box 4.

Body Response at 15^0C	Time Taken	Effect
Cold Water Reflex	2 to 3 minutes	Drowning
Swimming Fatigue	2 to 15 minutes	Drowning
Hypothermia	15 to 30 minutes	Death

Box 4. Survival times for people on the surface of the water with a maximum water temperature of 15^0C.

3.11 Chemical pollution

3.11.1 Where sewers carry trade effluents, chemicals can be carried into the flood waters. The risk will depend upon the type of chemical, its concentration, volume of spillage, dilution effect, and so forth.

3.11.2 Chemical pollution can also occur (such as through flotation of storage tanks causing connecting pipelines to sever), and the effects of this are dependent upon the type and volume of chemical released and its dispersion.

3.11.3 There is also potential for chemicals to be leached out of construction materials, eg. preservatives from treated wood.

3.11.4 Chemical storage tanks can float off their bases and overturn, spilling their contents. Alternatively, if prevented from floating, storage tanks may be crushed by the external water pressure and rupture, which may also lead to fuel spillage.

3.11.5 Flooding of bunded storage areas would result in previous spillage being released into the flood water.

3.12 Disinfectants and biocides

3.12.1 Disinfectants used in cleaning up after floods (eg. sodium hypochlorite) can cause injuries if inhaled or spilt onto unprotected flesh or inhaled.

3.12.2 The use of sodium hypochlorite (bleach) if mixed with acid cleaners can produce chlorine gas, which is poisonous.

3.12.3 Chemical used to kill moulds and fungi after flooding can also be detrimental to health and must be used strictly in accordance with manufacturer’s recommendations.

3.13 Lime

3.13.1 The use of lime plasters in preference to gypsum-based plasterboard may become more common in flood resilient and flood repairable construction.

3.13.2 Risks associated with lime are as follows:

Skin contact:	An irritant that may cause burns
Eye contact:	Causes painful irritation and may cause serious eye damage unless immediate first aid treatment is given
Ingestion:	Unlikely to cause any reactions. Larger doses may irritate the gastrointestinal tract.

3.13.3 The risks associated with the use of lime are not considered to be any worse than many other common construction materials and therefore, provided normal, sensible precautions are taken, its use should not be restricted.

3.14 General

3.14.1 Although potentially fatal, the WHO [3)] report that the physical hazards are more likely to result in injuries such as sprains, strains, lacerations and contusions.

4. HEALTH

4.1 Chemical contamination

4.1.1 Contact with hydrocarbons, released as described in 3.11 above, can lead to dermatitis and other skin problems.

4.1.2 Fungicidal treatments often use noxious chemicals (in the past formaldehyde was used), which can adversely affect health if the fumes are breathed in.

4.1.3 Disinfectants are designed to eliminate or inactivate micro-organisms and are therefore harmful to health.

4.2 Disease

4.2.1 Floodwater is likely to be contaminated with sewage (from flooded sewers). Sewage contamination, particularly where water supplies are contaminated or unavailable to allow proper personal hygiene, can result in serious diseases such as Salmonella, Amoebic Dysentery, Tetanus, Polio, Hepatitis and Weils Disease (Leptospirosis), all of which can be fatal. However, according to WHO3) there is little evidence of infectious diseases being associated with flooding in Europe. Less serious problems include wound infection, dermatitis, conjunctivitis, gastrointestinal illness, and ear, nose and throat infections.

4.2.2 Contamination by polluted flood water of food and drink, or eating or cooking utensils, can also transmit disease, ie. the faecal-oral disease route described by Few et al 5).

4.2.3 Research by WRc 9) research indicates that within a building, bacteria die off is rapid and contamination is normally removed naturally after 72 hours of the flood water receding, without the use of disinfectant. The only exception to this was for badly soaked plasterboard, where pathogens survived for up to a week.

4.2.4 WRc 9) research show that pathogens can survive on soil for as long as 20 days during the winter and, even with the destructive summer conditions of high UV light, warm temperature and little moisture, pathogens survived at least 9 days on soil.

4.2.5 Infestation by insects and rodents, attracted by flood damaged goods, can result in adverse health affects from bites etc. In particular, Weils Disease (Leptospirosis) is associated with rat's urine, which may be on litter etc resulting from the flooding. The early symptoms of Weils Disease are similar to colds and influenza but liver damage and death can result if not treated early.

