The Buncefield Incident 11 December 2005

The final report of the Major Incident Investigation Board

Volume 1

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Foreword

To Judith Hackitt, Chair HSE Board

In January 2006 your predecessor, Sir Bill Callaghan, appointed myself and others to investigate and report on the explosions and fires that occurred at the Buncefield oil depot on 11 December 2005.

Since then we have met as a full Board on over 30 occasions, and in working groups. We have published eight reports, responded to three consultation documents and issued early advice to the Competent Authority on important preventive measures arising out of the investigation. We have completed our review of the Competent Authority's policy and procedures for regulating the Buncefield site.

We recently concluded that the publication of this our ninth and final report would complete our terms of reference. You endorsed this conclusion, and we agreed that the Board should accordingly cease active business as of today.

It was a new departure to appoint an independent Chair to a Major Incident Investigation Board. The express intention was that the Board should conduct its work in an independent and objective way. Delivering this has been a key priority for me.

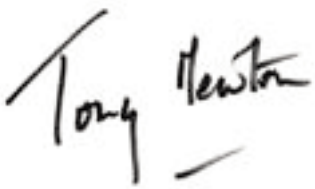
Volume 1 of this report draws attention to some of the ways the Board has set about its business. One of the advantages of our approach has been the freedom to make contact with so many of the individuals and organisations affected by the events at Buncefield. This has, among other things, given us a real feel for the distress and disruption that the event caused.

Another advantage has been the capacity to publish reports when we were ready to do so, subject only to legal constraints. Volume 2 brings together all our previous reports in a single publication for the public record and for future reference.

The Ministerial Statement made to Parliament on 13 November and the detailed response to our various recommendations which accompanied it provide some measure of the influence the Board's work has had. We recognise the effort required across Government in preparing such a response and were pleased to note its generally positive tone.

We also recognise that a detailed Government response could not at that stage be made to our most recent report, on land use planning and societal risk, but look forward to the substantive response from the Secretary of State for Communities and Local Government in due course.

As we conclude our work, I want to express my appreciation of the way in which my fellow Board members have blended their widely different skills, knowledge and experience in so thorough and professional a way. All of them would wish to join me in collective thanks to Taf Powell as Investigation Manager and Phil Kemball as Secretary to the Board, and to the many others who have given us so much valuable help, advice and encouragement in our work. I hope that together we have made an enduring contribution to reducing the risk that sites such as Buncefield present and to improving our country's capacity to respond effectively should any such incident occur again.



Lord Newton of Braintree
Chair of the Buncefield Major Incident Investigation Board

Executive summary

In this Final Report we draw together the findings of a three-year investigation into the Buncefield Incident as overseen by the Major Incident Investigation Board. The Buncefield complex had been designated as a top-tier site under the COMAH Regulations and the lessons learned here are important not only for fuel storage sites but also for the wide range of industrial installations that store or process hazardous substances in the UK and fall under the COMAH Regulations.

We give in Part One, Chapter One a description of the Buncefield fuel depot in Hemel Hempstead, Hertfordshire, England and an account of the incident itself, which was caused by the overfilling of a large petrol storage tank. The escaping petrol formed a flammable vapour cloud which spread off site and was eventually ignited with great violence. We describe the impacts of the explosions and fires in the vicinity of the depot and also refer to the work commissioned by the Board into understanding the mechanism for generating the high explosion overpressures that was still unexplained at the time of writing this Report.

In Chapter Two we summarise the immediate response by the Health and Safety Executive and the Environment Agency who, as the COMAH Competent Authority, regulate the Buncefield site. A major incident investigation was set up with an independent Chair, the first time that independent oversight has been applied to such an investigation. During the initial investigation three progress reports from the Investigation Manager explained the events leading up to the failure of containment of the fuel, which led to the catastrophic explosion, following which we published our own Initial Report setting out our main areas of concern. During this time we also made reports to the Competent Authority on matters requiring immediate attention for the safety at other sites and these were dealt with promptly.

Between the summer of 2006 and July 2008 we produced four reports addressing key areas requiring special recommendations. During this time the Competent Authority and the industry implemented early measures to improve containment of fuel. A more long-term and ambitious programme for improving safety and environmental protection around high-hazard industrial sites was also produced.

Chapter Three contains a summary of the economic impact of the Buncefield incident which broadly adds up to £1 billion comprising compensation for loss, costs to the aviation sector, the emergency response and the costs of the investigations. (We show in Annex 3 that although this is a very large sum compared to most other major incidents it is not unique.) We also provide some simple calculations of the range of costs for implementing our recommendations for avoiding overfilling tanks with petrol and estimate, in monetary terms, the benefits of the measures we recommend.

In Chapter Four we describe the key relationships of the Board with other events and stakeholders in the context of our independence of thought and action. Our relationships with the criminal investigation, with the Competent Authority via our review of its policies and procedures, and with the residential and businesses communities affected by Buncefield are described.

In Chapter Five we make a number of final observations for taking our recommendations forward, in the light of the 13 November statement by Government with its broadly positive response to our reports on design and operations of sites, and on emergency preparedness and response for major incidents. The areas of leadership, standards and guidance, and the timetable for

implementation are three key areas for maximising the chances of preventing another incident like Buncefield.

In Part Two we present all of our recommendations in one place for the first time. Our overarching aim is to achieve an effective regime for the control and mitigation of major accident hazards under COMAH which is more consistent than is currently the case. We see this being delivered through a system that integrates the design and operation of major hazard sites to avoid major incidents with measures for preparedness and response to major incidents should they occur, and which the land use planning system should take into account when making judgements on the suitability of off-site developments in the vicinity of COMAH sites.

Introduction

1 Early on Sunday 11 December 2005, a series of explosions and subsequent fire destroyed large parts of the Buncefield oil storage and transfer depot, Hemel Hempstead, and caused widespread damage to neighbouring properties.

2 The main explosion took place at 06.01:32 hours and was of massive proportions. It was followed by a large fire that engulfed 23 large fuel storage tanks over a high proportion of the Buncefield site. The incident injured 43 people. Fortunately, no one was seriously hurt and there were no fatalities. Nevertheless, there was significant damage to both commercial and residential properties near the Buncefield site. About 2000 people had to be evacuated from their homes and sections of the M1 motorway were closed. The fire burned for five days, destroying most of the site and emitting a large plume of smoke into the atmosphere that dispersed over southern England and beyond.

Figure 1 View from the west of the Buncefield Hertfordshire Oil Storage depot after the fires were all out. Tank 912, from which the petrol feeding the vapour that exploded escaped, is in the centre of the bund at the bottom of the picture. Cherry Tree Lane, a public road, cuts diagonally across the upper part of the picture and is flooded ('Lake Buncefield'). Across the road are the remains of Tank 12, a large aviation fuel storage tank. The roof of the fire pump house can be seen embedded in foam at middle left. The adjacent fire water lagoon is covered in escaped fuel

3 A major incident investigation was formally established by the Health and Safety Commission (now the Health and Safety Executive)[1] under section 14(2)(a) of the Health and Safety at Work etc Act 1974. The investigation's eight terms of reference included identifying the causes of the incident; reviewing the Competent Authority's policies and procedures for regulating the Buncefield site; and making recommendations for future action.

4 On 12 January 2006 Lord Newton was appointed to Chair the Major Incident Investigation Board (the Board) set up to oversee the investigation.

5 This report is made to the Health and Safety Executive (HSE) Board and the Board of the Environment Agency that together form the joint Competent Authority responsible in England and Wales for regulating the Buncefield site under the Control of Major Accident Hazards Regulations 1999 (COMAH).[2] The remit for this report is in the eighth of eight terms of reference for the Board, that asks it to make its final report public.

1 The Health and Safety Commission merged with the Health and Safety Executive on 1 April 2008. The roles and functions of the Commission have transferred to the 'new' Executive.

2 The COMAH Regulations are enforced by a joint Competent Authority comprising HSE and the Environment Agency in England and Wales and HSE and the Scottish Environment Protection Agency (SEPA) in Scotland.

Part 1

The incident, its impact and the Major Incident Investigation Board

Figure 2 Map showing Buncefield, in south-east England

1 The Buncefield incident 11 December 2005 – a summary of the site and events

6 This chapter and the following one are presented in a way that we hope makes them accessible to the interested lay reader, partly in response to a request from residents of Hemel Hempstead for a simplified account of the investigation and our subsequent work.

7 The Buncefield oil storage and transfer depot is a large fuel storage site (known as a tank farm) in Hemel Hempstead, Hertfordshire. In the early morning of Sunday 11 December 2005, a series of explosions followed by a large fire destroyed large parts of the depot and caused widespread damage to homes and businesses surrounding the site. This chapter explains the significance of the Buncefield depot and describes briefly how the explosions and fires happened and the damage they caused.

The Buncefield depot

8 The Buncefield depot is a large tank farm 3 miles (about 4.8 km) from the town centre of Hemel Hempstead, Hertfordshire. A tank farm stores fuels and other products in tanks before they are transported to other facilities such as petrol stations or airports. Buncefield was the fifth largest of 108 oil storage sites across the UK.

9 The Buncefield depot was very important in helping to distribute fuels to London and south-east England, including Heathrow Airport. It was built and began operating in 1968, when there were very few buildings in the surrounding area.

Figure 3 Buncefield from the north. The M1 motorway is to the east. On the west is the Maylands commercial estate. The smoke in the foreground emanates from a domestic garden

Figure 4 Schematic showing the pipeline system supplying Buncefield

10 In December 2005, the depot contained three sites:

- Hertfordshire Oil Storage Ltd (HOSL): a joint venture between Total UK Ltd and Chevron Ltd. The HOSL part of the depot was divided into two sections – HOSL East and HOSL West – and was permitted to store 34 000 tonnes of motor fuel and 15 000 tonnes of heating oil;
- British Pipeline Agency Ltd (BPA): a joint venture between Shell and BP, though the assets were owned by UK Oil Pipelines Ltd. The BPA site was also split into two sections – the 'North' (or 'Cherry Tree Farm') section and the main section. BPA had consent to store 70 000 tonnes of motor and other fuels; and
- BP Oil Ltd: at the southern end of the depot, this site had consent to store 75 000 tonnes of motor fuel.

11 Fuel was transported to these sites through three pipelines:

- Finaline – between Lindsey Oil Refinery in Humberside and the HOSL West site;
- M/B pipeline (Merseyside/Buncefield – between Merseyside and the BPA North site (the Northern limb of the Thames-Mersey line); and
- T/K pipeline (Thames/Kingsbury) – between Coryton Refinery and the BPA main site (the southern limb of the Thames-Mersey line).

12 The pipelines all transported fuel in batches. At the depot the various grades of fuel were separated into dedicated tanks according to the fuel type. Most of the fuel was then taken from the depot by road tankers, which were loaded using special facilities on the site. The jet aviation fuel left the BPA site via two pipelines, taking the fuel to the West London Walton Gatwick pipeline system. The fuel was then distributed to airports such as Heathrow and Gatwick.

13 The Maylands Industrial Estate is immediately west of the depot and residential areas surround the site. Hemel Hempstead town centre is to the south-west of the depot.

14 Fuel depots are designed to keep fuel inside the tanks and pipework that store the fuel. They also need to be able to stop the fuel (or any contaminated liquid, such as fire water) from spreading and running off the site if it does escape from the tanks or pipework. The tanks and pipework have controls, such as alarms which would be set off if the fuel in a tank gets to a certain level, to prevent overfilling. The tanks are positioned within a walled area designed to prevent any escaping liquid from spreading into (and outside) the site. These enclosures are called 'bunds', and often house several tanks.

The explosions and fire

15 Late on Saturday 10 December 2005 a delivery of unleaded petrol from the T/K pipeline started to arrive at Tank 912 in bund A at about 05:30 on 11 December. The safety systems in place to shut off the supply of petrol to the tank to prevent overfilling failed to operate. Petrol cascaded down the side of the tank, collecting at first in bund A. As overfilling continued, the vapour cloud formed by the mixture of petrol and air flowed over the bund wall, dispersed and flowed west off site towards the Maylands Industrial Estate. A white mist was observed in CCTV replays (see Figures 5, 10 and 11). The exact nature of the mist is not known with certainty: it may have been a volatile fraction of the original fuel such as butane,[3] or ice particles formed from the chilled, humid air as a consequence of the evaporation of the escaping fuel.

16 Petrol will not easily explode. However, up to 300 tonnes of petrol escaped from the tank, about 10% of which turned to vapour that mixed with the cold air eventually reaching concentrations capable of supporting combustion (ie the mixture became flammable). The formation of the vapour cloud and its distribution around and beyond the Buncefield site remains under scientific investigation.

17 Between 05.30 and 06.00 the vapour cloud was seen by eyewitnesses and CCTV cameras to thicken and spread, reaching almost as far west as Boundary Way in the Maylands Estate.

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3 Approximately 10% of the petrol in the batch being delivered into Tank 912 was butane. This formulation is usual in petrol blended for winter use to boost performance. At atmospheric conditions, butane is a gas but it compresses easily to a liquid state (as in cigarette lighters) and is in liquid form when blended with petrol.

Figure 5 HOSL CCTV footage

Figure 6 Firefighters laying down a foam blanket over Tank 913 in HOSL bund B. Foam is laid down to help prevent reignition of a flammable liquid by isolating it from the air. Bund A is in the foreground. The burning tank on the right is Tank 912 from which petrol escaped at the start of the incident

18 At 06:01 on Sunday 11 December 2005, the first of a series of explosions took place. The main explosion was massive and appears to have been centred on the Maylands Estate car parks just west of the HOSL West site. These explosions caused a huge fire which engulfed more than 20 large storage tanks over a large part of the Buncefield depot. The fire burned for five days, destroying most of the depot. A plume of black smoke from the burning fuel rose high into the atmosphere and could be seen from many miles away and in satellite images. As it developed, this plume eventually spread over southern England and beyond.

19 The main explosion at Buncefield was unusual because it generated much higher overpressures[4] than would usually have been expected from a vapour cloud explosion. The mechanism of the violent explosion is not fully understood and we have commissioned further scientific investigation to explain what occurs in large flammable vapour clouds.

20 The exceptional scale of the incident was matched by the scale of the emergency response. Gold Command (the Strategic Co-ordinating Group) was established within hours, co-ordinated by Hertfordshire Police and involving Hertfordshire Fire and Rescue Service, Hertfordshire County Council, Dacorum Borough Council, the Environment Agency and the Health Protection Agency, with HSE in support.

21 At the peak of the fire, at noon on Monday 12 December, 25 Hertfordshire pumps were on site with 20 support vehicles and 180 firefighters. Voluntary services also attended to cater for the welfare of emergency service personnel.

22 The full operation involved 1000 firefighters from Hertfordshire and across the country, supported by police forces from throughout the UK. It took 32 hours to extinguish the main blaze, although some of the smaller tanks were still burning on the morning of Tuesday 13 December. The following day a new fire started in a previously undamaged tank, but the fire service let it burn out safely. Overall, 750 000 litres of foam concentrate and 55 million litres of water were used during the firefighting operations.

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4 'Overpressure' is the pressure over and above normal atmospheric pressure caused by an explosion (a rapid release of energy).

Figure 7 Fire hose expertly laid around the Breakspear roundabout and connecting the fire ground with the water source (the Breakspear lagoon)

23 About 2000 people had to be evacuated from their homes during the emergency operation and nearby sections of the M1 motorway were closed. Some schools in Hertfordshire, Buckinghamshire and Bedfordshire were closed for two days following the explosion.

24 Once all the fires were out on 15 December the emergency services handed over the task of identifying what had caused the incident to a specialist Investigation Team from HSE and the Environment Agency. The long process of safely cleaning up the badly damaged areas on and around the site began within days. However, parts of the site remained too dangerous for investigators to access for weeks or months afterwards.

Effects of the explosions and fire

25 Nobody was killed in the incident, although 43 people suffered minor injuries. As well as destroying large parts of the depot, there was widespread damage to surrounding property and disruption to local communities. Some houses closest to the depot were destroyed and others suffered severe structural damage. Many residents had to move into temporary accommodation while repair work was carried out, some for long periods. Other buildings in the area, as far as 5 miles (8 km) from the depot, suffered lesser damage, such as broken windows, and damaged walls and ceilings.

26 Many residents affected by the blast faced difficulties as they tried to rebuild their lives following the incident. As well as damage to properties, many people lost personal possessions. Some people were also greatly affected by the trauma and needed psychological help. There were, however, no serious health effects reported among the public[ref 1] or the emergency response workers[ref 2] from exposure to the plume of smoke which dispersed over southern England. The hot plume rose rapidly and spread out over a deep inversion layer which persisted under very stable weather conditions and this pattern led to very low concentrations of smoke at ground level. The absence of rain for the duration of the fire meant there was no deposition of fire and combustion products either.

Figure 8 Failed bunds on the Buncefield site photographed after the fires were all out

27 Businesses on the Maylands Industrial Estate were badly disrupted. At the time of the explosion the estate housed 630 businesses and employed about 16 500 people. Some premises were destroyed and others required significant repair work. A few companies went into liquidation. Some jobs had to be relocated, but many of these were temporary. Some roads near the depot were closed for several months, as they had been made unsafe by the incident. The East of England Development Agency estimated that the incident cost local businesses £70 million. Local councils and other agencies set up several initiatives to help the recovery of the area and the affected businesses.

28 Environmental pollution outside the Buncefield depot mainly affected nearby soil and water that was contaminated by escaped fuel and firefighting foam and water. This contamination was mostly close to the depot and did not affect drinking water supplies. The threat of pollution remains nonetheless from products that have migrated into the ground water around Buncefield such as PFOS (from firefighting foam), BTEX and MTBE (constituents of motor fuels).[5] At Annex 5 we provide an update on the Environment Agency's monitoring programme and more description on the polluting products referred to above.

29 Any pollutants from the smoke plume were spread over a wide area and caused little damage to soil and plants. An initial report on the results of the air quality monitoring and the impact of the plume on human health (and vegetation) was published by the Department for Environment, Food and Rural Affairs (Defra) in May 2006.(ref 3) Overall, the report concluded 'there are unlikely to have been widespread air quality impacts at ground level due to pollutants emitted from the Buncefield fires'.

30 The loss of the depot caused temporary disruption to fuel supplies in the south-east, though fall-back arrangements were quickly put in place. Ground fuel supplies (for heating and for motor transport) were least disrupted. The longest severe

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5 Perfluorooctane sulphonates; benzene, toluene, ethyl-benzene, and xylenes; and methyl tertiary-butyl ether.

Figure 9 A dramatic picture of the early stages of the Buncefield smoke plume from an aircraft leaving Luton Airport to the north of the depot. The M1 motorway can be clearly seen heading south towards Buncefield. London is to the south-east, or upper left, of the picture and was itself covered by the plume. The sharply defined lower boundary of the plume marks the line of the temperature inversion layer present over southern England at the time of the incident. The low-lying mist over the ground indicates the low temperature and still air that were also associated with the incident

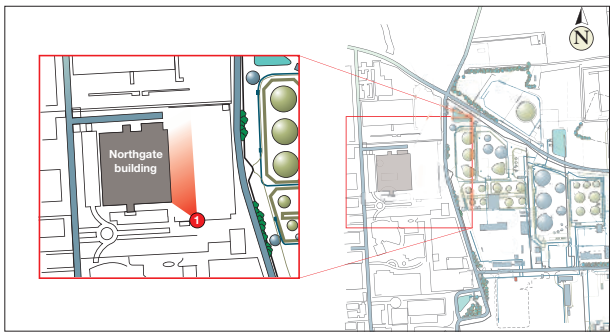
impact was on Heathrow Airport, which had previously received half its daily fuel supplies from Buncefield. At the time of completing this report Heathrow Airport's fuel supply arrangements were at full stretch and work was in hand to create additional supply capacity.

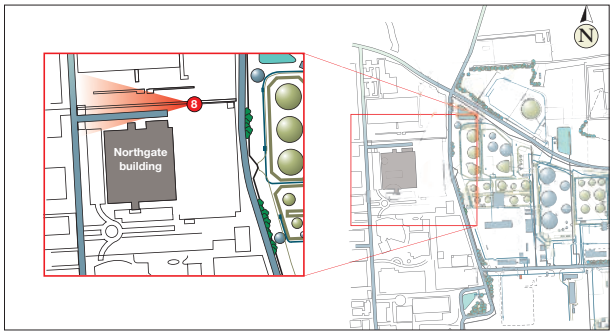
Work to understand the violence of the Buncefield explosion

31 The violence of the Buncefield explosion, which resulted in tremendous damage to the outlying area and the huge fires involving 23 large oil fuel tanks, remains, at present, only partially explained. An explosion can be produced when a gas cloud is ignited within a confined volume such as a building. As the flame propagates through the gas cloud it produces hot combustion products. The confinement prevents expansion of these combustion products and as a consequence, the pressure increases. In general, this continues until the confining structure fails, in some cases catastrophically. This mechanism does not explain the type of explosion that occurred at Buncefield as the majority of the cloud was not confined. It is recognised that two 'confined explosions' did occur, but these events alone could not explain the severity of the overall explosion.

32 Immediately following the incident, the Board accepted what appeared to be the view commonly held by the industry and the relevant expert community in Britain: that this was an unprecedented event. However, it was soon revealed during the investigation that other incidents which had involved large clouds of petrol vapour had occurred elsewhere.[6] Unfortunately, to our knowledge these events were not subjected to thorough investigation concerning the generation of high overpressures. Therefore conclusions relating to apparent similarities to Buncefield cannot be drawn.

[6] See Annex 4 for further explanation of open flammable cloud explosions. Annex 4 also deals with the aspect of credibility of an explosion and lists seven incidents of some similarity to the Buncefield incident (updated from the Board's Initial Report).





Figures 10 and 11 Stills from the CCTV cameras installed on the Northgate site to the west of bund A showing the migration of the 'white mist' that marks the flammable vapour.

33 From the outset the Board resolved that under its fifth term of reference[7] it would want research undertaken to understand the explosion mechanism that produced such high overpressures at Buncefield. It was the view of the Board that such understanding would provide further material assistance in guiding the design and operation of sites that store large quantities of vaporising flammable materials.

34 In paragraph 77 of our Initial Report(ref 4) of 13 July 2006 we said:

> 'Further work is needed to research the actual mechanism for generating the unexpectedly high explosion overpressures seen at Buncefield. This is a matter of keen international interest, and participation from a broad range of experts, as well as the industry, is essential to ensure the transparency and credibility of any research programme. The Board will consider further recommendations about the nature and scope of such work.'

35 The Board invited a team of explosion experts from academia and industry to form a working group to advise on the work that would be required to explain the severity of the Buncefield explosion. The Advisory Group began its work in December 2006 and had three further meetings before producing its report.(ref 5) It identified a number of possible explosion scenarios but within the time constraints could not fully test them against the considerable amount of information constraints. Nevertheless, the Group concluded that there is a strong likelihood that the cause of the severe explosion at Buncefield can be explained, although this will require further, more detailed work. However, it was the opinion of the Group that a comprehensive explanation is unlikely to be found without the conduct of further experimental and theoretical research.

36 It was recommended that a joint industry project be initiated with the task of completing the assessment started by the Advisory Group and, on the basis of its findings, defining the requirements of the research to be carried out in a second phase of the project. Guidance to industry and HSE should be a primary deliverable of the project. We support these recommendations and attach a great deal of importance to the effective conduct of the proposed research work.

37 The Board has set up the first phase of a technical programme to promote that research. The programme is overseen by a Steering Committee and supported by relevant technical experts (the Technical Group) who are considering the evidence available. At the time of publishing this report, several meetings have been held and work is progressing with a view to completion of Phase 1 in the first quarter of 2009. In his letter accompanying the publication of the Advisory Group report in August 2007 Lord Newton said 'We will wish to take a continuing interest in this important work'. The Board has taken steps to ensure that the independent work begun by the Advisory Group will be continued by the Steering Committee and the Technical Group through the appointment of Professor Dougal Drysdale, an independent member of the Board, to both committees of the Phase 1 programme. He has led for the Board in its explosion mechanism work and was instrumental in creating the Advisory Group, all the members of which have been invited onto the Technical Group.

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7 'To make recommendations for future action to ensure the effective management and regulation of major accident risk at COMAH sites. This should include consideration of off-site as well as on-site risks and consider prevention of incidents, preparations for response to incidents, and mitigation of their effects'.

Figure 12 Series of images taken by investigators of the damage on the Maylands estate

2 Summary of the Buncefield Board's work

The investigation

The immediate investigation response

38 HSE and the Environment Agency, as the joint Competent Authority under the COMAH Regulations, attended the incident from the start, beginning their on-site investigation on 16 December 2005. Taf Powell from HSE's Offshore Division was appointed as the Major Incident Investigation Manager on 19 December 2005.

39 The site was immediately placed under the control of prohibition notices and do-not-disturb notices. These were to ensure the investigation and clean-up work could be carried out, so far as reasonably practicable, without risks to the personnel involved, and also to preserve evidence. Early work included mapping debris and damage throughout the incident area, extending several kilometres beyond the depot. Site computers with their records of CCTV footage, fuel movements and tank configurations were of critical importance and, with the support of the police and firefighters, investigators were able to enter the precariously damaged site buildings and recover the computers before Christmas 2005.

40 The major incident investigation was formally established by the Health and Safety Commission (now the Health and Safety Executive)[8] under section 14(2)(a) of the Health and Safety at Work etc Act 1974. The investigation's eight terms of reference included identifying the causes of the incident; reviewing the Competent Authority's policies and procedures for regulating the Buncefield site; and making recommendations for future action.

41 On 12 January 2006 Lord Newton was appointed to Chair the Major Incident Investigation Board set up to oversee the investigation. Board members included three members of the Competent Authority and two independent members, Dr Peter Baxter and Professor Dougal Drysdale.

42 On 13 February 2006 the Investigation Manager advised the Competent Authority that the violent explosion at Buncefield was likely to have resulted from an escape of petrol that formed a vapour cloud which subsequently ignited.

43 The Investigation Manager's first progress report(ref 6) was presented to the Board in February 2006 and published on 21 February 2006. It described the incident and the emergency response; the environmental, social and economic impact of the incident; and initial evidence of the cause of the explosion gained from eyewitness reports, CCTV footage and preliminary forensic examinations. At the same time the Competent Authority (HSE, the Environment Agency and Scottish Environment Protection Agency) issued a Safety Alert and a joint survey of preventive measures at all (108) oil fuel storage depots in Great Britain in response to the notification from the Investigation Manager the previous week.

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8 The Health and Safety Commission merged with the Health and Safety Executive on 1 April 2008. The roles and functions of the Commission have transferred to the 'new' HSE.

Figure 13 The Buncefield site and surrounding ground at the time the police handed the investigation to the COMAH Competent Authority

Figure 14 Examining the interior of Tank 912

44 On publishing the first progress report we emphasised the importance of HSE reviewing, as information emerged from the investigation, the advice it gave to planning authorities in relation to sites such as Buncefield. The Board restated this view after subsequent reports and started to consider options for revisions to the land use planning (LUP) arrangements at fuel sites.

45 The Investigation Manager's second progress report[ref 7] was presented to the Board in April 2006 and published on 11 April 2006. It described the ongoing investigations by the Environment Agency into the environmental impact of

escaped fuel and fire water; the further progress of the investigation into how the fuel actually escaped; and early observations on bund integrity. At the same time the Environment Agency launched a separate further investigation into bunding and drainage at oil fuel storage depots in England and Wales.

46 The Investigation Manager's third progress report[ref 8] was presented to the Board in April 2006 and published on 9 May 2006. It described the timeline of events at Buncefield, explaining how Tank 912 in bund A on the HOSL West site overflowed at about 05:30 hours on 11 December 2005, while being filled at a high rate. The report also explained how the fuel-rich vapour that flowed off site might have formed and described potential sources of ignition, further progress with environmental issues and contacts with local businesses and residents.

47 On 13 June 2006 the Competent Authority published the preliminary findings of the follow-up survey to its February Safety Alert.[ref 9] It identified a high level of compliance in safety performance, but found that only 12% of sites had fully satisfactory environmental performance. On the same day the Buncefield Standards Task Group was set up to respond to emerging Buncefield issues. It was chaired by the industry and involved the Competent Authority.

48 In June 2006 the Investigation Manager advised the Competent Authority of concerns about the functionality of some high-level switches on fuel tanks. HSE responded with a Safety Alert to site operators on 4 July 2006.[ref 10] The alert applies to a certain kind of switch used in ultimate high-level alarm systems. To test that this kind of switch is working correctly, a lever or plate fitted to the head of the switch can be moved to simulate a high level of liquid in the tank. Failure to put the test lever or plate back to the correct position can lead to the switch being inoperative, which could result in a failure of the ultimate high-level detection system. Improvement notices were issued requiring the manufacturer to contact users or installers of these switches to alert them to the issue and to provide revised instructions and labelling on the safe use, setting, cleaning and maintenance of the switches.

49 The Board issued its Initial Report[ref 4] (as required by the investigation's sixth term of reference) on 13 July 2006. This marked a key stage in the Board's work, as its attention turned from investigating causes to making recommendations to improve safety and environmental performance at high-hazard sites. The report reviewed what had been learned about the incident and set out four areas of concern:

- design and operation of sites;
- emergency preparedness;
- land use planning; and
- the Competent Authority's policies and procedures.

50 The Initial Report established primary containment as a key area for regulator and industry attention. It asked HSE to review its approach to giving advice to planning authorities, with a view to taking greater account of risk. It restated the need for further research into the explosion mechanism. Finally, it provided extensive appendices of detailed information for further inquiry.

51 By this stage of the investigation the key challenge identified was that what had happened at Buncefield had not been considered a reasonably credible scenario for planning purposes. Nevertheless, the circumstances which led to the event were predictable even if the consequences were not. There was therefore a need to change current thinking towards managing certain major incident risks. This had implications

Figure 15 A view of the Kingsbury fuel storage depot in Warwickshire. Kingsbury is a facility of a similar size and function to Buncefield

for the controls and other arrangements put in place by site operators, local authorities, emergency responders and Government. We decided to give priority to making recommendations on design and operations, and on emergency preparedness.

The Board's recommendations and the sector's response

52 On 12 October 2006 the Buncefield Standards Task Group published interim guidance(ref 11) on eight key actions to improve standards at the 60 sites storing or handling petrol in similar circumstances to Buncefield.

53 Between November 2006 and February 2007 the Board discussed the need for changes to policy on land use planning and societal risk with relevant ministers in the Department for Communities and Local Government (CLG), the Department for Trade and Industry (now Business, Enterprise and Regulatory Reform (BERR)), the Department for Work and Pensions and Defra, as well as with HSE. On 27 February 2007 HSE began a public consultation on proposals to change its arrangements for giving advice to local planning authorities. This included options for extending consultation distances around fuel depots. We responded to HSE's consultation on 22 May 2007, stating our preference for a risk-based approach to land use planning[9] at all major hazard sites. On 4 December 2007 HSE published its interim policy on the control of development adjacent to fuel storage sites.(ref 12)

54 On 2 April 2007 the Government launched a public consultation on societal risk. We responded on 2 July 2007, restating our preference[10] for incorporating societal

9 Land use planning advice at fuel storage sites is based on protection against the worst credible event – normally failure of the largest tank creating a large pool fire. At major chemical sites land use planning advice is based on a site hazard risk assessment.

10 This preference was first stated in our Initial Report of July 2006 – see paragraph 86. See also paragraph 85 which refers to our interest in a risk-based approach to land use planning at all COMAH sites.

risk into a revised LUP system. On 21 January 2008 HSE published the outcome of the Government's consultation. This also favoured incorporating societal risk into LUP arrangements. The Government's pre-existing Ministerial Group on societal risk considered revisions to the planning system in the light of the consultation results.

55 The Board published its fifth report(ref 13) on 29 March 2007, on the design and operation of fuel storage sites, the first of the four areas of concern identified in the Board's Initial Report. The report restated the importance of primary containment and made 25 recommendations to improve the integrity of fuel storage operations. It also gave an update on research into the explosion mechanism. The report aligned closely with the findings of investigations into the Texas City, USA refinery incident of March 2005, particularly on the need to improve the attention given to process safety, human factors and organisational culture.

56 Also on 29 March 2007 the Competent Authority published a full report on its surveys of fuel sites in Great Britain.(ref 14) This revealed six instances where compliance levels were not to the appropriate standards, and action was taken by the Competent Authority to address these.

57 On 1 May 2007 we asked BP how the Board's recommendations on design and operations would be applied at BP's Buncefield depot when operations there recommenced. BP replied on 24 May that they were intending to apply applicable recommendations to their Buncefield operations.

58 On 27 June 2007 the Competent Authority published a consultation document(ref 15) on its proposed containment policy. This addressed issues arising from the Buncefield incident, particularly the need to prevent loss of containment of fuel from tanks and pipework etc and, in event of loss of containment, to prevent fuel escaping from bunds and from the site perimeter. We responded on 17 September 2007, encouraging the Competent Authority to adopt authoritative standards to ensure its policy is enforceable. The Competent Authority's revised containment policy came into effect on 20 February 2008.

59 The Board published its sixth report(ref 16) on 17 July 2007, on emergency preparedness, response and recovery; the second raft of recommendations to address the four areas of concern set out in the Board's Initial Report. The report emphasised that, while preventing incidents remains the prime objective, emergency preparedness remains important because there can be no guarantee against major incidents occurring. The report made 31 recommendations to improve the preparedness and response of industry, emergency services and public authorities; and to improve assistance to communities damaged by a major incident to help them to return to social normality. The recommendations included one requiring that a specific minister should be made responsible for seeing that incident responses are satisfactory and for ensuring subsequent recommendations are implemented; and a minister, with appropriate financial resources, to be responsible for overseeing the recovery of damaged communities.

60 The Buncefield Standards Task Group published its final report(ref 17) on 24 July 2007, setting out developments in practices and guidance since its initial report issued in October 2006, and setting out a further 16 recommendations for completion by mid-2008. The Competent Authority published its own report(ref 18) on the implementation by the sector of the Task Group's initial eight recommendations in February 2008. The Task Group was later replaced by the Process Safety Leadership Group (PSLG), also with a joint Competent Authority/industry membership, to take forward a number of workstreams including those relevant Board recommendations not already dealt with. PSLG met for the first time on 21 September 2007.

61 The Board published its seventh report[ref 5] on 16 August 2007 describing what had been learned so far about the mechanism of the violent explosion at Buncefield. From the start of the investigation it had been a matter of concern that the violence of the explosion was largely unexplained. The report identified similar earlier events overseas that appeared not to have been scientifically investigated. It analysed evidence from the investigation and estimated the likely overpressures at Buncefield and suggested a number of mechanisms that might explain how these overpressures had been generated in largely unconfined spaces. Finally the report made three recommendations for further analysis and research.

62 On 30 August 2007 the Investigation Manager alerted HSE that in the course of research to support the investigation, examples had been found where some electro-mechanical servo gauges were less reliable in service than claimed, and resistant to on-site maintenance. The outcome could be to place undue dependency on human response, on overfill prevention systems and on emergency systems. HSE referred the matter to PSLG on 21 September and it was incorporated into a programme for improvements to process safety systems across the sector.

63 On 20 September 2007 the Competent Authority held a workshop for front-line inspectors on the lessons learned from the Buncefield incident.

64 Early in 2008, the Competent Authority commenced a project to review and where necessary revise the regulatory regime for all COMAH sites. This project had been delayed by the Buncefield incident, but the delay allowed the project to absorb lessons from Buncefield. The COMAH Remodelling Programme Board met for the first time on 18 April 2008. Its membership included representatives from the Competent Authority, industry and a regulator from the Netherlands.

65 On 21 February 2008 HSE Chair Judith Hackitt chaired an international safety conference hosted by the UK Petroleum Industry Association. The conference brought together experts from industry, the regulators, professional bodies and trade associations to generate a wider debate on process safety and sharing best practice in the downstream oil industry. HSE's Chair and Chief Executive hosted a further platform for industry leaders to share good practice and learning from incidents such as Buncefield on 29 April 2008 at HSE's London conference 'Leading from the top – avoiding major incidents'.

66 The Board published its eighth report,[ref 19] into land use planning and societal risk, on 15 July 2008. Land use planning had been a key concern from the start of the Board's work, in particular the need to balance public protection with economic development. The report was based on both an analysis of evidence from the Buncefield investigation and on the results of research into risk-based planning. It made 18 recommendations for improvements in the UK planning system, including a fundamental review of the entire system, a consistent and fully risk-based system for planning controls at all major hazard sites, the incorporation of societal risk into assessments of planning applications, and for better alignment with the COMAH regime. Extensive appendices included the results of the Board's own sponsored research into a model risk-based system for land use planning.

67 On 13 November 2008 the Government published its response to the recommendations,[ref 20] dealing mainly with those on design and operations and on emergency preparedness, response and recovery. The Board was able to take this into account in this final report.

68 On 4 November 2008, the Chair of HSE formally accepted Lord Newton's advice that the work of the Buncefield Major Incident Investigation was substantially complete and that the Board should be wound up as soon as possible.

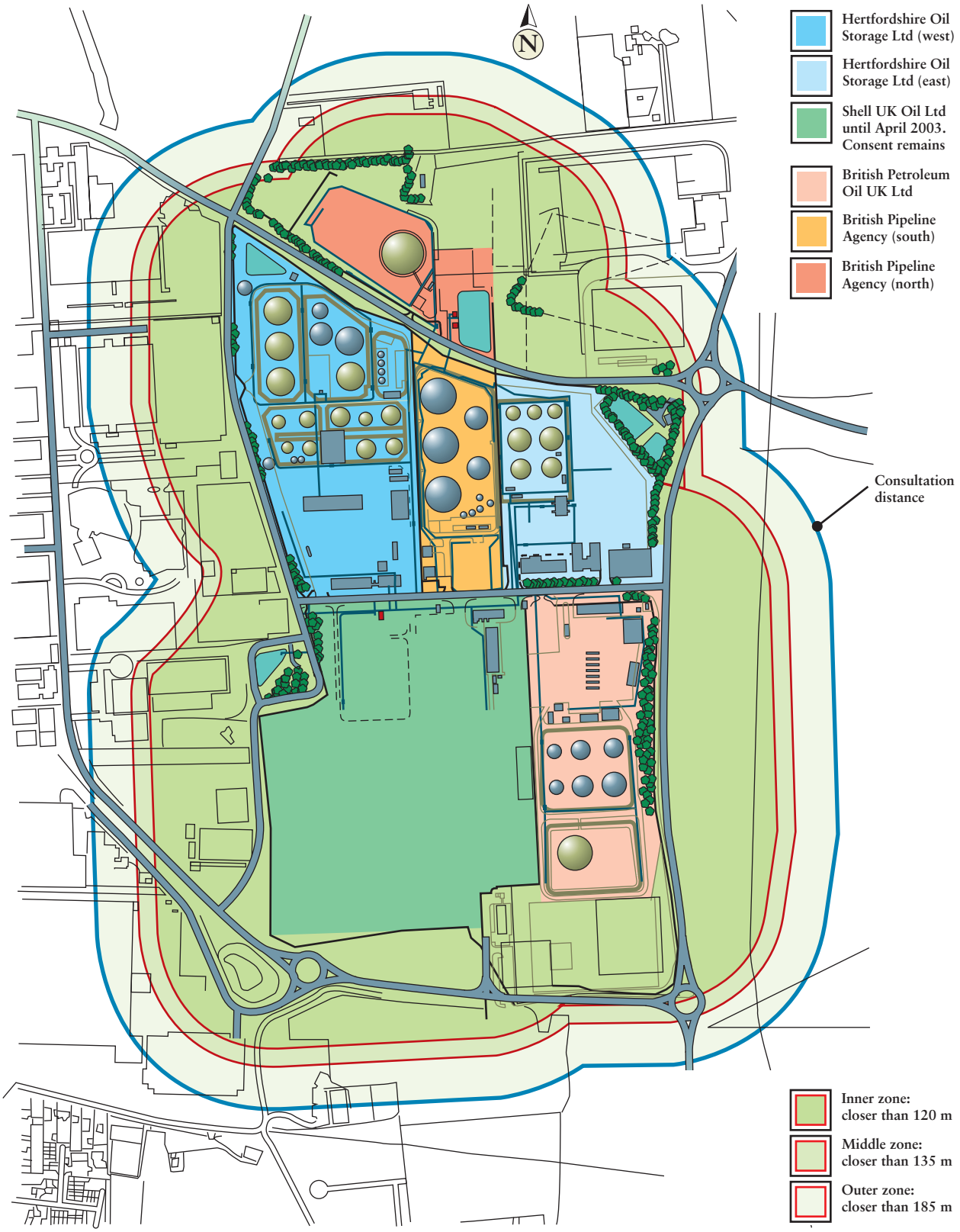

Figure 16 Plan representing the hazardous substances consents and consultation area around the Buncefield depot since July 2001

69 Shortly before the publication of this report, HSE and the Environment Agency announced that criminal proceedings had been commenced against five defendants relating to the causes of the explosions and fires, and to the environmental impact caused as a result of them.