4.3 Moulds and spores

4.3.1 As soaked timber and furnishings dry out, mould growth is likely to occur. Mould growth can also be caused by reduced ventilation and air flow in buildings where inappropriate flood mitigation measures are used.

4.3.2 BRE 10) report that mould growth is capable of causing Type I and Type III allergies, infections, toxic reactions, cancer and psychological symptoms.

4.3.3 A Type I allergy is considered by to be a major health risk, which can be caused by inhalation of spores from moulds. The allergic reactions produce symptoms similar to hay fever and asthma in individuals who have been sensitised, which BRE estimates to be around 10 – 20% of the population.

4.3.4 Acute Type III allergy requires a much greater exposure to mould spores and is characterised by chills, fever, cough, breathlessness and malaise, typically 4 – 8 hours after inhalation. Alternatively, continuous low-level or intermittent exposure may cause progressive breathlessness and a chronic cough. In contrast to Type I allergy, everyone appears to be susceptible to Type III allergy.

4.3.5 Susceptible people, such as neonates, patients undergoing immunosuppressive therapy and AIDS patients, are at increased risk of fungal infection. However, none of the fungi found in UK represent a serious infection hazard to healthy people.

4.3.6 Uptake of toxic substances from domestic moulds (mycotoxins) is most likely to be by inhalation of spores containing mycotoxins, which are easily absorbed from the respiratory tract. Although documented cases of illness are rare, some species can produce highly toxic mycotoxins which suppress the immune system, causing susceptibility to secondary bacterial infections. Mycotoxins can also cause nausea and diarrhoea. Dermal exposure can result in minor allergic reactions and skin irritation. Although only about sixteen types of mould have been identified as being toxic, they are often the types found in post flood or water damage events in homes and buildings.

4.3.7 www.disasteradvice.co.uk advises that some of the toxic mycotoxins (known as T2 toxins) have been used by the military as chemical weapon agents. They also state that destroying or neutralising mould safely is extremely difficult, because the mould spore can contain various toxic chemicals which may be released when the spore is destroyed or ruptured, thereby releasing the most toxic or allergenic chemicals. The size of a mould spore is typically between 1 and 20 µm, with released particles falling below the 7.5µm size which is respiritable. Some are less than 2.5µm size and these are considered to be the most dangerous, as they can lodge deep into the lung tissue and be infused directly into the blood stream.

4.3.8 Delayed induction or promotion of cancer growth is a particular type of toxicosis but, according to BRE, this is rare and there is little evidence of a link.

4.3.9 Psychological effects arising from living with moulds have not been quantified by BRE. However, they consider it plausible that living with mould causes occupants to worry about their health, which can be depressing, stressful and socially undesirable.

4.3.10 There is conflicting information about the seriousness of the health impact of moulds, with BRE considering that the psychological consequences probably pose a greater problem in terms of minor ill-health than the physical effects of moulds, whereas www.disasteradvice.co.uk state that mould is viewed in the USA as the new asbestos. This disparity could be due to the fact that the BRE work was focussed on properties that suffer mould as a result of lack of ventilation rather than because they have been flooded.

4.3.11 www.disasteradvice.co.uk advise that ideal conditions for mould growth is where the relative humidity is over 65% and temperatures are around 20ºC.

4.3.12 The advice of CIRIA given in Box 5 is that premises that have not been dried out over a period of three days should be vacated and workers should use respirators. However, some homeowners choose to remain in their homes and consequently remain living in damp and unhealthy conditions for some time.

Moulds can pose a health hazard, especially for infants, the elderly and those with asthma, allergies, or illnesses. If mould is present, or materials have not been cleaned and dried within two or three days of the floodwater receding, then vulnerable persons should stay away during restoration and precautions should be taken to protect workers. Well-fitting respirators with toxic particle cartridges are recommended; dust masks are not adequate. Respirators are available at DIY or building centres.

Mildew is a growing organism that can permanently damage most textile fibres - especially natural fibres such as cotton, linen, rayon and wool. Mould exposure may cause cold-like symptoms, watery eyes, sore throat, wheezing and dizziness and trigger asthma attacks. Because some mould spores are very small and can easily be breathed deeply into the lungs, it is not safe to live in houses with high mould levels.