70 On 11 December 2008, the third anniversary of the Buncefield incident, we published our final report and presented it to members and representatives of the local residential and business communities at a special meeting in Hemel Hempstead.

3 Economic impact

See also Annex 3

71 In this chapter we provide an estimate of the economic costs and benefits, reflecting both the costs of the incident itself and of the major measures prescribed to prevent recurrence. A more detailed report, including the costs of incidents elsewhere, is presented in Annex 3.

The economic costs of the Buncefield incident

Overview

72 The estimate of total quantifiable costs arising from the Buncefield incident comes close to £1 billion. The main components of this overall cost are shown in Table 1.

Figure 17 An unusual view of the M1 closed to all traffic in the vicinity of Buncefield. This otherwise busy stretch of motorway was for a time used to keep emergency vehicles assigned to the incident response

Table 1 Summary of the overall cost of the Buncefield incident, by main category

Sector	*Cost (£ million)*
Site operators (compensation claims)	£625
Aviation	£245
Competent Authority and Government response	£15
Emergency response	£7
Environmental impact (drinking water)	£2
Total	£894

73 These five cost categories are considered to be independent of each other and to capture most significant quantifiable costs. The largest single item is the compensation claims against the site operators, which includes claims from individuals, local authorities and businesses, both inside and outside the Buncefield site. The estimated costs to the aviation industry are also high, but based upon less robust data. The table does not include a specific sum for site rebuilding costs. This is explained in paragrah 84 below.

Localised effects

74 A key source of information about costs has been the compensation claims submitted ahead of the civil proceedings which are currently under way in the High Court. Table 2 gives the breakdown of claims listed by the Joint Claims Committee prior to the start of the civil case.

Table 2 Estimated total value of claims

Claimant type	*No. of claims*	*Estimate £ million*
Business		
inside site perimeter	5	£103
outside site perimeter	749	£488
Subtotal businesses	754	£591
Individuals	3 379	£30
Local authorities	7	£4
Totals	4 140	£625

Costs to business

75 Most of the affected businesses were located on the Maylands Estate. This contains 630 firms, employing 16 500 people and generating 2% of the Eastern Region's gross domestic product. Some 90 companies were severely affected because of damage to their premises and other business assets. A report in 2007 for Dacorum Borough Council[ref 21] estimated the total economic impact on Maylands' businesses to be in the region of £130–170 million. However, the aggregate costs to business are best identified by the compensation claims submitted to the civil case, as shown in Table 2.

Figure 18 Aircraft on the ground at Heathrow Airport. Until the 11 December 2005 incident, Heathrow drew about half of its 21 million litres daily consumption of aviation fuel from Buncefield via the West London Pipeline System

Unemployment

76 Though no trends attributable to the Buncefield incident were detectable at regional level, the Dacorum economic impact report identified many relocations and redundancies which would have affected the local economy. A specific study estimated that the combined cost of long and short-term job losses was around £10 million, though these are considered to be subsumed within the compensation claims category. It should also be kept in mind that job losses in one area may result in job gains elsewhere as businesses relocate for example, or other firms take up the market opportunity generated by the business loss. Therefore local business losses may not be reflected in the national economy.

Housing market

77 Most of the damage to domestic properties was minor (broken windows, cracked door frames etc) and the average claim from individuals (including non-housing claims) was a little under £9000. However, some residents living closer to the site suffered much more significant structural damage. Despite this, house prices in general appear to have remained unaffected.

Emergency response

78 Data available in the impact study of economic and business confidence(ref 21) estimates the total costs of the emergency response as £7.4 million. The main components of this are Hertfordshire Fire and Rescue Service at £2.1 million and Hertfordshire County Council at £2.3 million.

Environmental costs

79 Potential environmental impacts are of two sorts, pollution of the air and to the ground. However, these appear not to have been as bad as initially feared, but the opportunity cost arising from closure of a borehole used for water abstraction is estimated at over £2 million.

Personal injuries

80 Due to the day and time of the incident not many people were on or close to the site. There were no fatalities but 43 injuries were reported, none serious. Thus the cost in terms of human injury was relatively small.

Figure 19 The remains of the fire in Tank 12 at Buncefield, on the BPA depot. This was the largest tank on the Buncefield site and could store 19 million litres of aviation fuel

Wider impacts

National supply-chain implications

81 Buncefield supplied 20% of fuel to south-east England and 8% of fuel to the UK market as a whole, making it the fifth largest supplier. Some 2.34 million metric tonnes of fuels passed through Buncefield in 2004 with around 400 road tankers loaded each day. Some initial panic buying was reported, but overall there appear to have been no significant supply chain effects associated with motor fuels or other forms of so-called ground fuels (such as heating fuels).

Effects on the aviation industry

82 Buncefield was a major supplier of aviation fuel, for instance providing around 50% of Heathrow Airport's daily requirements of 21 million litres. The immediate impact of Buncefield was to force fuel rationing on airlines using Heathrow with severe implications for long-distance carriers. Following the incident, the British Airports Authority (BAA) implemented pre-arranged contingency plans which included working with other suppliers to ensure additional deliveries (including the Government Pipeline and Storage System), requesting airlines to carry extra supplies on inbound flights, and the rationing of fuel on a systematic basis. Although Heathrow is getting adequate supplies from other pipeline arrangements established after 2005, the current supply system is at full stretch.

83 By making a number of assumptions an approximate cost to the aviation industry has been estimated to be around £250 million.

Site rebuilding costs

84 Costs of rebuilding the Buncefield site have been reported as being around £70 million. However, this cost will be partly covered by the on-site claims shown in Table 1, and to avoid any double counting has been subsumed within that category.

Costs to the Government of the investigation response

85 Total costs to the Competent Authority are estimated to be in the region of £15 million. We estimate the investigators from HSE, the Environment Agency and the laboratories supporting the forensic work have put in at least 83 000 staff hours,

making it, we believe, the largest investigation of its kind in Britain. About 295 specialists and inspectors from the Competent Authority have been involved in the investigation, although more will have been involved if we include the intensive follow-up inspections of the 108 fuel storage sites in Britain. This represents the larger part of this sum at around £12.5 million. The rest comes from the cross-Government response to the incident. A report on this response was laid before Parliament on 13 November 2008.(ref 20)

Unquantified costs

86 An incident of this magnitude will create a number of adverse effects which it is not feasible to capture in this economic analysis. Examples of unquantified effects are:

- closure of M1, M10 and M25 motorways;
- loss of goods in local warehouses awaiting shipping (including Christmas goods that could not be sourced from elsewhere that Christmas);
- temporary loss of engineering and certification services affecting the services and manufacturing sectors;
- temporary outsourced payroll service disruptions;
- temporary loss of London congestion charging administration;
- temporary loss of outsourced medical records; and
- temporary loss of other public service records.

Estimation of the costs of the Board's recommendations (relating to design and operation of flammable storage sites)

87 This section focuses predominantly on Recommendations 3 and 6 of the design and operation report(ref 13) and attempts to quantify the costs of implementing these key technical recommendations about primary containment controls, and the benefits that accrue. The analysis has been developed through liaison with industry in the UK and USA, and requires a number of assumptions to be made. The methodology was to compute the range of costs to site operators, based on a 'typical site' with ten tanks, which are then grossed up to an assumed 500 tanks in scope nationally. The analysis uses three illustrative engineering solutions for implementing the recommendations and derives cost estimates in each case.

88 The illustrative scenarios with their notional central (ie mid-range) cost estimates are as follows:

Scenario 1 A single off-site automatic shut-off valve on the inlet pipe to the site, preventing the feeding of fuel to all tanks on site. Central cost estimate £23 million.

Scenario 2 An automatic shut-off valve on the inlet pipe to each tank, preventing the feeding of fuel to individual tanks and between tanks, and allowing tanks to be isolated in the event of a fire. Central cost estimate £82 million.

Scenario 3 Dual automatic shut-off valves at each tank, one on the inlet, one on the outlet. This isolates individual tanks and prevents transfer between tanks, even in the event of a valve failing. Central cost estimate £167 million.

89 In practice, the lower of the costs (£23 million) is likely to represent the absolute minimum costs for implementing the Board's recommendations for securing meaningful reductions in major incidents arising from overfilling petrol tanks in Britain. There is no meaningful upper limit on costs because companies may elect to do more than the minimum required, and costs may rise depending on the effectiveness of project planning and management, as with any project. For some time there was not a consensus in the sector in favour of Recommendations 3 and 6. Following the welcome announcement in September 2008 by UK Petroleum Industry Association (UKPIA)[11] and the Tank Storage Association to adopt these recommendations throughout the sector we anticipate the average costs of implementation will fall. Indeed we have had some feedback to this effect.

Benefits of the Board's recommendations

90 Our estimate of the benefits arising from these recommendations used a similar approach to that used in the Competent Authority's impact assessment[12] on containment policy. The benefit of reducing risk of a major incident is the fall in external costs associated with moving from one risk level to a lower one and it is assumed that everything remains constant apart from the level of risk. So the analysis focuses on changes in the safety integrity level of the containment measures adopted on site.

91 The analysis again uses the hypothetical ten-tank site and requires a number of assumptions regarding unwanted event frequencies, human and mechanical reliability, and consequence estimation. This means that the derived benefit estimates should be treated with caution. There is little historical data to determine accurate risk estimates for very infrequent incidents such as that at Buncefield and a base case event frequency per site for pre-Buncefield sites has been used of 1 in 10 000 years. The first benefit scenario is that the level of risk has been reduced to 1 in 100 000 years following implementation of the Board's recommendations. Analysis shows the benefit arising from moving from the base case to this benefit scenario is £162 million. The second benefit scenario is that the level of risk has been reduced to 1 in 1 000 000 years, and the analysis shows the benefit arising as £178 million. Both of these benefit scenarios assume an incident on the scale of Buncefield, and apply standard cost factors accordingly.

92 The cost of Buncefield has been very great, ie in the region of £1 billion as identified in our analysis. But the incident did not cause any serious or fatal injuries. This was very fortunate since even without the highly damaging explosion overpressures being generated, anyone within the flammable vapour envelope when it ignited would probably be killed. The benefit scenarios referred to in paragraph 91 assume that a typical incident (for the purposes of performing such an analysis) on the scale of Buncefield will fatally injure 15 people and cause 105 major injuries.

93 In the statistical analysis the costs of implementing our key recommendations for preventing overfilling of highly flammable liquids are shown to be proportionate to avoiding a major incident on the scale of Buncefield. As we said in paragraph 14 of our Design and operations report, the benefits in preventing another Buncefield incident are beyond argument, and we welcome the commitment to implement our key preventive recommendations as recently announced by the industry (see paragraph 123).

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11 See www.ukpia.com/news_press/automatic_shutdown_systems_to_prevent_overfill_at_fuel_storage_terminals_.aspx

12 www.environment-agency.gov.uk/commondata/acrobat/ria_1797221.pdf

4 The Board's role and its relationship with the primary investigation

The Board

94 Following the incident, an investigation was directed by the Health and Safety Commission using its powers under section 14(2)(a) of the Health and Safety at Work etc Act 1974. In January 2006 the Commission authorised Lord Newton of Braintree to supervise this investigation and appointed members to an independent Major Incident Investigation Board ('the Board'), which he chairs. The full terms of reference for the investigation are in Annex 1 and brief profiles of Board members are set out in Annex 2.

The Board's approach

95 The current arrangements for supervision of a major incident investigation through an independent board are unprecedented. An important challenge for the Board has been to conduct its business and make reports public in a timely way without interfering with ongoing criminal investigation.

Figure 20 View of the Buncefield site during the early stages of the investigation

96 These circumstances have necessitated developing our own ways of working. In doing so, we were guided by two key principles:

- maintaining the Board's independence from all other parties; but at the same time
- operating in an open way, both by listening to what others have to say and by making public the information we have subject only to legal considerations.

97 As regards independence, because the Board was established by the Health and Safety Commission with the sole purpose of delivering, under statutory provisions, the given terms of reference, the Board has been empowered to produce its own independent conclusions.

98 Certain members of the Board, its Secretariat and advisors are employed by either HSE or Environment Agency. This has been essential to provide a clear understanding of the remit and role of these organisations. Notwithstanding this, everyone acting as or for the Board has demonstrably acted in the best interests of the Board, and assisted in maintaining our independent position. The appointment of Lord Newton as Chair and Professors Drysdale and Baxter as independent members has been the key assurance of the Board's independence.

99 On openness, the Health and Safety Commission did not propose a public inquiry, in part because of the long time that can elapse before any conclusions emerge. Conscious of this, we set great store by making public significant findings of the investigation as they emerge. The major constraint on such openness has been the need to avoid prejudice to the criminal investigation or any person who may be affected thereby. We have published information on what happened and how but have been cautiously circumspect in suggesting why the incident occurred.

100 Our approach to releasing information was developed early on. The Investigation Manager's first progress report was published on 21 February 2006, only six weeks after the Board was set up and four weeks after its first meeting. We believe our ability to release important information as it emerged was a particular advantage of appointing an independent Board.

101 We held meetings with relevant ministers and Government officials, businesses, local authorities, public agencies and communities affected by the incident. Our network of contacts helped us develop our views and check our draft reports.

The Board's relationship with the criminal investigation

102 One of the main considerations of the Board throughout its spell of duty has been its relationship with the criminal investigation. The Board's first term of reference (TOR1) is:

> 'To ensure the thorough investigation of the incident, the factors leading up to it, its impact both on and off site, and to establish its causation including root causes.'

103 The investigation under TOR1 is managed by the Investigation Manager and reporting to him are inspectors and forensic specialists from the Competent Authority. The outcomes of the TOR1 investigation have informed the three published reports of the Investigation Manager to the Board and all of the Board's own published reports and recommendations. The outcomes of the same

investigation also inform the decision on whether criminal proceedings are justified.[13]

104 In practice, the TOR1 investigation and the criminal investigation are parallel activities conducted by the same core teams of inspectors and are sometimes referred to as the primary investigation. The role of the Board has been to oversee, in the public interest, the primary investigation managed by the Investigation Manager. The investigation findings have informed the three progress reports of the Investigation Manager and our own five reports and recommendations, but in the main we have undertaken the work needed to complete our own reports independently of the primary investigation. We were not appointed to take any decisions on legal proceedings that fall to be considered under the criminal investigation. The decision on criminal proceedings is for HSE and the Environment Agency as the enforcing authorities under the relevant regulations.

105 Shortly before publication of this report HSE and the Environment Agency announced that criminal proceedings were being commenced against five defendants relating to the causes of the explosions and fires and the consequences arising from them.

The relationship between the Policy and Procedures Review (PPR) and the criminal investigation

106 As our third term of reference makes clear, our role in regard to the Policy Procedures Review (PPR) was wider than just examining the way in which HSE and the Environment Agency regulated the activities on the Buncefield site before the incident. The PPR involved a broad examination of the adequacy of the arrangements for dealing with all sites of this type and the relevant dutyholders. For example, the PPR has examined the resourcing of the Competent Authority; the charging regime; the adequacy of the legal duties placed on dutyholders; the strategies and standards applying to regulatory functions and the assessment of safety reports; HSE's role in land use planning; and emergency preparedness and response issues.

107 The regulatory conduct of the Competent Authority at Buncefield before and immediately after the incident was examined by the legal team that supported the criminal investigation. The purpose was to see whether the prior role of the Competent Authority had any bearing on the events at Buncefield which might undermine any prosecution or support a defence in the event of criminal proceedings. The prior role examination by the legal team has not been seen by the Board.

108 It is rightly the task of those conducting the criminal investigation to examine whether any acts or omissions of HSE and/or the Environment Agency had any bearing on the Buncefield incident. The Board has not sought to make any determination of its own in this regard.

109 The completed PPR report has been given to HSE as the successor of the body which commissioned us to prepare it. Under the procedures for the preparation of such reports[14] following a major incident, they are not usually made public until after a decision on proceedings is announced or, should criminal proceedings be taken as in this case, until after proceedings are completed.

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13 The decision-taking process used by HSE and the Environment Agency is described in Annex 10 of the Board's Initial Report of July 2006.

14 See www.hse.gov.uk/foi/internalops/og/ogpressures/majorincident/review.htm

Figure 21 The smoke plume above Hemel Hempstead

The Board's relationship with the residential and business communities around Hemel Hempstead

110 The Board's fourth term of reference related directly to undertaking and managing communications activity around the Major Incident Investigation:

> 'To work closely with all relevant stakeholders, both to keep them informed of progress with the investigation and to contribute relevant expertise to other inquiries that may be established.'

111 From the outset it was our intention that the investigation be carried out in a transparent way. The incident affected a multitude of interests and we planned to keep members of the local business community, local residents, their representatives and others who have key decisions to make as a result of the incident informed of the investigation's progress.

112 The Board appointed a Community Relations Officer (CRO) to the investigation, who played an important role in establishing and maintaining relations with a wide range of local stakeholders who had, in their various ways, suffered consequences as a result of the incident, or had relevant experiences to pass on.

113 Key stakeholder groups included Dacorum Borough Council, businesses within Maylands Business Park, local residents, Hertfordshire County Council, MPs from local constituencies and particularly Mike Penning MP for Hemel Hempstead, and Hertfordshire police and fire services. The CRO provided a valuable service to the Board by:

- gaining access to these local stakeholders and providing understanding of the experiences of those affected. This arrangement also enabled a clear line to be maintained between public communications and the criminal investigation;

- providing residents directly with information and advice relating to important incident matters (either in person, on the phone or via e-mail). This information came directly from the Board or through the network of contacts developed after the incident. The CRO also provided support to local authority communications work, especially in the first year when such business was greatest. This included significant input to local events, forums and business meetings; and

- helping us to understand more clearly than we otherwise could have the social and economic impact of an incident on the scale of Buncefield. Our recommendations were informed by this, particularly our sixth report into emergency preparedness for, response to and recovery from major incidents, and our eighth report into land use planning and societal risk.

114 By the end of 2006, the workload no longer justified a full-time appointment, but it was continued as the joint function of our independent press officer. The important role of media and stakeholder relations was maintained throughout the investigation until the end of the Board's work.

115 Dacorum Borough Council has publicly acknowledged the benefits of the investigation's community relations support. There was reference made to the work in the Buncefield Public Adjournment Debate on 9 January 2008.

The Board's terms of reference

116 All of the terms of reference (see Annex 1) have been completed.

Figure 22 A view of the Buncefield site in the summer after the incident

5 Taking forward the Board's recommendations

117 The real impact of our work will be judged by the extent to which our recommendations are implemented.

118 Much work has already been done by the Competent Authority and industry as detailed in the 'Summary of the Buncefield Board's work'. The Ministerial Statement made in Parliament on 13 November 2008, accompanied by a report detailing the Government's and Competent Authority's response to the recommendations in our fifth and sixth reports, is a very substantial piece of work containing important commitments from Government and industry. We welcome this statement and report, and note its generally positive tone.

119 But much also remains to be done. The Government response contains an ambitious programme, largely aligns with our own thinking and for reasons we fully understand has yet to address the recommendations in our eighth report on land use planning and societal risk. So we would encourage Government to establish a mechanism for monitoring progress and reporting periodically upon it.

120 Discussions on bringing our recommendations into effect have mainly addressed:

- leadership;
- the role of standards and guidance; and
- the timetable for implementation.

121 These are three key areas for maximising the chances of preventing another incident like Buncefield.

Leadership

122 In Recommendations 24 and 25 of our *Design and operations* (D&O) report we call for leadership to ensure the Board recommendations result in sector-wide improvements so as to maximise the learnings and positive impact from Buncefield. First and foremost we mean the process safety leadership within the industry. Second are Government and regulatory leadership.

123 The industry-led Process Safety Leadership Group (PSLG) was established in 2007 and has taken forward the work of the Buncefield Standards Task Group that was set up in 2006 to introduce early improvements at fuel storage sites. On 25 September 2008 the UK Petroleum Industry Association (UKPIA) and the Tank Storage Association gave a public commitment to raise the standards for engineering integrity to ensure containment of petrol in the vessels and pipework to which it belongs – thus giving effect to what we see as the overriding priority in the storage of hazardous fuels.

124 In our sixth report into emergency preparedness and response, we called for joined-up leadership between industry, regulators, local authorities and emergency responders to achieve more effective arrangements. Such arrangements require substantial involvement by Government. In this report our aim has been to establish

Figure 23 The remains of the fire pump house at the HOSL West site. The wall of bund A is approximately 5 m in front of this picture. The pump house is a prime candidate ignition source for the explosion at Buncefield

Government's commitment both in learning lessons from all incidents that have a major impact on the social and economic environment in Britain, and in providing support to damaged communities on a more consistent basis than has sometimes been the case in the past.