Moulds can usually be detected by a musty odour and discoloration of surfaces is common with mould growth. The mould may change surfaces to white, green, brown, black or orange.

Reliable sampling for mould can be expensive since it requires special equipment and training, testing for mould is not generally recommended as a first step. The solution to mildew problems is to disinfect and dry.

Box 5. Moulds

From www.ciria.org/flooding/disinfection.htm

4.4 Stress

4.4.1 Flooding is a very stressful event and the effects of stress can manifest themselves a long time after the event. Stress can induce physical symptoms, such as problems with sleeping, anxiety and even personality changes.

4.4.2 Bystanders or relatives (who have possibly witnessed failed rescue attempts) will also be in a traumatised state and may require medical attention.

4.4.3 Clearing up after a flood can be as stressful and depressing as the flood, as the realization of loss of possessions sets in. This is worsened by household disruption and having to deal with clearing up and paperwork on top of normal work and home commitments. The stress can also be replaced with long term anxiety about future flooding, which will be more acute during rainfall or other reminders.

4.4.4 Stress and anxiety can be exacerbated by loss of income due to flooding and falls in property values.

4.4.5 Flooding can result in changes to the community and neighbourhood. The Walker, Burningham et al report 11) identified that there is a lack of empirical data upon community and neighbourhood changes after flooding. However, they consider that effects could include population change, closure of businesses and alterations in levels of, and perceptions of, social capital. The population change is likely to be because those who can afford to move away from the flood-affected area will do so, leaving behind those who are unable to do so. Such changes may result in a less sustainable and economically advantageous community; this in turn may cause increased stress levels for individuals in the neighbourhood.

4.4.6 Walker, Burningham et al 11) also point out that the impact of flooding differs between different social groups (eg. elderly, children, single parent families suffering proportionality more).

4.4.7 Tapsell et al 12) have developed a Social Flood Vulnerability Index (SFVI) to assess areas and populations that are likely to be most severely affected in terms of health and other “intangible” flood impacts.

4.5 General

4.5.1 In the Northern hemisphere, research by Few et al 5) indicates that there is no strong evidence of outbreaks of infectious disease associated with flooding and agree with other studies that mental health is the most significant health effect.

5 PROPOSED CHANGES TO BUILDING REGULATIONS FOR FLOOD MITIGATION

5.1 Building Regulations [13)] control “building work”, which is defined as:

a) the erection or extension of a building;
b) the provision or extension of a controlled service or fitting in or in connection with a building;
c) the material alteration of a building, or a controlled service or fitting;
d) work required by a material change of use;
e) insertion of insulation material into the cavity wall of a building;
f) work involving the underpinning of a building.

“Controlled service or fitting” is a service covered by Parts G, H, L or P of the Building Regulations, ie. sanitary accommodation, hot water, drainage and waste, heat producing appliances, conservation of fuel and power, and electrical safety.

5.2 Therefore many of the health and safety risks identified above are not covered by Building Regulations, either because they are not directly related to the building or because they relate to repairs and replacements, or how the building is used.

5.3 The Construction (Design and Management) Regulations [14)] (CDM Regs) impose a wider requirement upon designers to consider all matters relating to health and safety, taking account of construction, use, maintenance and future demolition. Therefore, matters that are not covered by Building Regulations should still be considered by designers.

5.4 The purpose of Building Regulations is principally to protect the health and safety of building occupants. It does this by making requirements, which are supported by a number of Approved Documents that provide guidance on ways in which the requirements may be fulfilled. The reasons for the requirements are not explicitly stated, although their intention is usually fairly obvious.

5.5 Flood mitigations measures should be “built in” as far as possible, rather than relying on people to take measures themselves.

5.6 The Approved Documents provide a good vehicle for ensuring that the health and safety of building occupants is not compromised by the adoption of flood mitigation. Proposed changes to the Approved Documents are described below.

5.7 Approved Document C [15)] (AD C)

5.7.1 As an essential first step to improved health and safety, Approved Document C [15)] should require the preparation of a Flood Risk Assessment (FRA), to identify:

- source/type
- extent and depth of flooding
- speed of rise
- routes and velocity
- duration
- probabilities and consequences.

The FRA should also take account of the different facilities and needs of different users of the building, eg. the young, elderly or disabled, when assessing risks and planning evacuation routes etc.