125 For the regulators, an incident on the scale of Buncefield is an opportunity to make changes that may previously have been inhibited for resource and other related reasons. We are therefore particularly pleased that the Competent Authority has set up a comprehensive programme for reviewing the COMAH regime.[15]

126 We welcome these commitments from industry and Government to raising standards of public protection at hazardous industrial sites. We anticipate that all those with a responsibility for improvements will want to collect and report evidence of them which will confirm that these commitments are being delivered; and to collect and share data on incidents and near misses over the longer term.

127 At major hazard sites, monitoring of improvement in process safety and environmental protection is most effective in organisations where it is integral to the top-level management of facilities, and in regulatory intervention programmes (eg in safety report assessment and site inspection). We do not doubt that local authorities, emergency responders, resilience forums, regulators and central Government will further assist in giving leadership and supervision of emergency preparedness and the integrity of the land use planning system.

128 We believe it would be helpful to have an independent evaluation of progress against these commitments within, say, three years.

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15 Known as the COMAH remodelling programme. See page 12 of the *Health and Safety Executive Business Plan 2008/09* at www.hse.gov.uk/aboutus/strategiesandplans/bplan0809.pdf

Standards

129 As we have already indicated, the Competent Authority has confirmed that a major plank of its programme is to remodel the COMAH regime. Similarly PSLG has incorporated our design and operations recommendations into its future work plans.

130 Effective standards are those that are both authoritative and enforceable. But a number of approaches to achieve this are possible – standards generated by the industry with the regulators' support; standards developed through national standards committees; or nationally and internationally recognised guidance, standards and ACOPs which are capable of being insisted upon by law.[16]

131 For such standard-setting, three areas (from each of our main reports) which illustrate the different nature of the standards that are needed are:

- establishing a formal methodology for industry to determine safety integrity levels required for overfill protection at each site (D&O Recommendation 1) because this underpins all of the Board's recommendations;

- updating the definitive HSE text on the subject of risk criteria in land use planning: *Risk criteria for land use planning in the vicinity of major industrial hazards* 1989(ref22) (LUP Recommendation 16) because there has been fairly continuous updating of knowledge of risk applying to planning without updating of this guidance on the subject since 1989; and

- clarification by CCS of integrating guidance on emergency preparedness for a range of major incident hazards (Emergency preparedness for, response to and recovery from incidents (EPR&R) report Recommendation 11) because the current diversity of guidance risks inconsistency in the relevant planning.

Timetable for bringing our recommendations into effect

132 We note with approval that firm timetables are established for the implementation of many of our recommendations – for example where we have called on the Competent Authority to agree site-specific remedial programmes. We hope a comparable approach to our land use planning recommendations will be adopted. Where standards and guidance need to be developed or overhauled there should be programmes agreed for the relevant bodies to take the work forward – while of course recognising that agreed timetables must be realistically achievable.

133 In Part 2 of this report we present all our recommendations together as our view of what we need to aim for. Taken together, the 78 recommendations amount to an ambitious programme for industry, the Competent Authority, and local and central Government. The outcomes will produce an integrated system for controlling the major incident risks at COMAH sites that balances the social and economic needs of our country. There are already encouraging signs that the

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16 Under Britain's 'goal-setting' regime for controlling major hazard risks it is usual for guidance, ACOPs and model codes of practice to use examples to demonstrate the minimum legal standard to be attained. It follows that goal setting should allow for other suitable means of legal compliance with the standard if it can be demonstrated that the other means provide similar or better control of the risks.

Figure 24 The northern and lowest lying edge of the Buncefield site, showing the banked descent into Cherry Tree Lane on the left of the picture. The Buncefield incident was reported to the EU as a major accident to the environment (MATTE) under EU criteria for environmental pollution

challenges in delivering the programme are being met. For people living and working near to COMAH sites the completion of the programme for implementing our recommendations will provide the necessary assurance against the recurrence of a major industrial incident on the scale we have witnessed at Buncefield.

Part 2
The Board's recommendations

Part 2 The Board's recommendations

134 In Part 2 ('Issues of concern') of our Initial Report (paragraphs 59, 60 and 77), published on 13 July 2006, we identified a number of principal workstreams that would form the basis for our continuing work and developing recommendations. Those workstreams were:

- design and operation of storage sites;
- emergency preparedness for, and response to, incidents;
- advice to planning authorities;
- examination of HSE's and the Environment Agency's roles in regulating the activities on the Buncefield site; and
- further work to understand the actual mechanism for generating the unexpectedly high explosion overpressures.

135 We made four reports between March 2007 and July 2008 making recommendations in four of these areas of concern in furtherance of our fifth term of reference.[17] We have not published a report into the regulation of the site by the Competent Authority. As we explain in paragraph 109 of this report, the Policy and Procedures Review (PPR) remains a restricted document until conclusion. However, we have incorporated the relevant findings of our PPR into the recommendations that we have published in the four reports.

136 In developing our recommendations we have been entirely consistent that the measures for controlling major incident risks must integrate:

- integrity levels at major hazard sites in relation to containment of dangerous substances and process safety;
- mitigation against the effect of a major incident on off-site populations and buildings;
- preparedness for emergency response to limit the escalation of potential major incidents;
- land use planning and the control of societal risk; and
- the regulatory system for inspection and enforcement at major hazard industrial sites.

137 Our four reports of recommendations, taken as a whole, incorporate all of these key measures. In our latest report on land use planning we ask, at Recommendation 2, that the Government's review of the whole land use planning system should take account of our integrated approach.

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17 TOR3: 'To examine the Health and Safety Executive's and the Environment Agency's role in regulating the activities on this site under the COMAH Regulations, considering relevant policy guidance and intervention activity.'

138 Below we list all of our published recommendations, in one place for the first time.

Design and operation of fuel storage sites

139 Our starting point in developing these recommendations was our view on the importance of primary containment,[18] as expressed in paragraph 63 of our Initial Report:

> 'The occurrence of a massive fuel vapour explosion confirms the overriding need to ensure the integrity of the primary means of containment; in other words, to make sure that liquid does not escape from the vessels in which it is normally meant to be confined.'

140 The recommendations build on the broad conclusions set out in paragraphs 61–77 of our Initial Report. Recommendations 1–16 therefore emphasised the need to increase the protection provided by primary containment systems to reduce the likelihood of such a failure. The implementation of our recommendations would make such events even rarer. The Buncefield incident highlighted the need for high integrity systems for this purpose. There remains the need for an effective means of preventing environmental pollution in the event of a failure of primary containment. Recommendations 17–18 therefore deal with improvements to secondary and tertiary containment should such an incident occur.[19]

141 Recommendations 1–18 dealt with technological matters and their management. However, paragraph 74 of our Initial Report noted that human and organisational factors are also important and these were covered in Recommendations 19–22. Finally, Recommendations 23–25 dealt with broader strategic objectives relating to sector leadership and culture, essential to ensuring that the benefits of the more detailed recommendations are fully realised.

142 Achieving the full benefit from the technological improvements to process safety and environmental protection in our recommendations depends on human and organisational factors such as the roles of supervisors, the way work is organised, and the robustness of communications on critical tasks. Standards should be consistent across the industry if high reliability organisations are to flourish, which therefore requires a stronger safety culture generally.

143 At the time of writing our report on design and operations, both the United States Chemical Safety Board (CSB) and the James Baker Panel were examining the BP Texas City disaster in which 15 workers were killed and 170 injured on 23 March 2005, nine months before Buncefield. Both incidents occurred due to loss of primary containment by overfilling of a vessel resulting in the formation of large flammable vapour cloud that subsequently ignited.

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18 Primary means of containment are the tanks, pipes and vessels that hold liquids and the devices fitted to them to allow them to be operated safely.

19 Secondary means of containment are enclosed areas around storage vessels (often called bunds), created usually by concrete or earth walls. Their purpose is to hold any escaping liquids and any water or chemicals used in firefighting. Tertiary means are features such as drains designed to limit the passage of chemicals off site, or raised kerbs to prevent liquids that have breached the bunds from escaping into the general area around the site.

144 Both the CSB and Baker reports identified numerous failings in equipment, risk management, staff management, working culture at the site, maintenance and inspection and general health and safety assessments. Baker and CSB found that cost cutting had eroded safety performance, that occupational safety was emphasised at the expense of major hazard risk controls (which in the Texas City context is mainly ensuring integrity of primary containment), and there was a failure to understand critical signs of loss of control of the major hazard prevention systems. Both reports concluded that senior management drove such an adverse culture.

145 CSB refers to 'the definition by UK safety authorities' 'that human factors are those environmental, organisational, and job-related factors that influence behaviour at work and can impact safety performance'. Our report is equally strong on the importance of human factors in the overall programme.

146 The CSB report emphasised that process safety protection systems should not rely on operator response to alarms and that overfill protection must be independent of normal operational monitoring. This is entirely consistent with our Recommendation 3 that the regime needs to have a fixed point to set the standard expected. That fixed point is installing overfill prevention systems that will automatically stop the supply to a dangerously full tank by means that are fully independent of the tank gauging system and the personnel.

147 Both ours and the Baker report called for the adoption of better measures of performance that are more useful to major hazards sectors than injury rates and other measures that are primarily occupational safety-related. The referenced work HSG254(ref 23) advocates *inter alia* setting appropriate process safety indicators, eg recording when level gauges fail, or high-high alarms fail to actuate, and also advocates these indicators are routinely reviewed by senior management. Leading indicators capture positive attributes such as the measurement of process safety indicators and regular reviews by managers of the process safety indicator records. Lagging indicators reveal where failures have occurred. Both are needed in a high reliability operation.

148 Baker and CSB require the commitment to safety to be evident from the Boardroom to the control room. CSB called for the appointment of a process safety specialist to the Board and Baker called for an independent agent to monitor BP's performance for five years. Our report called for operators to build and operate high reliability organisations and for the sector to set standards and share knowledge of incidents and failures. In Recommendation 19 we provided key characteristics of high reliability organisations (in full) that are echoed in the Baker and CSB reports.

Systematic assessment of safety integrity level requirements

Recommendation 1

Recommendation 1 The Competent Authority and operators of Buncefield-type sites should develop and agree a common methodology to determine safety integrity level (SIL)[20] requirements for overfill prevention systems in line with the principles set out in Part 3 of BS EN 61511.(ref 24) This methodology should take account of:

- the existence of nearby sensitive resources or populations;

[20] A SIL is a measure of the safety system performance, in terms of the probability of failure on demand. There are four discrete integrity levels, SIL 1–4. The higher the SIL level, the higher the associated safety level and the lower the probability that a system will fail to perform properly.

- the nature and intensity of depot operations;
- realistic reliability expectations for tank gauging systems; and
- the extent/rigour of operator monitoring.

Application of the methodology should be clearly demonstrated in the COMAH safety report submitted to the Competent Authority for each applicable site. Existing safety reports will need to be reviewed to ensure this methodology is adopted.

Protecting against loss of primary containment using high integrity systems

Recommendation 2 Operators of Buncefield-type sites should, as a priority, review and amend as necessary their management systems for maintenance of equipment and systems to ensure their continuing integrity in operation. This should include, but not be limited to reviews of the following:

Recommendation 2

- the arrangements and procedures for periodic proof testing of storage tank overfill prevention systems to minimise the likelihood of any failure that could result in loss of containment; any revisions identified pursuant to this review should be put into immediate effect;
- the procedures for implementing changes to equipment and systems to ensure any such changes do not impair the effectiveness of equipment and systems in preventing loss of containment or in providing emergency response.

Recommendation 3 Operators of Buncefield-type sites should protect against loss of containment of petrol and other highly flammable liquids by fitting a high integrity, automatic operating overfill prevention system[21] (or a number of such systems, as appropriate) that is physically and electrically separate and independent from the tank gauging system.

Recommendation 3

Such systems should meet the requirements of Part 1 of BS EN 61511 for the required safety integrity level, as determined by the agreed methodology (see Recommendation 1). Where independent automatic overfill prevention systems are already provided, their efficacy and reliability should be reappraised in line with the principles of Part 1 of BS EN 61511 and for the required safety integrity level, as determined by the agreed methodology (see Recommendation 1).

Recommendation 4 The overfill prevention system (comprising means of level detection, logic/control equipment and independent means of flow control) should be engineered, operated and maintained to achieve and maintain an appropriate level of safety integrity in accordance with the requirements of the recognised industry standard for 'safety instrumented systems', Part 1 of BS EN 61511.

Recommendation 4

Recommendation 5 All elements of an overfill prevention system should be proof tested in accordance with the validated arrangements and procedures sufficiently frequently to ensure the specified safety integrity level is maintained in practice in accordance with the requirements of Part 1 of BS EN 61511.

Recommendation 5

[21] The factors that determine the type of independent automatic system required will include the effects on the upstream system, for example if filling from a refinery process, a ship or a railway vessel. For all systems the outcome required is the same, ie automatically stopping supply to the dangerously full tank by means that are fully independent of the tank gauging system.

Recommendation 6

Recommendation 6 The sector should put in place arrangements to ensure the receiving site (as opposed to the transmitting location) has ultimate control of tank filling. The receiving site should be able to safely terminate or divert a transfer (to prevent loss of containment or other dangerous conditions) without depending on the actions of a remote third party, or on the availability of communications to a remote location. These arrangements will need to consider upstream implications for the pipeline network, other facilities on the system and refineries.

Recommendation 7

Recommendation 7 In conjunction with Recommendation 6, the sector and the Competent Authority should undertake a review of the adequacy of existing safety arrangements, including communications, employed by those responsible for pipeline transfers of fuel. This work should be aligned with implementing Recommendations 19 and 20 on high reliability organisations to ensure major hazard risk controls address the management of critical organisational interfaces.

Recommendation 8

Recommendation 8 The sector, including its supply chain of equipment manufacturers and suppliers, should review and report without delay on the scope to develop improved components and systems, including but not limited to the following:

- alternative means of ultimate high[22] level detection for overfill prevention that do not rely on components internal to the storage tank, with the emphasis on ease of inspection, testing, reliability and maintenance;
- increased dependability of tank level gauging systems through improved validation of measurements and trends, allowing warning of faults and through using modern sensors with increased diagnostic capability; and
- systems to control and log override actions.

Recommendation 9

Recommendation 9 Operators of Buncefield-type sites should introduce arrangements for the systematic maintenance of records to allow a review of all product movements together with the operation of the overfill prevention systems and any associated facilities. The arrangements should be fit for their design purpose and include, but not be limited to, the following factors:

- the records should be in a form that is readily accessible by third parties without the need for specialist assistance;
- the records should be available both on site and at a different location;
- the records should be available to allow periodic review of the effectiveness of control measures by the operator and the Competent Authority, as well as for root cause analysis should there be an incident;
- a minimum period of retention of one year.

Recommendation 10

Recommendation 10 The sector should agree with the Competent Authority on a system of leading and lagging performance indicators for process safety performance. This system should be in line with HSE's recently published guidance on *Developing process safety indicators* HSG254.(ref 23)

[22] Also commonly known as 'high-high' level alarms.

Engineering against escalation of loss of primary containment

Recommendation 11 Operators of Buncefield-type sites should review the classification of places within COMAH sites where explosive atmospheres may occur and their selection of equipment and protective systems (as required by the Dangerous Substances and Explosive Atmospheres Regulations 2002). This review should take into account the likelihood of undetected loss of containment and the possible extent of an explosive atmosphere following such an undetected loss of containment. Operators in the wider fuel and chemicals industries should also consider such a review, to take account of events at Buncefield.

Recommendation 11

Recommendation 12 Following on from Recommendation 11, operators of Buncefield-type sites should evaluate the siting and/or suitable protection of emergency response facilities such as firefighting pumps, lagoons or manual emergency switches.

Recommendation 12

Recommendation 13 Operators of Buncefield-type sites should employ measures to detect hazardous conditions arising from loss of primary containment, including the presence of high levels of flammable vapours in secondary containment. Operators should without delay undertake an evaluation to identify suitable and appropriate measures. This evaluation should include, but not be limited to, consideration of the following:

- installing flammable gas detection in bunds containing vessels or tanks into which large quantities of highly flammable liquids or vapour may be released;
- the relationship between the gas detection system and the overfill prevention system. Detecting high levels of vapour in secondary containment is an early indication of loss of containment and so should initiate action, for example through the overfill prevention system, to limit the extent of any further loss;
- installing CCTV equipment to assist operators with early detection of abnormal conditions. Operators cannot routinely monitor large numbers of passive screens, but equipment is available that detects and responds to changes in conditions and alerts operators to these changes.

Recommendation 13

Recommendation 14 Operators of new Buncefield-type sites or those making major modifications to existing sites (such as installing a new storage tank) should introduce further measures including, but not limited to, preventing the formation of flammable vapour in the event of tank overflow. Consideration should be given to modifications of tank top design and to the safe re-routing of overflowing liquids.

Recommendation 14

Recommendation 15 The sector should begin to develop guidance without delay to incorporate the latest knowledge on preventing loss of primary containment and on inhibiting escalation if loss occurs. This is likely to require the sector to collaborate with the professional institutions and trade associations.

Recommendation 15

Recommendation 16 Operators of existing sites, if their risk assessments show it is not practicable to introduce measures to the same extent as for new ones, should introduce measures as close to those recommended by Recommendation 14 as is reasonably practicable. The outcomes of the assessment should be incorporated into the safety report submitted to the Competent Authority.

Recommendation 16

Engineering against loss of secondary and tertiary containment

Recommendation 17

Recommendation 17 The Competent Authority and the sector should jointly review existing standards for secondary and tertiary containment with a view to the Competent Authority producing revised guidance by the end of 2007.

The review should include, but not be limited to the following:

- developing a minimum level of performance specification of secondary containment (typically this will be bunding);
- developing suitable means for assessing risk so as to prioritise the programme of engineering work in response to the new specification;
- formally specifying standards to be achieved so that they may be insisted upon in the event of lack of progress with improvements;
- improving firewater management and the installed capability to transfer contaminated liquids to a place where they present no environmental risk in the event of loss of secondary containment and fires;
- providing greater assurance of tertiary containment measures to prevent escape of liquids from site and threatening a major accident to the environment.

Recommendation 18

Recommendation 18 Revised standards should be applied in full to new build sites and to new partial installations. On existing sites, it may not be practicable to fully upgrade bunding and site drainage. Where this is so operators should develop and agree with the Competent Authority risk-based plans for phased upgrading as close to new plant standards as is reasonably practicable.

Operating with high reliability organisations

Recommendation 19

Recommendation 19 The sector should work with the Competent Authority to prepare guidance and/or standards on how to achieve a high reliability industry through placing emphasis on the assurance of human and organisational factors in design, operation, maintenance, and testing. Of particular importance are:

- understanding and defining the role and responsibilities of the control room operators (including in automated systems) in ensuring safe transfer processes;
- providing suitable information and system interfaces for front line staff to enable them to reliably detect, diagnose and respond to potential incidents;
- training, experience and competence assurance of staff for safety critical and environmental protection activities;
- defining appropriate workload, staffing levels and working conditions for front line personnel;
- ensuring robust communications management within and between sites and contractors and with operators of distribution systems and transmitting sites (such as refineries);
- prequalification auditing and operational monitoring of contractors' capabilities to supply, support and maintain high integrity equipment;

- providing effective standardised procedures for key activities in maintenance, testing, and operations;
- clarifying arrangements for monitoring and supervision of control room staff; and
- effectively managing changes that impact on people, processes and equipment.

Recommendation 20 The sector should ensure that the resulting guidance and/or standards is/are implemented fully throughout the sector, including where necessary with the refining and distribution sectors. The Competent Authority should check that this is done.

Recommendation 20

Recommendation 21 The sector should put in place arrangements to ensure that good practice in these areas, incorporating experience from other high hazard sectors, is shared openly between organisations.

Recommendation 21

Recommendation 22 The Competent Authority should ensure that safety reports submitted under the COMAH Regulations contain information to demonstrate that good practice in human and organisational design, operation, maintenance and testing is implemented as rigorously as for control and environmental protection engineering systems.

Recommendation 22

Delivering high performance through culture and leadership

Recommendation 23 The sector should set up arrangements to collate incident data on high potential incidents including overfilling, equipment failure, spills and alarm system defects, evaluate trends, and communicate information on risks, their related solutions and control measures to the industry.