This is necessary in order to inform those making decisions about the type of flood mitigation to be provided and design parameters to be used.

5.7.2 The best method of flood mitigation to minimize health and safety risks is flood avoidance and therefore this should continue to be the preference expressed in AD C. Flood avoidance includes not constructing basements and cellars in areas at risk from flooding, thereby avoiding the risk of being trapped in a flooded basement.

5.7.3 AD C should specifically require that where flood mitigation measures are proposed, all other requirements of building regulations shall be complied with.

5.7.4 Where flood resilient or flood repairable construction is proposed, AD C should include recommendations for a flood warning system and means of escape, similar to the recommendations in Approved Document B 16) for fire. There are situations where the technology does not currently exist to provide warnings by external bodies (eg. Environment Agency and emergency services) for certain types of flood event, so consideration should be given to local alarms connected to detectors within the building.

5.7.5 Consideration should be given to restricting the use of flood mitigation measures to, for the sake of argument:

Type of flood mitigation	**Max depth of flooding**	**Reason**
Flood avoidance	1.25m	To enable evacuation or emergency rescue (based upon the information in Box 1)
Flood resistant	1m	Unlikely to be successful in greater depths of water
Flood resilient	1.25m	To enable services to be fitted above flood level and to enable evacuation or emergency rescue
Flood repairable	0.5m	To avoid damage higher up

5.7.6 Where flood resilient or flood repairable construction is proposed, buildings should be a minimum of two stories, with the floors above flood level being designed to act as a refuge during a flood event.

5.7.7 Food storage and food preparation areas should be located above flood level (eg. at first floor level where flood resilient or flood repairable techniques are proposed). Similarly, sanitary accommodation, designed to be capable of being used during a flood event, should be available above flood level. Although these recommendations could be made in Approved Document G 17) , as they are a direct consequence of the choice of flood mitigation measures, inclusion in AD C is considered to be more appropriate.

5.7.8 To maintain essential services (eg. electricity, gas and telephone) during a flood and immediately afterwards, services should be installed above flood level where practicable or with separate circuits so that upper floors of a building can safely remain connected, with lower floors being capable of being safely disconnected during a flood.

5.7.9 Heating apparatus should be sited above flood level where practicable.

5.7.10 To avoid risks of carbon monoxide poising, AD C should recommend that the ventilation requirements of Approved Document J 18) should be capable of operating during a flood.

5.7.11 In order to avoid the risk of spillage from storage tanks (eg. for fuel oil or gas), they should either be located above flood level or designed to withstand floatation, even when empty. Any openings or vents should be either sealed or set higher than flood level. Tanks should also be designed to resist the external water pressure when empty to avoid collapse and rupture. (This recommendation is proposed for inclusion in AD C rather than in AD J as it is a direct consequence of the choice of flood mitigation measure.)

5.7.12 AD C should include recommendations upon the use of materials, used in flood resistant, resilient and repairable construction. Ideally this should be in the form of a simple table with common construction materials being categorized as “Suitable”, “Unsuitable” or “Use with caution”. The recommendations should take account of leaching of contaminants (eg. word preservative), the risk of mould growth following flooding, and ease of drying and cleaning.

5.7.13 The use of “waterproofing” on walls is likely to reduce their ability to “breathe”, which in turn will increase the risk of mould growth inside buildings during normal occupation. If ventilation is reduced to prevent water ingress, this will further increase the problems of mould growth. Therefore, there should be a specific mention in AD C that the ventilation requirements of Approved Document F 19) must still be met and, if practicable, increased where water-proofing is used.

5.8 Approved Document A [20] (AD A)

5.8.1 Where flood resistant construction is proposed (ie. keeping water out of the structure), the structure will need to be designed to resist the forces imposed by the worst anticipated flood conditions. As well as resisting hydrostatic pressure, the design should consider hydrodynamic effects caused by the velocity of the water, waves, debris and silt. This should apply to floors as well as walls.

5.8.2 Flood resistant structures should be designed against flotation, without being dependent upon a drainage system.

5.8.3 If a building is designed to float, services and drainage connections should be designed to accommodate the likely movement, without damage or interruption.

5.8.4 The structural design should take account of the increased weight of the structure from absorbing water and of potentially higher imposed loadings on upper floors from temporary storage above flood level.

5.8.5 The structural design should take account of reductions in the strength of building materials and components resulting from immersion and erosion.

5.8.6 Foundations should be designed to accommodate any likely erosion or undermining caused by floodwater.

5.9 Approved Document H [21] (AD H)

5.9.1 Consideration could be given to a recommendation in AD H that covers on drains and sewers liable to surcharge should be bolted down, to avoid the hazards of open chambers. However, a cover lifting often relieves pressure in the system and prevents backflow into a building.

5.9.2 AD H already contains provisions to prevent backflow of sewage – contaminated flood water through drains but this should be cross-referenced to the proposed AD C requirement for a FRA, in order to highlight where anti-backflow precautions are needed.

5.10 Approved Document G [17] (AD G)

5.10.1 A cross-reference should be made in AD G to the proposed recommendation in AD C that useable sanitary accommodation should be available above flood level.

5.11 Approved Document J [18] (AD J)

5.11.1 AD J should include a cross-reference to the proposed recommendation in AD C, that fuel storage should be sited above flood level or designed to resist immersion without spillage of contents.

5.11.2 Section 5 of AD J should include guidance of complying with the recommendation for fuel storage to resist flooding.

6 RECOMMENDATIONS FOR RESEARCH (TO PROVIDE DESIGN GUIDANCE IN BUILDING REGULATIONS)

6.1 Hydrodynamic effects

6.1.1 Design guidance is required on the hydrodynamic forces on a building, including:

- flow velocity (is it $V^2/2g$?)
- waves
- impact from debris
- increased density due to silt.

6.2 Loadings

6.2.1 Design guidance is needed on the likely increase in weight of normal construction materials due to absorbing flood water.

6.2.2 Guidance is required on whether there needs to be an increased imposed loading on upper floors due to temporary storage above flood level.

6.3 Strength

6.3.1 Design guidance is needed upon the decrease in strength of materials and components used in buildings after prolonged immersion.

6.3.2 Knowledge of the likely erosion caused by flood water upon materials used structurally is needed in order to assess suitable factors of safety to be applied.

6.4 Contamination

6.4.1 The risk of contamination being leached out of construction materials should be included in the testing regime of Work Package 5.

6.5 Mould growth

6.5.1 The ability of materials to support or encourage mould growth following flooding should be assessed as part of the testing.

7 OTHER MITIGATION

7.1 Many of the health and safety affects described above may be mitigated to some extent by the proposed changes to buildings, as these take account of flood resilient construction. However, many of the risks are associated with how people use the building and how they react during an emergency.

7.2 Drying out of the buildings, without the use of heat, should be commenced as soon as practicable after the flooding has subsided, in order to minimize mould growth.

7.3 Open containers should not be stored in areas at risk from flooding and chemicals should be stored above flood level.

7.4 It is essential that occupants should be aware of the fact that the building has been designed to be flood resilient. This will enable them to prepare for a flood, which reduces not only the physical danger but also the stress of being flooded. Contingency planning for use in the event of flooding (or other emergency) should include:

- use of flood resilient construction (the subject of this research) to minimize clearing up and damage
- ensuring receipt of flood warnings (see Appendix A)
- knowing how to turn of power supplies
- having dry clothes ready to change into
- identification of precious goods to be moved when a flood warning is received (particularly items of sentimental value)
- storing spare medicines or other medical requirements
- having friends or making other arrangements for the contingency plan to be put into operation should a flood occur whilst away from the property
- storing baby wipes for use in the event of not having clean water available for washing and always maintaining good hygiene before eating
- storing food and bottled water
- ensuring walls and other structures are sufficiently strong to withstand water on one side only, or perforating to ensure water cannot build up
- keeping spare batteries for mobiles phones (as charging may not be practical)
- identifying places to stay during a flood event
- identifying a safe evacuation route and marking it
- identifying trip hazards and marking them
- providing scene lighting, particularly adjacent to hazards
- providing security for the property so that it can be safely left empty for a time (ie. during a flood event and the subsequent clean up)
- maintaining and understanding the building and contents insurance policies and claims procedures
- putting contingency plans into operation early, whilst movement is simple and options exist

- identifying firms and agencies who will assist in the clearing and, in particular, carry out specialist tasks such as fumigation and restoring electricity
- trial runs of contingency plans, to establish their practicality.