Recommendation 23

Recommendation 24 The arrangements set up to meet Recommendation 23 should include, but not be limited to, the following:

Recommendation 24

- thorough investigation of root causes of failures and malfunctions of safety and environmental protection critical elements during testing or maintenance, or in service;
- developing incident databases that can be shared across the entire sector, subject to data protection and other legal requirements. Examples[23] exist of effective voluntary systems that could provide suitable models;
- collaboration between the workforce and its representatives, dutyholders and regulators to ensure lessons are learned from incidents, and best practices are shared.

Recommendation 25 In particular, the sector should draw together current knowledge of major hazard events, failure histories of safety and environmental protection critical elements, and developments in new knowledge and innovation to continuously improve the control of risks. This should take advantage of the experience of other high hazard sectors such as chemical processing, offshore oil and gas operations, nuclear processing and railways.

Recommendation 25

23 Such as HSE's Offshore Hydrocarbon Releases Database and the Rail Safety and Standards Board's National Incident Reporting System, NIR-Online.

Emergency preparedness for, response to and recovery from incidents

149 This report concentrated on the second of the Board's main areas of concern – emergency preparedness and response. Our broad aim in making these recommendations was to ensure that the lessons of Buncefield will be used to make improvements in emergency planning, response and recovery arrangements for fuel storage depots and all other top-tier COMAH sites throughout Britain including in the devolved administrations. It builds on the broad conclusions set out in paragraphs 78–79 of our Initial Report. We also drew on information from other sources, such as the published recommendations and reviews by the many organisations who had been involved in the planning for and responding to the Buncefield incident.

150 The priority for major hazard sites such as Buncefield is in improving measures for prevention of loss of containment and escalation of an incipient major incident. However, improving the arrangements to prevent fires and explosions in no way lessens the need to have effective emergency planning and response arrangements in the rare event of a major incident. This report covered both planning for emergencies and the effectiveness of the response.

151 Operators of top-tier COMAH sites are required by law to prepare adequate emergency plans to deal with the on-site consequences of possible incidents and they must also provide local authorities with information to enable them to prepare emergency plans to deal with the off-site consequences, a task that requires the close involvement of regional resilience teams and local emergency responders. The adequacy of these plans depends, among other things, on a full appreciation of the potential for major accidents and the safety report prepared by the site operator is a necessary document to ensure this.

152 The emergency services, particularly the fire and police services, responded impressively and on a massive scale that was probably unprecedented in modern times. Inevitably there were lessons to be learned from such an exceptional event. This was particularly important given the newness of the local, regional and national resilience arrangements tested at Buncefield.

153 Like the emergency response to Buncefield itself, emergency preparedness is a multi-agency task that requires a clear lead. We felt it crucial in our ongoing work to establish a clear picture of the central Government lead provided for first responders, who reported a number of views to us on this issue.

154 The Buncefield incident, because of when it occurred, very fortunately caused no fatalities or serious injuries, and the large smoke plume remained elevated throughout the fire by the prevailing stable meteorological conditions, so that little air pollution occurred at ground level which would have affected the public or the emergency teams. Nevertheless, the scale of the impacts on local residents and businesses, as well as on communities further away, the huge devastation and the extent of the work required to enable full recovery, highlighted the need to learn as much as possible from the experience. Indeed, the incident also provides important insights in planning for comparable fire and explosion risks at other COMAH sites where the potential consequences for public safety and health, and the environment, are being considered.

155 The need to reduce the risk of a major incident at fuel storage sites is the first priority. Our previous report on design and operation of fuel storage sites[ref 13] therefore made recommendations to ensure the sector and the Competent Authority are continually alert to the major hazard potential of fuel storage operations. This principle was carried forward into this report and Recommendation 1 called upon site operators and the Competent Authority to

ensure they have identified all probable major hazard incidents and associated emergency scenarios. Recommendations 2–7 addressed the plans and arrangements to contain a developing incident on site, should primary containment be lost.

156 The second priority is to ensure that the emergency preparedness and response arrangements are effective, because however much improvement is made in control measures for preventing an incident there can be no guarantee that a major hazard incident could not occur, however unlikely such an event might be. The recommendations in this report therefore followed closely on our design and operation recommendations. Indeed there was some overlap between them, reflecting the close relationship between planning to prevent an incident and planning to deal with its potential consequences.

157 The Buncefield incident was a major test for contingency planning and for the new national arrangements introduced under the Civil Contingencies Act 2004 (CCA) from September 2005. Recommendations 8–20 dealt with planning and implementing an emergency response by those concerned. The impressive emergency response to Buncefield effectively relied on initiative and good working relations of the responders in dealing with an incident that had been unforeseen and therefore not planned for. Recommendations 21–26 addressed the primary response to major incidents, including setting up a means of assessing the public health implications. An important issue in chemical incidents is having the capability to ascertain the level of exposure to the public of any unintended chemical release, and having the capacity to undertake the environmental monitoring needed in an emergency is included in Recommendation 21.

158 We acknowledged the efforts of many organisations in the response to Buncefield and the great resilience of the local community and businesses in the ongoing recovery effort to bring the affected local community back to social normality. Recommendations 27–32 addressed the recovery from a major incident with Buncefield-like consequences.

159 Our recommendations addressed the need to improve emergency arrangements at local, regional and national levels. An important element was to ensure that emergency arrangements to meet the requirements of COMAH were fully integrated with those established under the Civil Contingencies Act 2004. Recommendations 10–12 dealt in particular with central government leadership in the planning for and early response to a major incident.

Assessing the potential for a major incident

Recommendation 1 Operators of Buncefield-type sites should review their emergency arrangements to ensure they provide for all reasonably foreseeable emergency scenarios arising out of credible major hazard incidents, including vapour cloud explosions and severe multi-tank fires that, before Buncefield, were not considered realistically credible. The Competent Authority should ensure that this is done.(ref 25: Rec 2)

Recommendation 1

Managing a major incident on site

Recommendation 2 The Competent Authority should review the existing COMAH guidance on preparing on-site emergency plans. This guidance needs to reflect the HSE's Hazardous Installations Directorate (HID) Chemical Industries Division inspection manual used by inspectors to assess the quality of the on-site plan in meeting the COMAH Regulations. In particular, reference should be made to the need to consult with health advisors and emergency responders.(ref 25: Rec 1)

Recommendation 2

Recommendation 3

Recommendation 3 For Buncefield-type sites, operators should review their on-site emergency plans to reflect the revised guidance on preparing on-site emergency plans as per Recommendation 2. The Competent Authority will need to check that this is done.

Recommendation 4

Recommendation 4 Operators should review and where necessary revise their on-site emergency arrangements to ensure that relevant staff are trained and competent to execute the plan and should ensure that there are enough trained staff available at all times to perform all the actions required by the on-site emergency plan.(ref 13: Recs 6 & 19) (ref 26: Rec 10)

Recommendation 5

Recommendation 5 For Buncefield-type sites, operators should evaluate the siting and/or suitable protection of emergency response facilities such as the emergency control centre, firefighting pumps, lagoons or manual switches, updating the safety report as appropriate and taking the necessary remedial actions.(ref 13: Rec 12)

Recommendation 6

Recommendation 6 Operators should identify vulnerable critical emergency response resources and put in place contingency arrangements either on or off site in the event of failure at any time of the year and make appropriate amendments to the on-site emergency plan. This should include identifying and establishing an alternative emergency control centre with a duplicate set of plans and technical information. (ref 26: Rec 10)

Recommendation 7

Recommendation 7 For COMAH sites, if the operator relies on an off-site Fire and Rescue Service to respond, the operator's plan should clearly demonstrate that there are adequate arrangements in place between the operator and the service provider. The Competent Authority will need to check that this is done.

Warning and informing the public

Recommendation 8

Recommendation 8 COMAH site operators should review their arrangements to communicate with residents, local businesses and the wider community, in particular to ensure the frequency of communications meets local needs and to cover arrangements to provide for dealing with local community complaints. They should agree the frequency and form of communications with local authorities and responders, making provision where appropriate for joint communications with those bodies.(ref 26: Rec 3)

Recommendation 9

Recommendation 9 The Competent Authority should review the COMAH guidance to assist operators in complying with Recommendation 8 and should work with the Cabinet Office to integrate the COMAH guidance and the CCA *Communicating with the public guidance*,(ref 27) so that communications regarding COMAH sites are developed jointly by the site operator and the local emergency responders.

Preparing for and responding to a major incident off site

Recommendation 10

Recommendation 10 The Cabinet Office should initiate a review of the arrangements to identify a minister (and their devolved counterparts) and their role to complement and support the emergency responders following a major incident to ensure national arrangements work as intended and there is continuity of government attention throughout the response and recovery phases. The review should include communications, public reassurance, the interface with planning for a return to social normality (Recommendation 27), and arrangements to ensure that recommendations made following major incidents are implemented.

Recommendation 11

Recommendation 11 The Civil Contingencies Secretariat, working with the Competent Authority, should ensure that COMAH emergency arrangements are fully integrated with those under the CCA with the aim of ensuring that major

hazard events are dealt with consistently at all levels, from on site to national, in terms of planning, shared resources, and practical arrangements. The review should include, but not be limited to, confirmation that:

- response arrangements take account of devolved responsibilities;
- lead responsibility in government for ensuring emergency response arrangements at COMAH sites is dealt with consistently under COMAH and CCA;
- procedures and guidance are suitably aligned; and
- deployment of emergency equipment considers both COMAH and CCA sectors and sites.

Recommendation 12 Communities and Local Government should complete and, where necessary, initiate an assessment of the need for national-level arrangements to provide, fund and maintain, emergency response equipment (such as high volume pumps, firefighting foam and specialist pollution containment equipment). The review could also consider criteria for allocation and use of this equipment across the UK.

Recommendation 12

Recommendation 13 The Civil Contingencies Secretariat should review guidance to responders on assessing the extent of the impact of an incident at a COMAH site to ensure appropriate scales of response and resources are provided, at local, regional or national levels.

Recommendation 13

Review of off-site emergency plans

Recommendation 14 The Civil Contingencies Secretariat, working with the Competent Authority, should arrange for national guidance to local authorities to be prepared, addressing as a minimum the areas covered in Recommendation 15. Guidance should also address the competencies required for emergency planners, and be clear on the resources that may be demanded for an effective emergency planning function. The guidance should be a living document, ie periodically updated in the light of new knowledge of handling major emergencies.

Recommendation 14

Recommendation 15 Local authorities should review their off-site emergency response plans for COMAH sites in line with the revised guidance produced in response to Recommendations 13 and 14, and in the case of fuel storage sites, to take account of explosions and multi-tank fire scenarios. The aim is to ensure plans contain the key information from relevant COMAH safety reports (without compromising the safety reports' confidentiality), which should be provided by site operators following their reviews of arrangements under Recommendation 1. The review should include but not be limited to the following:

Recommendation 15

- input from trained and competent emergency planners following clear guidance;
- working in conjunction with Regional Resilience Forums, and their equivalents in Scotland and Wales, in preparing their off-site emergency plans to understand potential impacts on the Region.(ref 28) The Local Resilience Forum structure encourages multi-agency co-operation and information sharing within a county. The Regional Resilience Forum,[24] and their equivalents, should determine where

[24] The Regional Resilience Forums are established by each Government Office to discuss civil protection issues from the regional perspective and to create a stronger link between local and central government on resilience issues. Similar arrangements are made in the devolved administrations.

further consultation is applicable and determine how this is done within and across regions;

- working in conjunction with neighbouring local authorities in developing their off-site emergency plans and involving these authorities in training and in emergency exercises;
- extending co-operation beyond the statutory consultation distance (CD) supplied by HSE to take into account the worst possible impact of a major incident, in effect re-calibrating the public information zone, which conventionally aligns with the CD;
- considering with other primary responders the fitness for purpose of the plans for the different tiers of the command and control structure (gold/silver/bronze);
- taking account, with appropriate expert input, of the local environment to identify what would be at risk and to identify the potential consequences.

CCS and the Competent Authority, as the enforcing authority under COMAH, should ensure the reviews are carried out.

Recommendation 16

Recommendation 16 HPA [Health Protection Agency], HPS [Health Protection Scotland] and NPHS [National Public Health Service] Wales, EA [Environment Agency], SEPA and EHSNI [Environment and Heritage Service Northern Ireland] should provide local contact details to local authorities and Local Resilience Forums[25] (LRFs) to facilitate emergency plan development. This will ensure local authorities have clear consultation routes for the public health and environment aspects of their off-site emergency plans.(ref 13: Rec 5)

Recommendation 17

Recommendation 17 Local authorities should ensure their off-site emergency plans give due consideration to meeting the welfare needs of responders, including arrangements to provide food and drink and toilet and washing facilities, on all shifts. This will also need to include guidance on rest breaks and the provision of accommodation for responders from outside of the local area. Plans should make provision for the contribution of the volunteer community in attending major incidents in the welfare and other supporting roles.(ref 26: Rec 26) (ref 25: Rec 38)

Recommendation 18

Recommendation 18 In reviewing their off-site emergency arrangements for COMAH sites, revised in accordance with our recommendations, local authorities should identify the facilities, resources and actions that are critical to successfully respond to an emergency and should provide contingencies for Buncefield-type sites. Local authorities should review and where necessary revise emergency arrangements to ensure that relevant staff are trained and competent and that there are enough trained staff and resources to perform the actions required by the emergency plan at all times.

Recommendation 19

Recommendation 19 Local authorities should ensure their revised off-site emergency arrangements for COMAH sites are tested within 12 months of production. Exercise scenarios based on real incidents should be compiled by CCS and the Competent Authority and available for multi-agency exercise development:

- All Category 1 responders should ensure their staff are trained within six months of production to deliver the emergency response.(ref 25: Recs 7, 14 & 16)

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25 The principal mechanism for multi-agency co-operation between all Category 1 and 2 responders in a local police area is the Local Resilience Forum (LRF). The aim of LRF is to facilitate fulfilment of the statutory duties of the members. The LRF is not a statutory body, but it is a statutory process under the Civil Contingencies Act 2004.

- Local authorities should arrange for councillors and elected members to have awareness training regarding their role in planning for, responding to and recovering from emergencies to effectively represent their communities.[26]

Recommendation 20 Local Resiliance Forums and devolved equivalents should assess and advise operators, local authorities and the Competent Authority on the effectiveness of communications with residents, local businesses, dutyholders and the wider community in the event of a major incident. The assessment should use an agreed standard in line with CCA2004 guidance *Communicating with the public*(ref 27) and include arrangements with local media to avoid conflicting advice being received, and to ensure key messages are transmitted.

Recommendation 20

Responding to a major incident

Recommendation 21 The CCS should conclude their review of arrangements for obtaining and using air quality data in an emergency. This revision of arrangements should be delivered no later than 2008. The review should include:[27]

Recommendation 21

- agreement on clear notification procedures;
- agreement on roles and responsibilities for collecting air quality data;
- arrangements to disseminate the above to all responders and include them in emergency plans;
- agreement on performance standards for quality and delivery;(ref 25: Recs 5 & 15)
- consideration for the provision of local meteorological stations in the vicinity of COMAH sites, which can provide local wind direction and speed.

Defra should ensure that financial or resource restraints do not hinder the delivery of a robust air monitoring capability.

Recommendation 22 The Civil Contingencies Secretariat and Department of Health should clarify the different roles for providing health advice at Strategic Co-ordinating Group [SCG] (Gold Command and Control Centre) to local responders. Local agreements should be in place in advance to allow health agencies to decide quickly who will do what in any incident so that the SCG chair receives the support they need. Different arrangements will exist in devolved areas and planning should take account of these.(ref 25: Rec 23) Information relevant to public health arising from the incident at the major hazard site in question should be available at the outset to enable health responders to give accurate, useful advice when first needed.

Recommendation 22

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26 Training is available at the Emergency Planning College, Easingwold www.epcollege.gov.uk/EMSEM.

27 Defra has proposed that the Environment Agency take on the co-ordinating role for air quality in a major incident, excluding radiological and nuclear incidents or those involving chemical warfare agents. The project to draw up and implement the coordination arrangements includes Defra, Welsh Assembly Government, Health Protection Agency, Met Office, Food Standards Agency, Government Decontamination Service, local authorities and Fire Services. SEPA and EHS (Environment and Heritage Service Northern Ireland) are due to be consulted and included.

Recommendation 23

Recommendation 23 The operators of industrial sites where there are risks of large explosions and/or large complicated fires should put in place, in consultation with fire and rescue services at national level, a national industry–fire service mutual aid arrangement. The aim should be to enable industry equipment, together with operators of it as appropriate, to be available for fighting major industrial fires.(ref 26: Recs 2 & 25) (ref 29: p5) Industry should call on the relevant trade associations and working group 6 of the Buncefield Standards Task Group to assist it, with support from CCS. The COMAH Competent Authority should see that this is done.

Recommendation 24

Recommendation 24 Fire and rescue authorities and their equivalents in Wales, Scotland and Northern Ireland should review the availability of materials and equipment nationally and determine if they are sufficient to respond to and manage major incidents.[28] (ref 26: ch 7 & Ref 10) Critical interface components, such as foam equipment couplings used by the FRS, should be capable of use both by the FRS and with any industry the authority may call upon. The administrations of Scotland and Wales should be involved in such a review as responsibility for the FRS is devolved. Communities and Local Government and equivalent administrations should see that this is done.

Recommendation 25

Recommendation 25 The recommendations in the Hertfordshire Fire and Rescue Service report(ref 26) into the lessons learned from the Buncefield fires that are widely applicable, should be put into effect where it is practical to do so as soon as possible. Communities and Local Government ministers, in cooperation with the Civil Contingencies Secretariat and equivalent administrations, should see that this is done.

Recommendation 26

Recommendation 26 The Civil Contingencies Secretariat should review the procedures and arrangements[29] in government offices in the English regions for deploying liaison staff to ensure effective communications between central government and Gold Command (Strategic Control Group) in a major emergency. The review should ensure that communications are managed in a way which minimises the demands on Gold Command and maximises efficiency. It should also ensure that the necessary level of human and technical resources can be sustained over a significant period if required by the demands of the response and recovery phases. The review should be conducted with the equivalent administrations to ensure equivalent improvements in communication arrangements for incidents in devolved areas.

Recovering from a major incident

Recommendation 27

Recommendation 27 The Cabinet Office should confirm formally, to avoid any doubt, where lead ministerial responsibility lies for the recovery phase following a major incident until the affected community has regained social normality. We believe responsibility should lie, in most foreseeable situations, with Communities and Local Government (or its successors, or in the case of Scotland and Wales, its devolved administration counterparts) supported as necessary by other central

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28 This is being taken forward by the Fire Service Practitioners Forum 'Buncefield Task and Finish Group'.

29 GO East and HPA have recognised the need to deliver incident management training and to increase the number of liaison officers and assistants as part of their reviews. Cabinet Office has identified workstreams to review the central government arrangement for responding to an emergency and for the provision and management of information in support of the central response. This will address issues that arose between Gold Command and central government.

departments. In the event it is agreed that another minister should assume this role in a specific situation, the transfer of responsibility should be made clear. Emergency arrangements should take full account of the need to ensure recovery starts as soon as possible, including a smooth handover of lead ministerial responsibility where appropriate.

Recommendation 28 Local authorities should ensure that recovery plans dovetail with off-site emergency response plans and the Regional Economic Strategy[30] (and devolved equivalents) to ensure that all relevant organisations are involved at an appropriately early stage.

Recommendation 28

Recommendation 29 Communities and Local Government should review options for government support to communities affected by a disaster and produce practical recommendations without delay. The review should consider the merits and mechanisms for providing immediate, short-term financial assistance to affected communities, for instance through establishing special status, and how long the period of special treatment should last. The lead minister for recovery that we ask to be confirmed in Recommendation 27 should have responsibility for controlling special funding provided for recovery. Suitable indicators of social and economic well-being should be adopted to assist in the monitoring of the recovery. The equivalent administrations should be involved in the review to ensure that appropriate financial support arrangements are put in place in their areas.

Recommendation 29

Recommendation 30 Central government should give urgent consideration to support to assist in the recovery of the area around Buncefield, including to both help restore business confidence and attract new workers and new employment. The aim would be to apply to the Buncefield area the principles of our recommendations right away. The Secretary of State for Communities and Local Government should see this consideration takes place.

Recommendation 30

Recommendation 31 The Health Protection Agency and equivalent health bodies (HPS, NPHS and DHSSPS (Department of Health, Social Services and Public Safety, Northern Ireland)) should agree a framework for continued co-ordination of health impact assessment and response after the acute incident response phase stands down.

Recommendation 31

Recovery of the environment

Recommendation 32 The Environment Agency (in consultation with SEPA and the Northern Ireland Environment and Heritage Service) should complete, as quickly as possible, its review of methodologies for assessing the potential harm to the environment arising out of credible major incidents at COMAH sites, and from the emergency response scenarios attaching to them. The objective is to improve information provided to aid planners and emergency responders. The work should align with the arrangements introduced for the Scientific and Technical Advice Cell (STAC).

Recommendation 32

30 The RDA would play a key role in driving economic development in the region, especially if a major incident had an economic impact across a number of local authority areas or across the whole region.

Investigation of the explosion mechanism

160 The massive explosion at Buncefield had not been anticipated in any major hazard assessment of the oil storage depot before the incident. In our Initial Report, we said that:

> 'Further work is needed to research the actual mechanism for generating the unexpectedly high explosion over-pressures seen at Buncefield. This is a matter of keen international interest, and participation from a broad range of experts, as well as the industry, is essential to ensure the transparency and credibility of any research programme. The Board will consider further recommendations about the nature and scope of such work.'

161 In the Autumn of 2006 we invited explosion experts from academia and industry to form a working group to advise on the work that would be required to explain the severity of the Buncefield explosion. The first meeting of this Advisory Group was held in December 2006. The Group then had three subsequent meetings to review evidence and agree a report to the MIIB.

162 In our report *Recommendations on the design and operation of fuel storage sites* in March 2007 we said:

> 'We have asked the panel to advise us whether research is justified and if so the scope of such research, likely methods of funding it, and its governance arrangements, to ensure a satisfactory outcome. We have asked the panel to present its findings to us shortly after Easter and we shall make our recommendations known soon afterwards.'

163 The recommendations below are the response to our request.

Recommendation 1

Recommendation 1 It is recommended that a joint industry project be initiated that will, in its first phase, have the objectives of completing the assessment started by the Group and, on the basis of this, of defining the requirements for further research. This research – experimental and theoretical – would then be completed in a second phase of the project. Guidance to industry and HSE should be a primary deliverable of the work.

Recommendation 2

Recommendation 2 Governance of the project should be through a steering committee comprising stakeholders from industry and HSE, as regulator. The first phase of work would be conducted primarily by a technical committee, one member of which would act as project manager.

Recommendation 3

Recommendation 3 The Group recommends that this project should be initiated as soon as possible, with the first phase to be completed in early 2008. The additional experimental and theoretical work should then be completed within the following 18–24 months. To facilitate the first phase of the project being completed to schedule, it is suggested that there should be a maximum of ten sponsors. Broader support may be required for the second phase of the work.

Land use planning and the control of societal risk around major hazard sites

164 This report concentrated on the third of our main areas of concern – the system for land use planning and the control of societal risk around major hazard sites in Britain. It builds on the broad conclusions set out in paragraphs 80–86 of our Initial Report, but ranges more widely over the key components of the planning system around major hazard sites, not just HSE's contribution to it.

165 We said in paragraph 80 of our Initial Report that one of the starkest issues raised by the event is the location of sites with such major hazard potential alongside neighbouring residential and commercial development. The strategic importance of major hazard sites must be balanced by high standards of safety and control. The incremental growth in populations around major hazard sites had not prior to Buncefield been subject to a policy of limitation. The potential for developing unacceptable levels of societal risk around major hazard industrial sites through incremental off-site population growth, although recognised by Government, had not been fully addressed.

166 Mitigation, or reducing the risk, of the off-site consequences of a major incident is achievable by controlling the uses to which land in the immediate vicinity of major hazard sites can be put. In this context land use planning takes into consideration the extent of the danger posed beyond the boundaries of the site and the size and nature of any proposed development. It seeks to balance the need for making best use of the land available for development with the protection of those who will occupy or use these developments. It is this subject that the following recommendations addressed.

167 It was clear at the outset of our investigation that land use planning (taken as a whole, and not just HSE's role in it) was the most difficult issue for us to address. The planning history of the Buncefield site and neighbouring developments is illustrative. The site opened some 40 years ago, before a specialised planning system around major hazard sites had developed. There were few houses and no commercial buildings in the immediate vicinity at that time. Since then activities within the site have intensified and vigorous residential and commercial development has taken place around it. Prior to Buncefield the planning advice at flammable storage sites would not have covered the likelihood of a violent explosion, just as the risk control measures and the emergency response arrangements at such sites would not have been primarily directed at the possibility of a large flammable vapour cloud forming and moving offsite. These facts made it clear to us, as expressed in our fifth and sixth reports, that the system for giving planning advice around major hazard sites must become more integrated with the COMAH regulatory system for controlling the risks of major hazards to humans and the environment created by the site itself.

168 While the principle of decisions being taken by the local planning authority and in line with broader development plans for the region remains sound, a weakness is the separation between the COMAH regulatory system and the system for developing advice to planning authorities. We concluded the roles of the COMAH Joint Competent Authority and the site operators in the planning system around major hazard sites therefore needed to be remodelled.

169 In Part 1 we focused on improving the way that all the stakeholders in the planning system for major hazard sites are organised. We developed the case for integrating the land use planning and the COMAH systems to achieve sensible consistency in the measures for safety and environmental protection around major hazard sites. Recommendation 1 called for a wide-ranging review of the system for land use planning around major hazard sites to begin without delay and include the incorporation of societal risk into land use planning decision making. Recommendations 2–5 asked for the economic case for land use planning and control of societal risk to be clarified, and for the workings of the planning system to be set out in clear guidance for the general public.

170 In Part 2 we identified a number of primarily technical issues relating that need to be addressed in parallel with the wide-ranging review if changes to the system are to be delivered within five years. Recommendations 6–8 called for the simplified, generic approach to risk assessment currently used around flammable

storage sites to be replaced by a site-specific assessment of risks, using QRA [quantitative risk assessment] methods, leading to a planning system that is more responsive to the levels of risk posed by each particular site. The revised approach should take account of revised hazard scenarios and move away from expressing harm in terms of 'dangerous dose or worse' to a risk of fatality.

171 Recommendations 9–11 called for alignment in the risk assessment approach in the COMAH safety report system with land use planning, and in setting priorities on the management of sites to ensure continuing integrity of the control measures incorporated in the planning decisions. Recommendation 12 addressed some of the anomalies attaching to the hazardous substances consents system at dormant sites and where the quantities of consented substances greatly exceeds the quantities that can physically be stored.

172 In Recommendations 13–17 we called on the key stakeholders – some of whom have had little involvement to date – to demystify the concept of societal risk and to envisage a future system where they support the planning authority in coming to transparent decisions on what level of societal risk can be accepted in a planning application. This should be subject to guidance on tolerability limits developed by HSE and agreed nationally. We asked for the land use planning controls to be extended to pipelines conveying petrol. We also called for the planning authorities to be suitably resourced to develop the expertise and procedures necessary for their role.

173 We commissioned a report to describe what a risk-based system incorporating societal risk might look like at a flammable storage site which confirmed that a fully risk-based land use planning system around all high-hazard sites is feasible (and is used elsewhere in Europe). We concluded our report by addressing, in Recommendation 18, retrospective application of this method since there will inevitably be some places where the societal risk will be of concern due to developments which have already taken place.

Improving the organisation of the land use planning system around major hazard sites

Recommendation 1

Recommendation 1 We recommend a cross-government and wide-ranging review of the land use planning system around major hazard sites in Britain. The review should include:

- the system for hazardous substances consents;
- the system for determining planning applications around major hazards sites;
- the relationship between planning applications around major hazard sites and development plans and planning;
- the scope of hazardous installations to which the land use planning system should be applied; and
- the integration of societal risk into the planning system around major hazard sites.

The aim of the review should be to revise the planning system around major hazard sites in Britain to produce a more consistent and transparent system across the non-nuclear, onshore major hazards sector. The system should be responsive to levels of risk presented at each site. It should ascribe responsibilities to

duty holders and the relevant authorities, including in the devolved administrations, in a proportionate and targeted manner. A minister should be responsible in each administration for seeing the review is carried out.[31]

The review should be commenced without undue delay in order to implement its conclusions within a reasonable timeframe. Wherever feasible, work on revising the elements of the system should be undertaken simultaneously rather than sequentially.

Recommendation 2 The review should take account of our approach to improving the control of major hazard risks at major hazard sites.

Recommendation 2

Our approach integrates:

- integrity levels of the major hazard sites in relation to containment of dangerous substances and process safety;
- mitigation against the effects of a major incident on off-site populations and installations;
- preparedness for emergency response to limit the escalation of potential major incidents;
- land use planning; and
- the regulatory system for inspection and enforcement under COMAH and other relevant law.

Economic considerations

Recommendation 3 We recommend that the economic case for a revised land use planning system around major hazard sites arising from the wide-ranging review should consider the full range of the costs and benefits of restricted development, including costs to the relevant industry sectors, local businesses and regional economies, and the use of land for housing and public amenity.[32] This should be undertaken as part of the wide-ranging review called for in Recommendation 1.

Recommendation 3

Recommendation 4 We recommend that the use of market-based mechanisms identified in HSE's recently published economics working paper,(ref 30) are considered further to assess their potential application within the revised land use planning system around major hazard sites. We would expect HSE to co-ordinate this work with the wider economics community having an interest in the planning system.

Recommendation 4

Public understanding

Recommendation 5 We recommend that the workings of the revised land use planning system around major hazard sites are described in guidance in a form accessible to the general public. The guidance should have ownership of all the key government stakeholders, including the devolved administrations.

Recommendation 5

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31 In Recommendation 10 of our sixth report we call for a minister to be responsible, *inter alia*, for seeing that lessons learned from major incidents – and therefore our recommendations – are carried out.

32 See the Board's response to the regulatory impact assessment accompanying CD211, available on the Buncefield website www.buncefieldinvestigation.co.uk.

Risk assessment and other technical issues

Recommendation 6

Recommendation 6 We recommend HSE adopts a policy for the consistent application of formal risk assessment of land use planning applications around major hazard sites that is responsive to levels of risk at particular sites.

Recommendation 7

Recommendation 7 Priority should be given to improving source terms and frequency data relevant to QRA at major hazard sites. This should include:

- improvements in defining major hazard scenarios at flammable storage sites called for in Recommendation 1 of our sixth report;(ref 16)
- improving recording and sharing of incident data and improvements to investigation of root causes of incidents and near misses called for in Recommendations 23–25 of our fifth report;(ref 13) and
- integrating the outcomes of the explosion mechanism project group set up in response to our seventh report.(ref 5)

We call on the COMAH operators and the Process Safety Leadership Group[33] to take the lead in delivering these outcomes, and the Competent Authority to give technical support.

Estimating consequences of an event

Recommendation 8

Recommendation 8 We recommend that HSE universally adopts individual risk of fatality as the criterion for expressing the consequence of events, in preference to the risk of receiving a dangerous dose or worse.

Reliability of engineered systems

Recommendation 9

Recommendation 9 We recommend that the risk assessment methodology and criteria for land use planning purposes align with those for risk assessment under the COMAH regime. The methodology should take account of the reliability of the engineered systems designed to achieve improved standards of primary containment, as called for in Recommendation 1 of our fifth report. The methodology should also incorporate a realistic major incident scenario in the light of Buncefield (explosions, multi-tank fires) as called for in Recommendation 1 of our report making recommendations for emergency preparedness etc.(ref 16) Account should also be taken of the vulnerability of the surrounding population and any mitigatory measures that apply to people or buildings and other physical assets.

The Competent Authority should see that these revisions are carried out to a satisfactory standard and that appropriate guidance is issued to ensure the necessary improvements to risk assessments are delivered in practice.

Roles of the site operator and the Competent Authority

Recommendation 10

Recommendation 10 Operators of major hazard sites should, as a priority, review and amend as necessary their management systems for maintenance of equipment and systems to ensure their continuing integrity in operation. Where there are a number of operators at a facility (as there were at Buncefield) the review should be integrated between site operators to the appropriate extent. The Competent Authority should see that this is done.

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33 The Process Safety Leadership Group was established in August 2007, replacing the Buncefield Standards Task Group.

Recommendation 11

Recommendation 11 We recommend that the regulatory regime for major hazard sites should ensure proper assessment of safety integrity levels (SILs) through the development of appropriate standards and guidance for determining SILs. Application of the methodology should be clearly demonstrated in the COMAH safety report submitted to the Competent Authority for each applicable site. Existing safety reports will need to be reviewed to ensure this methodology is applied.

Consented quantities

Recommendation 12

Recommendation 12 We recommend that CLG and the relevant ministers in the devolved administrations, HSE and BERR consider reforms to the major hazardous substances consent system, with the aims of:

- streamlining and simplifying the withdrawal of consents on sites that are 'dormant'; and
- allowing the size and nature of the hazardous inventories to be varied to enable realistic risk assessment for off-site planning purposes, including for revised development plans.

Existing and new developments

Recommendation 13

Recommendation 13 In moving to a fully risk-based system, and as part of the review called for in Recommendation 1, there should be a wider perspective given to the management of new planning applications where off-site development already exists. Consideration should include:

- the parties who should come together to give relevant and necessary advice and expert support to the planning authority;
- the size and nature of the existing population exposed to the risks on site;
- the safety integrity levels and environmental protection measures on the site relevant to the nature and intensity of operations;
- the mitigatory measures (ie means of reducing the consequences of a major incident) achievable for off-site buildings;
- the emergency preparedness and response arrangements;
- the needs of the regional economy as formally determined by the relevant authorities, and expressed in regional policies such as the Regional Spatial Strategy and Regional Economic Strategy;
- the strategic economic/national interest issues if relevant; and
- the further reductions that may be achieved in residual risk arising from the major hazard site.

CLG, the Welsh Assembly Government, the Scottish Government and HSE should give consideration to this issue and produce the necessary guidance to see the revised approach is implemented effectively.

Technical issues relating to societal risk

Recommendation 14

Recommendation 14 We recommend that HSE should bring together key stakeholders and experts in the planning system (planning authorities, developers, operators, regulators, risk assessment specialists) with a view to reaching agreement as early as possible on:

- the way societal risk is measured and assessed;
- the data sources required for assessment purposes;
- the acceptability criteria for societal risk values around particular sites; and
- a suitable weighting factor for more serious, less frequent events (scale aversion).

Recommendation 15

Recommendation 15 HSE should take necessary steps to amend the Pipeline Safety Regulations with the aim of extending land use and emergency planning controls (and other suitable regulatory protections if necessary) to major pipelines carrying gasoline (petrol).

Public understanding

Recommendation 16

Recommendation 16 We recommend that HSE should review, update and publish documentation on the process for handling land use planning risk assessments around major hazard sites by local authorities, and the main contributors to the decision-making process. The resulting publication should be capable of being understood by a lay audience.

Local planning authority resources

Recommendation 17

Recommendation 17 Local planning authorities and the administrations responsible for them should ensure the necessary expertise and other resources are available to implement the revised planning system around major hazard sites, as well as management systems to ensure maintenance of competencies, monitoring, audit and review of the planning systems in their authority.

Implementation and priorities

Recommendation 18

Recommendation 18 The Competent Authority should agree a priority programme with site operators and planning authorities for assessing societal risk at sites of identified concern using the risk assessment methodologies developed in line with our recommendations. Account should also be taken whether the ALARP [as low as reasonably practicable] threshold has been raised due to considering previously unaccounted hazard scenarios.

Annex 1

Terms of reference

1 To ensure the thorough investigation of the incident, the factors leading up to it, its impact both on and off site, and to establish its causation including root causes.

2 To identify and transmit without delay to dutyholders and other appropriate recipients any information requiring immediate action to further safety and/or environmental protection in relation to storage and distribution of hydrocarbon fuels.

3 To examine the Health and Safety Executive's and the Environment Agency's role in regulating the activities on this site under the COMAH Regulations, considering relevant policy guidance and intervention activity.

4 To work closely with all relevant stakeholders, both to keep them informed of progress with the Investigation and to contribute relevant expertise to other inquiries that may be established.

5 To make recommendations for future action to ensure the effective management and regulation of major accident risk at COMAH sites. This should include consideration of off-site as well as on-site risks and consider prevention of incidents, preparations for response to incidents, and mitigation of their effects.

6 To produce an initial report for the Health and Safety Commission and the Environment Agency as soon as the main facts have been established. Subject to legal considerations, this report will be made public.

7 To ensure that the relevant notifications are made to the European Commission.

8 To make the final report public.

Annex 2

Members of the independent Board

The Rt Hon Lord Newton of Braintree has been a life peer since 1997 after spending 23 years as a Conservative Member of Parliament for Braintree, Essex. From 1982 to 1988 he held ministerial positions at the Department of Health and Social Security. In 1988 he joined the Cabinet as Chancellor of the Duchy of Lancaster and Minister at the Department for Trade and Industry. He then held the post of Secretary of State for Social Security from 1989 to 1992 when he was appointed Leader of the House of Commons, which he held until 1997. In 2002 he chaired the Committee that reviewed the operation of the Anti-terrorism, Crime and Security Act 2001.

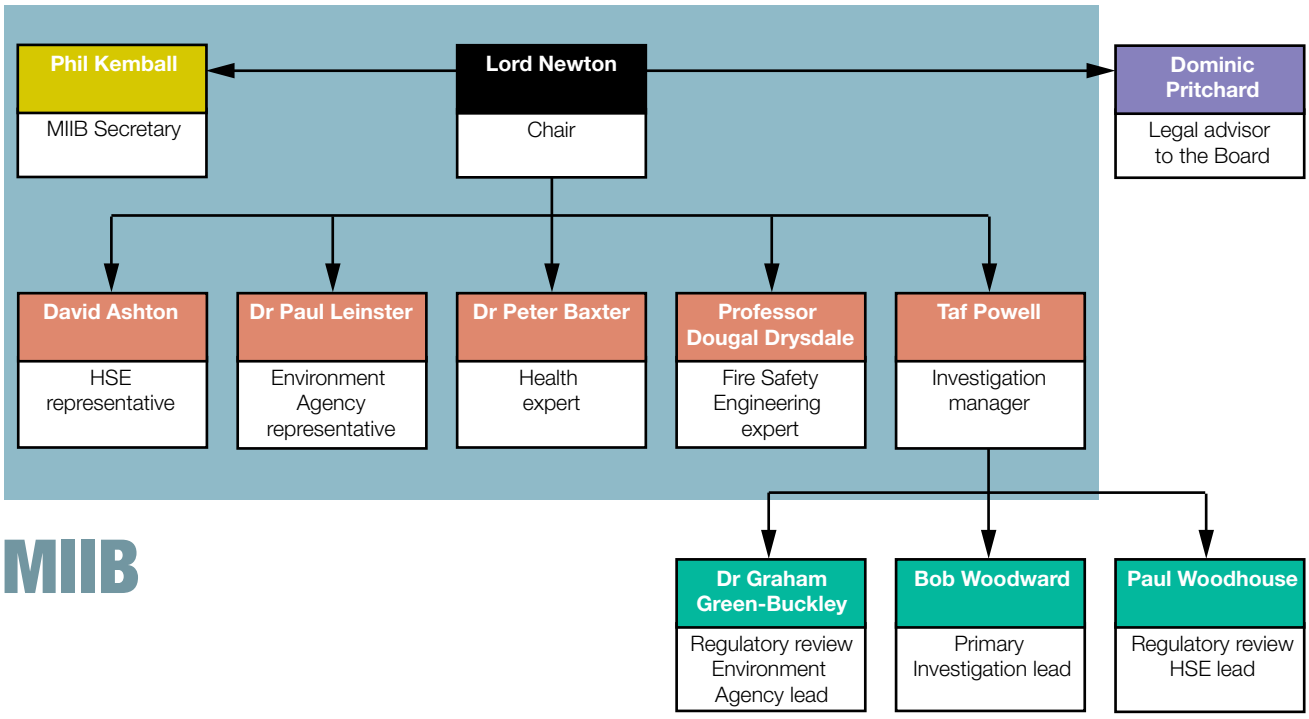
Professor Dougal Drysdale is one of the leading international authorities in fire safety engineering. He was the Chairman of the International Association of Fire Safety Science until September 2005 and is currently the editor of the leading scientific journal in the field, *Fire Safety Journal*. His wide range of research interests includes the ignition characteristics of combustible materials, flame spread and various aspects of fire dynamics. He is a Fellow of the Royal Society of Edinburgh and a Fellow of both the Institution of Fire Engineers and the Society of Fire Protection Engineers.

Dr Peter Baxter is a Consultant Physician in occupational and environmental medicine at Cambridge University and Addenbrooke's Hospital, Cambridge. In the past, he has advised the government on the impacts on public health relating to air quality standards, major chemical incidents, natural disasters and climate change.