7.5 The contingency plan should also reflect the needs and limitations of all likely occupants and users of the building, in particular the young, elderly or disabled.

7.6 External Agencies (such as Local Authorities) should also prepare contingency plans, which address the needs of different social and vulnerable groups. This should include links to support services, health and social services, child care, schooling and care for the elderly and disabled.

7.7 One problem that needs to be resolved is the conflict between taking measures that maintain the householder's awareness of flooding and state of alertness compared with the desire to avoid anxiety about being flooded. There is a similar conflict between ensuring that householder's expectations of flood mitigation measures are realistic (ie. that they could fail in exceptional circumstances) and in not causing anxiety.

7.8 During clearing up, chemicals should be used strictly in accordance with manufacturer's recommendations, preferably by specialists. WRc 9) research indicates that relatively mild cationic surfactant based compounds such as quaternary ammonium is just as effective at neutralizing sewage contamination as a more aggressive industrial strength disinfectant. Such compounds are likely to cause less of a problem when used in habited properties but it is still recommended that building is quarantined until disinfectant fumes have dissipated.

7.9 Disinfection of external areas is not generally considered to be effective and is therefore not recommended. Instead, once the ground is no longer waterlogged and after cleaning up any obvious solid matter and rags, the area should be quarantined to allow the contamination to be destroyed by sunlight. Guidance on quarantine periods are given by WRc9) are given in Box 4.

7.10 An extended circle of family and friends appears to be invaluable in not only returning to normality as soon as possible, but also in minimizing the stress of a flood event. Therefore, people living alone or new residents who may not have established links or friends with the local community are likely to suffer additional stress. Consequently, it is particularly beneficial for community leaders to organize events that encourage a sense of belonging in communities at risk of flooding and to actively offer support to people that have suffered from flooding.

Spring and autumn	Min 12 days (for spills on to turf and clay)
	Max 26 days (for spills on to loose soil and sand)
Summer	Min 6 days (for spills on turf)
	Max 9 days (For spills on to soil)
Winter	Min 11 days (for spills on to soil)
	Max 18 days (for spills on to turf)

Box 6. Quarantine Periods

From WRc Report PT.2099

8 CONCLUSIONS

8.1 Proposed changes to the Approved Documents A, C, G, H and J will make improvements in the design of flood resistant, flood resilient and flood repairable buildings to minimize risks to physical health and safety. However, they may not reduce the main identified health and safety risk of flooding, which is to mental health, nor to the impact upon communities. Therefore any decision to adopt these forms of construction must ensure that the risk is acceptable to building occupants (particularly as the politicians, developers and designers who decide upon the type of flood mitigation to be used will not be living there when a flood occurs).

7 REFERENCES

1) Lancaster J W, Preene M and Marshall C T, “Development and flood risk – guidance for the construction industry” CIRIA Report C624 , CIRIA 2004

2) Future Flooding Report, Office of Science and Technology, April 2004 (www.foresight.gov.uk)

3) Report on a WHO meeting 30 June – 2July 2002 “Floods: climate change and adaption strategies for human health.” WHO 2002

4) Hajat S, Ebi K L, Kovats S, Menne B, Edwards S and Haines A “The human health consequences of flooding in Europe and the implications for public health: a review of the evidence. Applied Environmental Science and Public Health 2003:1 (1). Open Minds Journals Ltd 2003

5) Few R, Ahern M, Matthies F and Kovats S “Floods, health and climate change: a strategic review” Tyndall Centre for Climate Change Research November 2004

6) Samwinga V, Proverbs D G and Homan J “Exploring the experience of UK homeowners in flood disasters” presented at COBRA 2004, 7-8th Sept 2004, Headingly, Leeds, RICS London

7) Tapsell S M, Tunstall S M and Wilson T “Banbury and Kidlington four years after the flood: an exanimation of the long-term health effects of flooding” Report to the environment Agency. Enfield: Flood Hazard Research Centre.

8) Draft R&D Output. Flood risks to People, Phase 2 Project Record. FD 2321/PR Flood and Coastal Defence R&D programme. Defra/Environment Agency

9) Report PT.2099 “Pollution prevention and control in sewer systems – microbiological decay rates” WRc Sept 2000

10) Raw G J, Aizlewood C E and Hamilton R M “Building Regulation, health and safety” Report BR417 BRE 2001

11) Walker G, Burningham K, Fielding J, smith G, Thrush D and Fay “Addressing Environmental Inequalities: Flood Risk” Science Project reference: EA 144426. Bristol environment Agency

12) Tapsell SM, Penning-Rowsell EC, Tunstall SM and Wilson TL “Vulnerability to flooding:health and social dimensions” Phil Trans, Royal Society , London, A(2002), 360, pp 1511-1525

13) The Building Regulations 2000, Statutory Instrument 2000 No. 2531

14) Construction (Design and Management) Regulations 1994. Statutory Instrument 1994 No 3140

15) The Building Regulations 2000. Approved Document C “Site preparation and resistance to contaminants and moisture” ODPM 2004

16) The Building Regulations 2000. Approved Document B “Fire safety” ODPM 2002

17) The Building Regulations 2000. Approved Document G “Hygiene” ODPM 2000

18) The Building Regulations 2000. Approved Document J “Combustion appliances and fuel storage systems” ODPM 2002

19) The Building Regulations 2000. Approved Document F “Ventilation” ODPM 2000

20) The Building Regulations 2000. Approved Document A “Structure” ODPM 2002

21) The Building Regulations 2000. Approved Document H “Drainage and waste disposal” ODPM 2002

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APPENDIX A

ENVIRONMENT AGENCY FLOOD WARNINGS

A. ENVIRONMENT AGENCY FLOOD WARNINGS

A.1 Areas at Risk of Flooding

In England and Wales the Environment Agency (EA) operates a flood warning service in areas at risk of flooding from rivers or in the sea and maintains and operates flood defences.

The EA uses the latest technology to monitor rainfall, river and sea levels 24 hours a day. The information is used to forecast the possibility of flooding from rivers and the sea using a set of four easily recognisable codes. Warnings of flooding are delivered by a combination of methods including direct telephone calls to properties in high-risk locations, local radio and TV and in few locations sirens.

The EA warn of two types of flooding:

(i) Tidal / Coastal Flooding.

(ii) Inland (Fluvial) Flooding.

Flooding may occur at any time of the year due to any of the following factors:

(a) Prolonged rainfall coupled with factors limiting absorption into the ground.

(b) Rapid thaw of heavy snow.

(c) Intensive localised rainfall due to freak storms.

(d) Abnormally high river levels caused by any of the above leading to overtopping or bursting of riverbanks.

(e) Burst water mains giving rise to localised flooding.

A.2 Definition of Warning Codes

The Flood Warning Code system operates a four-stage system that includes an “all clear” stage when all flood warnings and flood watches are removed. The action necessary at each stage will be clearly identified and communicated to the relevant agencies from the Environment Agency.

Each of the four codes indicates the level of danger associated with the warning. The four codes show the risk of flooding from rivers or the sea. They are not always used in sequence; for example in the case of a flash flood a Severe Flood Warning may be issued immediately, with no other warning code before it.

The alert warnings are as follows:

- **Flood Watch** – Flooding is possible in the (xxxx) area. Be aware, be prepared, Watch out!

- **Flood Warning** – Flooding of homes, businesses and main roads is forecast in the (xxxx) area. Act now!
- **Severe Flood Warnings** – Severe flooding is expected in the (xxxx) area. There is imminent danger to life and property. Act now!
- **All Clear** – There are no Flood Warnings or Flood Watches currently in force in the (xxxx) area. All Clear is issued when flood watches or warnings are no longer in force. Flood water levels receding. Check all is safe to return. Seek advice.

The value of the staged warning system is that it progressively warns people who may be at risk of flooding of the degree of danger to life and property. It will also describe the necessary action to be taken.

A.3 Flood Warning Service

The Environment Agency is currently improving the flood warning service.

Telemetry Network Improvements – Increasing the number of outstations, e.g. river level sites.

Advanced Flood Warning Weather Radar – Installing a new dual polarisation radar.

Southern Flood Forecasting Scheme – A new real time flood forecasting system. Coastal Modelling, Wave overtopping and Inundation Mapping.

Multi Media Dissemination System – Replacing the automatic Voice Messaging System.