Taf Powell is Director of HSE's Offshore Division. He graduated in Geology and Chemistry from Nottingham University. His oil field career has been split between working in the UK and abroad in offshore exploration and development and regulation of the sector in licensing, well operations, policy and safety regulation. In 1991 he joined HSE's Offshore Division from BP and started work to develop the new offshore regulatory framework, one of Lord Cullen's recommendations following his inquiry into the Piper Alpha disaster. As HSE's Operations Manager, based in Aberdeen, he then led inspection teams and well engineering specialists responsible for enforcing the new regulations until 2000 when he took up his current role.

Dr Paul Leinster is Director of Operations at the Environment Agency. Up until March 2004 he was the Director of Environmental Protection, having joined the Agency in 1998. Before this he was the Director of Environmental Services with SmithKline Beecham. Previous employers also include BP International, Schering Agrochemicals and the consultancy firm Thomson-MTS where he was Managing Director. Paul has a degree in Chemistry, a PhD in Environmental Engineering from Imperial College and an MBA from the Cranfield School of Management. He has worked in the health and safety and environmental field for 30 years.

David Ashton is Director of HSE's Field Operations North West and Headquarters Division. He joined HSE in 1977 as an inspector in the west of Scotland where he dealt with a wide range of manufacturing and service industries, including construction, engineering and the health services. In 1986 he joined Field Operations HQ to deal with machinery safety. He then held the post of Principal Inspector of manufacturing in Preston for two years, before being



appointed as a management systems auditor to examine offshore safety cases in the newly formed Offshore Division. In 1993 he became Head of HSE's Accident Prevention Advisory Unit, looking at the management of health and safety in organisations. Between 1998 and 2003 David was HSE's Director of Personnel, before being appointed to his current position.

Annex 3

Economic factors

1 In this annex we provide further information in support of the 'Economic impact' chapter in Part 1 of this report. The information is in three parts:

- the total economic impact of the incident;
- the scale of the incident compared to other large-scale industrial accidents elsewhere in the UK and abroad;
- the costs and benefits of the Buncefield Board's recommendations (relating to design and operations of flammable storage sites).

The total economic impact of the incident

2 Table 3 shows that the overall cost of the Buncefield incident is estimated to be close to £1 billion. This is made up predominantly of compensation claims against the site operators. These include claims from individuals, local authorities and businesses (both those on and off site). The estimated costs to the aviation industry are also high, although this estimate is based upon much less robust data. Within this annex we break down further the costs presented in Table 3 into their component parts.

Table 3 Summary of the overall costs of the Buncefield incident, by affected sector

Sector	*Cost (£ million)*
Aviation	£245
Site operators (compensation claims)	£625
Competent Authority and Government interventions	£15
Environmental impact on water supplies	£2
Emergency response	£7
Total	£894

Costs to business

3 Most of the businesses affected by the Buncefield incident were located on the Maylands Estate, which was responsible for generating 2% of the gross domestic product (GDP) of the East of England. A total of 630 businesses were located at Maylands, employing around 16 500 people. Including the supply chain, businesses employing 25 000 were affected. Although many businesses suffered disruption for a couple of days after the Buncefield incident, some 90 businesses, from micro-enterprises to large businesses, were 'severely affected' by the incident because of total or partial destruction to their premises and other business assets.

4 Consultancy SQW was commissioned by Dacorum Borough Council and the East of England Development Agency (EEDA) to produce reports on the social impacts[ref 31] and the economic/business confidence impacts[ref 21] of the Buncefield incident. The economic and business confidence impact study showed that of the 90 severely affected firms, 12 were large companies (employing 200+ people in the Maylands area), 16 were medium-sized companies (employing 51–200 people), 33

were small companies (employing 11–50 people), 19 were very small companies (employing 1–10 people), and ten were companies of non-specified size. The economic impact study arrived at this breakdown by using an internet-based survey of local businesses. Dacorum Borough Council has identified that of 92 severely or directly affected firms (employing 9500 people), 14 businesses (employing around 200 people) had relocated since the incident and several were operating in temporary premises, although many businesses have now moved back to Maylands. Two firms employing a total of 25 people also went into liquidation.

5 Maylands was formed of a number of different types of businesses including: transport, storage, communication, retail, wholesale, motor vehicle repair, real estate, social and personal services, and IT. Many of these businesses were interdependent, and supply chains, both upstream and downstream of Maylands-based companies, were disrupted. As there was a high level of interdependence amongst the 630 firms operating at Maylands, even those firms whose premises were not damaged by the blast will have suffered through the loss of suppliers or customers who were affected.

6 The survey commissioned by the East of England Development Agency found that many small companies located at Maylands were reliant upon other Maylands-based businesses for all of their revenue, and many suffered around 80% of business loss as a result of the Buncefield incident. The survival of many of these small companies was dependant upon whether larger businesses continued to operate at the Maylands Estate. The main impacts upon businesses, identified by Dacorum Borough Council, have been increased operating costs, reduced orders, reduced ability to meet existing orders (particularly among very small to medium-sized companies) and lack of adequate insurance for smaller businesses. It is likely that the reduced ability to meet existing orders will have benefited companies in other regions who will have been able to offset the shortfall in goods or services provided directly by companies on the Maylands Estate. Although economic impacts to local businesses may have had little overall economic impact on a national scale, the surveys commissioned by Dacorum Borough Council and by the East of England Development Agency indicate that the impacts to many local businesses were considerable.

7 Data supplied by the Joint Claims Committee set up by HOSL shows that potential costs of the 749 claims submitted by businesses outside of the HOSL perimeter fence were in the region of £490 million. Table 4 presents the estimated total value of the claims against HOSL. This table was provided by HOSL's Joint Claims Committee and presents a breakdown of the total estimated value of claims of £625 million. The majority of the claims presented have been submitted by businesses off site.

Table 4 Estimated total value of claims against Buncefield site operators

Claimant type	*Number of claims*	*Estimate (£ million)*
Business		
inside site perimeter	5	£103
outside site perimeter	749	£488
Subtotal businesses	754	£591
Individuals	3 379	£30
Local authorities	7	£4
Totals	4 140	£625

8 Recovery costs will be incurred as part of the regeneration process at Maylands, and the East of England Development Agency had announced previously that it planned to commit over £2 million to the regeneration. Much of the cost to Maylands firms should be covered by insurers, so to avoid double counting we shall assume that recovery costs are included in the £625 million estimate, although this is likely to be a conservative assumption, as some of the reovery costs may not have been coveredby insurers.

9 Businesses on the Maylands trading estate were reported to have suffered severe losses due to damage to buildings and other assets, loss of stock, disruption to business and loss of sales. The report *Economic and Business Confidence Impact Study*(ref 21) highlighted such problems, of which the total economic impact on Maylands' businesses was estimated to be in the region of £130–170 million.

Unemployment

10 Some short-term unemployment followed on from the Buncefield incident. However, analysis of Jobcentre Plus data regarding the numbers of claimants of Job Seekers Allowance in Dacorum has shown that although rising initially, the change in the number of claimants has followed an identical trend to that of the rest of the East of England and a trend similar to Hertfordshire and the rest of the nation. Despite these trends, the SQW reports (which included survey analysis) have shown that large amounts of job relocations and redundancies occurred. Job relocations have little effect on the overall economic impact of the Buncefield incident, but it will have affected the local economy. As part of this inquiry, Jobcentre Plus, the Citizens Advice Bureau and the Buncefield Community Task Force have all pointed to evidence of Buncefield-related job losses and redundancies.

11 Unemployment not only led to costs to individuals, via loss of income and increased hardship, but also to affected businesses via lost output and redundancy payments. The Economic and Business Confidence Impact Study attempted to cost permanent and short-term job losses based on sample data from 18 severely affected firms. For an estimated 35 people, short-term job losses (valued at £1750 for a five-week lay-off) totalled £61 250. For an estimated 118 permanent job losses (lasting one year and valued at £18 000 each including national insurance contributions) the total cost amounted to £2 124 000. Grossed up this would provide a crude estimate of unemployment costs of around £10 620 000. We consider this cost to be included in the estimate of claims against the site operators received from businesses (as provided by the Joint Claims Committee in Table 4).

12 The sample survey of severely affected firms also estimated total costs of lost output to be £13 552 000. However, we assume gross value added and asset losses to be included in claims against the site operators.

Housing market

13 Damage not only occurred to commercial properties but also people's homes. Many properties were damaged, although most of the damage was minor (broken windows, cracked door frames etc). Some residents living closer to the site suffered significant structural damage, with one resident claiming damage of around £1.3 million. It is important to note however that this is an extreme case with the average claim from individuals (including non-housing claims) being £8900.

14 Costs of re-housing people whose property was severely damaged is likely to have fallen to insurance companies. Some families have been displaced due to ongoing problems repairing the extensive damage to their homes. However, house prices in general appear to have remained largely unaffected.

15 The effect of the Buncefield incident on local house prices was reviewed by GO-East (the Government Office for the East of England) in July 2006. Local estate agents reported that there had been little or no decrease in house sales and value. Research (carried out by Lambert Smith Hampton) found a strong demand for commercial properties in the area and the market was not expected to be affected by a Buncefield legacy in the future.

16 Conflicting messages are predictably apparent. A resident of the local area claimed to have received only one offer for a property which fell short of the asking price by £255 000. However, these singleton events can be due to any of a number of factors unrelated to Buncefield.

17 A study by Dacorum Borough Council[ref 32] (using Land Registry data) showed that local house prices have been rising since 2001. However, there was a temporary downward fluctuation in October–December 2005, presumably due to the Buncefield incident. There was also a sharp decline in the sale-to-asking-price percentage in December 2005, but even this was around 1% higher than in December 2004.

18 It is likely to be the case that those properties most badly damaged and/or near to the depot will have suffered a larger decline in market value relative to the rest of Dacorum.

19 On a larger scale the Buncefield incident has also had little effect upon regional house price data. Data for average house prices in Hertfordshire show that these have remained higher than those in the rest of England and Wales and followed a similar trend.

Emergency response – Fire and Rescue Service

20 The Hertfordshire Fire and Rescue Service incurred costs associated with putting out the fires at the Buncefield site, such as the use of firefighting foams, extra staffing costs such as overtime, regional assistance, equipment and fuel costs. A number of firefighters and services were drafted in from 32 other fire services to help deal with the blaze. 750 000 litres of firefighting foam was used, costing £1.4 million alone. The overall cost to the Hertfordshire fire service was in excess of £2 million.

Table 5 Costs to Hertfordshire Fire and Rescue Service

Overall cost		£2 100 000
of which:	foam	£1 400 000
	equipment	£250 000
	regional assistance	£280 000
	staff	£150 000
	fuel, subsistence, accommodation etc	remainder

21 Less recent data available in the SQW impact study of economic and business confidence presents the following data on the costs of the emergency respose:

Table 6 Costs of the emergency response

	Cost (£)
Hertfordshire Fire and Rescue	3 807 000
Hertfordshire County Council	2 291 000
Hertfordshire Chamber of Commerce	10 000
Hertfordshire Constabulary	409 000
Hertfordshire Prosperity	12 000
Dacorum borough Council	880 000
	7 409 000

22 Total costs (including planned expenditure at the time) amounted to £7.4 million, of which £3.3 million was judged to be reclaimable from central government. Damage to infrastructure and premises are likely to be the main drivers for the County Council's costs. We have used a conservative figure of £7 million in Table 3 to account for these in the overall total.

Environmental costs

23 Environmental costs arose both directly and indirectly as a result of the Buncefield incident. However, costs such as diverted air traffic (due to visibility impairment, and the need for Heathrow aircraft to refuel elsewhere as a result of reduced supply to Heathrow airport) will have resulted in greater volumes of aviation fuel being used and a greater amount of noise pollution around the contingency refuelling stops (such as Stanstead airport). We do not attempt to quantify these impacts here due to the lack of reliable data on the additional distances travelled and the amount of additional noise pollution generated as a consequence of the Buncefield incident.

24 Some 800 000 litres of contaminated water were reported to have leaked into the river Colne and although some firefighting foams do not break down in the environment, Defra found that there was no substantial pollution in the soil. Defra, the Department of Health and the Health Protection Agency also reported that large quantities of pollutants were released into the atmosphere. However, there were no significant health effects associated with air pollution as the plume rose into the air above the area within the boundary of the site and ground level pollution of a significant nature did not occur.[ref 3]

25 The Environment Agency and industry monitors report hydrocarbon pollutants and elements of firefighting foams (perfluorooctane sulfonate (PFOS)) in groundwater up to 2 km to the north, east and south-east of the Buncefield site. The Environment Agency has taken over 900 water and soil samples in the area and continues to monitor the level of pollutants both on and off site. Pollutants have not been identified in boreholes used for drinking water, but further encroachment of pollution into the aquifer may reduce water abstraction by removing supply boreholes. The Bow Bridge borehole used for water abstraction by Three Valleys Water Company was in fact closed as a precaution. It is estimated that if this borehole remains closed, the cost of alternative sourcing is estimated to exceed £2.1 million.

26 Around 16 million litres of heavily contaminated fire water was stored and required treatment; however, the cost of this exercise to the Buncefield site operators has not been revealed. Some of it will be recoverable through the commercial action.

Human costs

27 At the time of the explosion (a December Sunday at 6 am) there were not many people working on or around the site. This was particularly fortunate as the human costs could have been substantial, as other large-scale major hazard accidents in recent times (considered comparable to the Buncefield incident) have shown. The 2001 explosion at the AZF (Azote de France) fertiliser factory at Toulouse, France, killed 29 people, while a fire at the SE Fireworks depot in Enschede, Netherlands in 2000 killed 22 people and injured over 900.

28 The Health Protection Agency (HPA) identified that there were 244 people who attended A&E for a check up as a result of the fires at Buncefield, three quarters of whom were people from the emergency services. No serious injuries were reported but 117 people had some symptoms (38 members of the public) and most were suffering shortness of breath and a sore throat. There were 43 reported injuries, none serious, and West Hertfordshire Primary Care Trust reported that six people were treated for long-term stress. We do not attempt to value the stress-related impact of the Buncefield incident in this report.

29 Applying the HSE's appraisal values we arrive at the following costs of injuries: 43 minor injuries @ £350 = £15 050. HSE's appraisal values are formed of human costs, resource costs and costs of lost output. More information on these valuations can be found on the HSE website at www.hse.gov.uk/economics/eauappraisal.htm.

Wider impacts

National supply-chain implications

30 There will have been some downstream effect of the reduced production capacity at the Maylands estate, with many firms unable to meet orders, but this is likely to be more of a localised short-term impact, as other goods or service providers from elsewhere are likely to compensate for any shortfalls in production from the Maylands estate. The main supply chain effect is likely to have been to the industries that were directly supplied by the Buncefield fuel storage site, as, without prearranged delivery, such large quantities of fuel are difficult to acquire in a short period of time and are costly to transport. At least in the short term the ability to switch to alternative suppliers of fuel was therefore very limited.

31 Buncefield was a key supplier (the fifth largest) of fuel to the UK market, supplying 8% of UK fuel and 20% of supply in the south-east. Some 2.34 million metric tonnes of fuels passed through Buncefield in 2004 with around 400 road tankers loaded each day. Buncefield also supplied facilities such as Heathrow Airport by pipeline. It appears the impact of disruption of the fuel supply chain was greatest to the aviation industry (see paragraphs 34–44).

32 Reports in the media stated that there were some initial fuel supply shortages on petrol station forecourts, but this remained short-lived. The UK Petroleum Industry Association stated on 4 January 2006 that there were in fact no widespread supply problems. According to fuel price monitoring website www.petrolprices.com, prices actually fell marginally on the day of the incident, with the average price of unleaded petrol down by 0.1 p/litre to 87.60 p and diesel down by 0.3 p/litre to 91.99 p. This could indicate that there has been no supply chain effect associated with road fuels. However, the impact of the Buncefield incident on petrol prices can not be determined without accounting for a range of other changes in the market for petrol that may have occurred over the same period.

Effect on the aviation industry

33 The main supply chain effect of the Buncefield incident appears to have been on Heathrow airport which was pipe-fed with 7 million litres daily of fuel from the Buncefield site (accounting for 35–40% of Heathrow's total daily fuel supply).

34 In response to the supply disruption, the British Airport Authority (BAA) implemented pre-arranged contingency plans that included working with other suppliers to ensure additional deliveries, requesting airlines carry extra supplies on inbound flights, and the rationing of fuel. There were no reported cancellations as a result of the fuel shortage. However, there were delays caused to flights on the morning of the explosion because of a dense fog and the huge smoke plume that covered the local area and meant one of the four 'stacking' routes into the airport had to be closed. Further delays were caused in the first few weeks after the incident as there was a need for some long-haul flights to make stopovers on outbound flights from Heathrow at airports such as Stanstead and other European airports for refuelling. Quantas estimated this was extending the journey time of a trip to Sydney by 90 minutes. South African Airways also had to refuel their flights at Milan Airport en-route.

35 American Airlines placed a levy of £3 per passenger on each of its 16 daily flights to cover additional costs incurred, such as having divert some of its flights to other airports to refuel, or reduced fuel efficiency. This reportedly amounted to costs of around £11 000 per day, 83 airlines were affected. It is assumed that other airlines will have absorbed similar costs.

36 Domestic airlines were allowed to refuel a greater percentage of their tanks at Heathrow than foreign airlines, thus the additional refuelling costs for domestic airlines are assumed to have been lower. Fuel rationing occurred to a greater degree for short-haul flights, compared to long haul. However, for the purposes of analysis we have used the rationing levels imposed upon long-haul flights as the costs to short-haul flight operators are likely to have been smaller, with more frequent opportunities to refuel.

37 Below we attempt to quantify the costs to the airline industry below. For the purposes of estimation, and due to uncertainty regarding many of the impacts on airlines, the following assumptions have been made:

- all non-domestic airlines faced equal costs and rationing of fuel upon refuelling equivalent to of 82% of aircraft fuel capacity;
- all domestic airlines faced equal costs and rationing of fuel upon refuelling equivalent to of 70% of aircraft fuel capacity;
- American Airlines represents the average foreign airline operating at Heathrow;
- airlines suffered 480 days of disruption.

38 The analysis below attempts to provide an indication of the magnitude of costs to all airlines operating from Heathrow airport. The costs presented here use a number of assumptions and hold a high degree of uncertainty. Average numbers are used as a means to arrive at a total cost to the aviation industry. However, the length of flights operated, ability to refuel elsewhere and the type of aircraft belonging to each fleet will vary greatly.

39 Taking Civil Aviation Authority (CAA) data for 2006 we find that the total number of passengers travelling with domestic airlines in 2006 to be 36 800 000. The total number of passengers travelling with foreign airlines in 2006 was 30 700 000. Therefore the average daily passenger journeys are estimated to be 101 000 with domestic airlines and 84 000 (foreign).

40 The assumed cost passed on was £3 per passenger for foreign airlines. These airlines were rationed to 70% of their normal fuel demand, equivalent to £252 000 (84 000 x 3).

41 Domestic airlines were allowed to 82% of normal demand. (£3 x 70 / 82) = £2.56 per passenger, equivalent to a total daily cost of £258 000 (101 000 x 2.56).

42 Therefore the total daily extra cost for all airlines operating from Heathrow was, by this method, £511 000 (252 000 + 258 000). The voluntary rationing scheme continued at Heathrow airport for at least 16 months or 480 days, suggesting an overall extra cost of £245 million (258 000 x 480).

43 Our cost estimates exclude any increased cost that may have been experienced by the airfreight industry or costs resulting from stopping to refuel elsewhere.

On-site costs – lost profit, rebuild, compensation/insurance claims

44 As a result of the incident 2000 people were evacuated from their homes, 300 council properties were damaged (mostly windows), several families remained in temporary accommodation for an extended period after the explosion. A survey of 761 homeowners found that 76% experienced some damage mostly in the form of damage to windows, doors, roofs, and cracks in walls. HOSL received over 4000 compensation claims worth up to £625 million – 3400 claims from individuals (£30 million), 2800 of which were for sums of less than £10 000.

45 Costs of rebuilding the Buncefield site have been reported to be estimated at around £70 million. This cost will be partly covered by the on-site claims and has been unaccounted for in the analysis presented here to avoid any double counting. The total estimated cost of inside-the-fence claims is £103 million; however, this estimate (see Table 4 above) will not include costs to the site operators themselves in terms of business disruption and rebuild costs. It is assumed that future supply chain relationships will not be affected due to the high demand for fuel and the fact that the Buncefield site pipe feeds Heathrow airport (this infrastructure advantage means that it is unlikely that those downstream of the Buncefield facility are unlikely to look for alternative and possibly more expensive suppliers, when risks of supply shortfall could be broadly similar).

46 For further information on claims refer to Table 4. These costs are expected to be covered by the insurers, although premiums in general should remain fairly static due to the infrequency of events such as this.

Costs of the Government and Competent Authority response

47 Total costs to the Competent Authority are estimated to be in the region of £15 million. We estimate the investigators from HSE, the Environment Agency and the laboratories supporting the forensic work have put in at least 83 000 staff hours making it, we believe, the largest investigation of its kind in Britain. About 295 specialists and inspectors from the Competent Authority have been involved in the investigation, although more will have been involved if we include the intensive follow-up inspections of the 108 fuel storage sites in Britain. This represents the larger part of this sum at around £12.5 million. The rest comes from the cross-Government response to the incident. A report[ref 20] on this response was laid before Parliament on 13 November 2008.

Unquantified costs

48 An incident of this magnitude will create a number of adverse effects which it is not feasible to capture in this economic analysis. Examples of unquantified effects are:

- closure of M1, M10 and M25 motorways;
- loss of goods in local warehouses awaiting shipping (including Christmas goods that could not be sourced from elsewhere that Christmas);
- temporary loss of engineering and certification services affecting the services and manufacturing sectors;
- temporary outsourced payroll service disruptions;
- temporary loss of London congestion charging administration;
- temporary loss of outsourced medical records; and
- temporary loss of other public service records.

Uninsured losses

49 Insurance policies will cover many of the losses faced by residents and businesses. However, uninsured losses and insurance policy excess premiums may place an additional burden on individuals and small businesses. The extent of such losses has not been surveyed.

50 Based on the analysis presented in this annex, total economic costs of Buncefield are estimated to have been around £1 billion when rounded. This does not include a number of costs that have not been quantified, and does not account for some potential longer-term impacts. In some instances we have not been able to quantify costs. For comparison purposes, estimated costs of other UK and international incidents are provided in the next section. This shows that the magnitude of the Buncefield economic impact, though undoubtedly great, is not without precedent.

The scale of the incident compared to events elsewhere in the UK and abroad

51 The impacts of the Buncefield incident, as outlined previously, resulted in a total economic cost of around £1 billion. This cost is large even by comparison to some other large-scale major industrial incidents.

52 Looking at the historical evidence on the costs of major hazard accidents we can see that the overall cost of Buncefield is relatively high, yet this could have been greater still had the timing of the accident not been so fortunate. The costs of other such incidents are presented below and, although differing in their methods of estimation, provide a barometer as to the magnitude of the costs arising from the Buncefield incident.

53 The Board's third report[ref 8] referred to three other major hazard incidents: Toulouse in France (2001), Enschede in the Netherlands (2000) and Danvers in Massachusetts, USA (2006).

54 For comparison with the explosion at Buncefield the costs of the event at Tolouse appears to be of the greatest relevance. The incident that occurred at Toulouse in 2001 generated costs that are estimated to be of a similar magnitude to Buncefield.

However, there may be inconsistencies in the methodologies used between the estimates, or differences in contributing factors which can affect the scale of the economic impacts. Such factors may include population density within the immediate vicinity of the site or the types of developments around the site.

55 Where estimates can be found these have been converted to pound sterling values and expressed in current (2007/08) prices to allow easier comparison.

Toulouse, France (21 September 2001)

Description
56 At 10:15 am on 21 September 2001 a huge explosion occurred at the AZF (Azote de France) fertiliser factory, located about 3 km (2 miles) outside the city of Toulouse in France. The explosion shattered shop and car windows and tore doors from their hinges in the city centre. Over 500 houses became uninhabitable. At least 29 people were killed and thousands were injured.

57 Various hypotheses have been proposed but the exact cause of the explosion remains unexplained. What is known is that at the time of the explosion, some 200–300 tons of ammonium nitrate was stored in the warehouse. This material had been classed as unsaleable; it included off-spec product and it was contaminated with oil from handling equipment, bitumen from the original floor in the building, iron oxide and sulphur. Such conditions could have increased its susceptibility to explosive ignition.

58 A secondary blast at a nearby explosives factory was also reported, which was believed to have been caused by sparks created by the explosion at AZF.

Characteristics
59 The AZF plant was built in 1924. At this time the plant was located on a rural plot in the countryside surrounding the city of Toulouse. Growth saw Toulouse become France's fourth largest city and the associated urban sprawl led to the other developments being built within the immediate vicinity of the AZF plant. Homes were built near the plants huge chimney stacks and other industrial developments including two other chemical works, Tolochimie and SNPE (an explosives manufacturer), were also built next to the AZF plant. Toulouse currently has a population of around 1 million people.

60 French public research body INERIS carried out an assessment of the impact of the explosion at Toulouse finding that there were:

- 30 fatalities (21 on site with nine off site);
- 10 000 injured;
- 14 000 curing post-traumatic acute stress;
- 27 000 housings damaged;
- 1300 companies damaged;
- €1 500 to €2 000 million of damages;
- no major domino effects on site and neighbouring sites;
- emergency response: 1570 firemen and militaries, 950 policemen;
- 75 000 notifications to insurers.

61 The cost to the French government was €228 million and total economic cost of €1.3 billion. The total economic costs comprise costs for all affected groups, including costs to the French government, but also costs to businesses and individuals. Cost in pounds is approximately £1.1 billion in 2007/08 prices (based on the exchange rate at 19 November 2008).

Enschede, Netherlands (May 2000)

Description

62 A fire broke out within the SE Fireworks depot in the eastern Dutch city of Enschede on 13 May 2000. The fire caused a massive explosion, killing 22 people, including four firefighters and injuring over 900. Around 1500 homes were damaged or destroyed, and 1250 people were left homeless. The cost of the damage was estimated to be more than €500 million.

63 Emergency services from all around the area, including Germany, assisted at the scene. However, concern was raised that the preparedness for such a disaster was insufficient. In particular, Enschede fire and rescue service had insufficient information about the site, or the products stored by the company. This lack of information resulted in tactical difficulties.

64 The cause of the fire has never been officially determined. The Oosting Committee, charged with investigating the incident, noted that not only had the company stored more fireworks at the depot than they had permits for, but also that most of these fireworks were wrongly classified as presenting no significant hazard (1.4G) or fire hazard (1.3G) rather than as a mass explosion hazard (1.1G). The explosives storage permits allowed only 1.3G fireworks and the lower hazard, 1.4G fireworks.

65 The Committee's report also describes several storage issues which may have contributed to the origin and/or escalation of the fire.

66 However, the Committee was also critical of the role played by local and national government. The municipal administration was criticised for insufficiently inspecting the company and for not taking action against the company for a detected violation of the environmental permit in force. It was also criticised over planning issues and new development monitoring issues. The national government was blamed for failing to act on recommendations from an investigation following the 1991 explosion of a fireworks factory in Culemborg, which showed problems with the classification of fireworks.

Characteristics

67 The factory at Enschede was surrounded by industrial and residential properties, as is apparent from the sheer quantity of homes that were damaged or destroyed. Land use planning arrangements were in place; however, they have been described as 'faulty' in addition to the criticisms of containment/on-site measures.

Costs

68 The costs of the material damage resulting from the explosion at Enschede amounted to 1 billion guilders. This figure does not appear to include the costs of fatalities and injuries. Cost in pounds is approximately £450 million in 2007/08 prices.

69 Some key facts and figures:

- size of the disaster area: 40 ha;
- 4163 inhabitants in most affected zone;
- 293 completely destroyed houses;
- ±50 completely destroyed business and industrial buildings;
- 1500 damaged houses outside mostly affected zone;
- 22 people killed (four firefighters);
- 947 people injured;
- 250 homeless people;
- ±10 000 people had to be evacuated;
- total material damage: 1 billion guilders. (Cost in pounds in 2007/08 money = c. £450 000 000.)

Danvers, Massachusetts (22 November 2006)

Description
70 A massive chemical explosion occurred at a factory in Danvers, Massachusetts in the early morning of 22 November 2006. The factory, which produced solvent-based commercial printing inks, was destroyed and more than 100 homes and businesses up to one mile away were damaged, some beyond repair. As of early May 2007, over 50 families were still unable to return to their homes. No one was killed in the incident, but ten members of the local community were injured.

71 Investigators from the US Chemical Safety Board believe that the explosion was caused by 'the inadvertent overheating of solvents left stirring overnight in an unsealed mixing tank, releasing flammable vapour which accumulated and ignited'. Minor concerns were expressed regarding the environmental impact of the incident. It was noted that the water runoff from the water used by firefighters had left a purple sheen on the river. Tests carried out by the US Environmental Protection Agency following the incident showed low levels of the solvent toluene. This was not seen to be a significant risk, as the chemical evaporates quickly, and the water was not a local drinking water supply. Danvers' Fire Chief also stated that there was no risk of toxic fumes getting into the air.

72 It has not been possible to derive the economic costs of this incident.

Other incidents

73 HSE has previously commissioned the report *A review of high-cost chemical/petrochemical accidents since Flixborough 1974*.[ref 33] The review was carried out by consultants WS Atkins Safety and Reliablity and published in 1997. The following information has been taken from the Atkins review paper and updated to be presented in current prices.

74 The cost estimates below do not appear to include valuations of the human costs of fatalities and injuries. The data presented here has been presented in today's prices using the GDP deflator time series as presented by HM Treasury.

Table 7 UK accidents

Company	*Location*	*Date*	*Quoted cost at time of accident (£ million)*	*2007/08 values (£ million)*
Texaco/Gulf	Pembroke, Dyfed	24.07.1994	-	-
BP Oil	Grangemough, Edinburgh	22.03.1987	-	-
Laporte Chemicals	Warrington, Cheshire	15.09.1984	25	56.9
National Freight Consortium	Brightside Lane, Sheffield	14.12.1984	21.3	48.5
BASF	Wilton, Teeside	09.10.1995	20	27.2
J Kelman Transport	Braehead, Renfrew	04.01.1977	6	11.9
Amoco	Milford Haven, Pembrokeshire	30.08.1983	10	23.9
RA Lister	Dursley, Gloucestershire	27.07.1983	9	21.6
Morganite Ceramic Fibres	Bromborough, Merseyside	13.10.1984	5.8	13.2
Shell	Ellesmere Port, Cheshire	20.03.1990	8	13.8
Laporte Chemicals	Warrington, Cheshire	04.06.1985	5.5	11.9
BP Chemicals	Baglan Bay, Swansea	12.10.1990	7.1	11.4
CK Addison	Lough, Lincolnshire	26.11.1981	3.5	4.9
Associated Octel	Ellesmere Port, Cheshire	01.02.1994	-	-
BP Oil	Llandarcy, West Glamorgan	17.01.1981	3	8.8
Universal Freight	Woodkirk, Yorkshire	13.02.1982	3	8.1
Allied Colloids	Bradford, Yorkshire	21.07.1992	4.5	5.6
Unichema	Bromborough, Merseyside	18.01.1991	4	6.4
British Drug House	Poole, Dorset	21.06.1988	3	3.6
Hickson & Welch	Castleford, Yorkshire	21.09.1992	£1.5–3	2.2–4.4

Table 8 Overseas accidents

Location	*Date*	*Cost (US $ million 1996)*	*Includes business interruption losses?*	*Cost £ million 2007/08*
Pasadena, Texas	23/10/1989	1 456	Yes	1 231.3
La Mede, France	11/09/1992	458	Yes	387.3
Pampa, Texas	14/11/1987	396	Yes	334.9
Antwerp, Belgium	07/03/1989	356	Yes	301.1
Thessaloniki, Greece	24/02/1986	300	No[34]	253.7
Norco, Louisiana	05/05/1988	293	No[34]	247.8
Sweeny, Texas	04/13/1991	264	Yes	223.3
Romeoville, Illinois	23/07/1984	241	No[34]	203.8
Port Neal, Iowa	13/12/1984	182	Yes	153.9
Sodegaura, Japan	16/10/1992	172	No[34]	145.5
Seadrift, Texas	02/12/1991	172	Yes	145.5
Umm Said, Qatar	03/04/1977	156	No[34]	131.9
Shuaiba, Kuwait	20/08/1981	148	No[34]	125.2
Sterlington, Louisiana	05/01/1991	148	Yes	125.2

[34] The January 1997 issue of the Loss Control Newsletter reports on analysis of 119 events at petrochemical, chemical and refinery sites, concluding that business interruption losses were on average 2.7 times property damage losses. However, there were wide variations between individual cases.

The costs and benefits of the Board's recommendations (relating to design and operation of flammable storage sites)

75 Within this section we attempt to quantify (where possible) the costs of some of the Board's recommendations on the technical aspects of primary containment controls as outlined in our report on design and operation of fuel storage sites.(ref 13)

76 There will be different approaches to upgrading primary containment measures on different sites in Britain. Some site operators may find that work required to bring their sites up to standard may be done most cost effectively in conjunction with other site upgrades. Others may hold spare capacity on site (such as cabling etc) which in turn will reduce the size of initial financial outlays but will still create costs in the form of reduced capacity and a greater need for investment if the structure of the site is to be changed in the future. Costs may be higher for those operators who wish to go beyond the recommended minimum level of primary containment. However, the costs of our recommendations are solely the costs of upgrading sites to the required basic level of safety integrity.

77 This section focuses predominantly on Recommendations 3 and 6 of our fifth report making recommendations for the design and operation of fuel storage sites:

> Recommendation 3
>
> Operators of Buncefield-type sites should protect against loss of containment of petrol and other highly flammable liquids by fitting a high integrity, automatic operating overfill prevention system (or a number of such systems, as appropriate) that is physically and electrically separate and independent from the tank gauging system.
>
> Such systems should meet the requirements of Part 1 of BS EN 61511 for the required safety integrity level, as determined by the agreed methodology (see Recommendation 1). Where independent automatic overfill prevention systems are already provided, their efficacy and reliability should be reappraised in line with the principles of Part 1 of BS EN 61511 and for the required safety integrity level, as determined by the agreed methodology (see Recommendation 1).
>
> Recommendation 6
>
> The sector should put in place arrangements to ensure the receiving site (as opposed to the transmitting location) has ultimate control of tank filling. The receiving site should be able to safely terminate or divert a transfer (to prevent loss of containment or other dangerous conditions) without depending on the actions of a remote third party, or on the availability of communications to a remote location. These arrangements will need to consider upstream implications for the pipeline network, other facilities on the system and refineries.

78 Due to wide variations between sites and site operators we used three different scenarios for the measures taken by site operators. These are merely illustrative for the lay reader of the range of engineering approaches to implement our recommendations. Based upon these three scenarios we developed a broad range of costs for a 'typical site' of equal-sized large fuel storage tanks.

79 The estimates of costs in this section account for both material and non-material (labour) costs of implementing Recommendations 3 and 6.

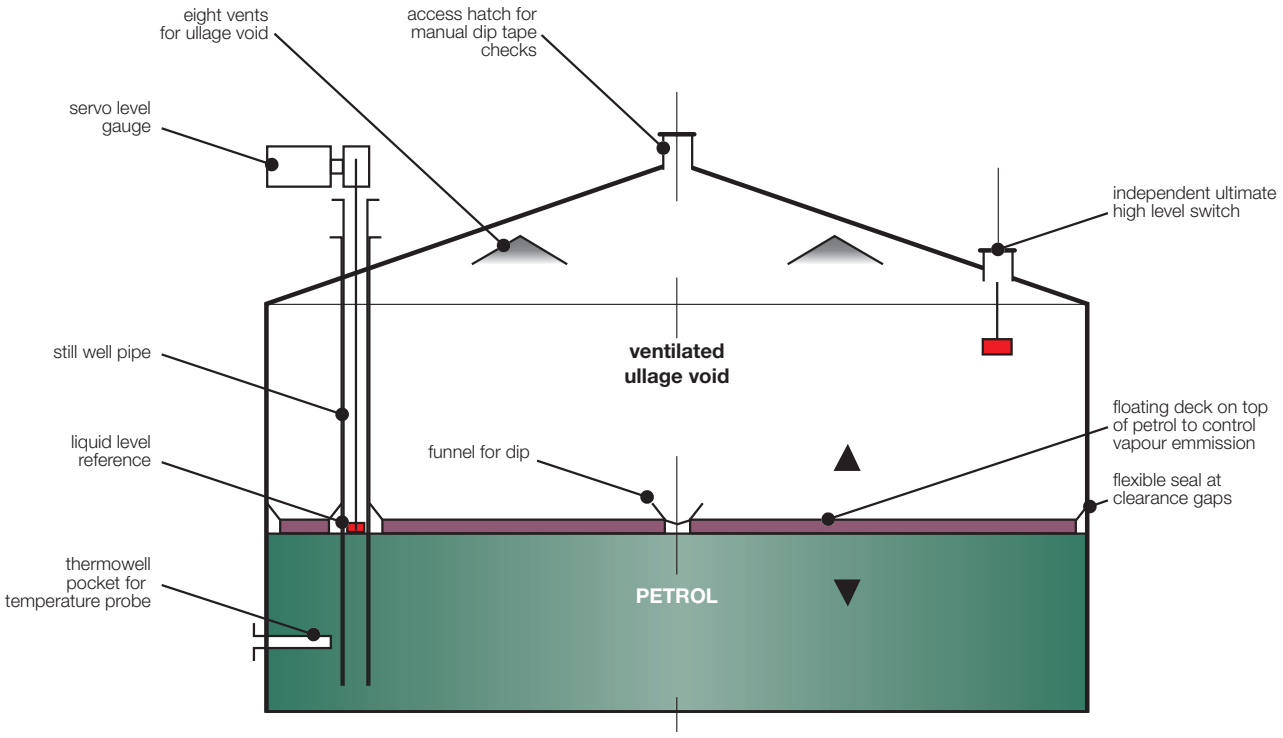


Figure 25 General schematic of a typical internal floating roof tank

80 The analysis has been developed through liaison with industry in the UK and USA, and requires a number of assumptions to be made. The methodology was to compute the range of costs to site operators, based on a 'typical site' with ten tanks, which are then grossed up to an assumed 500 tanks in scope nationally. The analysis uses three illustrative engineering solutions for implementing the recommendations and derives cost estimates in each case.

81 The illustrative scenarios are:

Scenario 1 A single off-site automatic shut-off valve on the inlet pipe to the site, preventing the feeding of fuel to all tanks on site.

Scenario 2 An automatic shut-off valve on the inlet pipe to each tank, preventing the feeding of fuel to individual tanks and between tanks, and allowing tanks to be isolated in the event of a fire.

Scenario 3 Dual automatic shut-off valves at each tank, one on the inlet, one on the outlet. This isolates individual tanks and prevents transfer between tanks, even in the event of a valve failing.

82 To arrive at the cost estimates below we took detailed figures provided by industry sources (oil companies and contractors) on the costs of implementing the three scenarios. Such detailed analysis is not presented in this annex. The costs in Table 9 are just the key component costs. These were added together in each case to arrive at the cost for our 'typical site' of ten tanks and grossed up to represent national costs before being discounted. We used a range of +/-30% to calculate low, medium and high estimates for each scenario. It is possible that the range of real costs may vary to a greater extent than this due to site-specific and project-specific factors that are not considered in this illustrative analysis.

Table 9 Scenario 1

1 valve per site

	Estimate		
	Low	*Medium*	*High*
total cost per tank £	32 000	46 000	60 000
total cost for all tanks in scope £	16 000 000	23 000 000	30 000 000

Table 10 Scenario 2

1 valve per tank

	Estimate		
	Low	*Medium*	*High*
total cost per tank £	115 000	165 000	214 000
total cost for all tanks in scope £	58 000 000	82 000 000	107 000 000

Table 11 Scenario 3

2 valves per tank

	Estimate		
	Low	*Medium*	*High*
total cost per tank £	234 000	335 000	435 000
total cost for all tanks in scope £	117 000 000	167 000 000	218 000 000

83 The main variables resulting in different costing between the three scenarios are the labour costs, the number of remotely operated shut-off valves required and associated equipment such as switch and power supply.

84 Under Scenario 1 material costs (spending on mechanical aspects of the installation such as valves, alarms, switches etc) amount to £39 000 per tank and non-material costs (labour, freight, design etc) amount to £7000 per tank. Adding these costs together (39 000 + 7000) we arrive at a total cost per tank of £46 000. Scaling this cost up by an assumed 500 tanks in scope we arrive at our mid-range estimate of £23 million (46 000 x 500).

85 Under Scenario 2 material costs amount to £90 000 per tank and non-material costs amount to £74 000 per tank. Adding these costs together (90 000 + 74 000) we arrive at a total cost per tank of £165 000. Scaling this cost up by an assumed 500 tanks in scope we arrive at our mid-range estimate of £82 million (165 000 x 500).

86 Under Scenario 3 material costs amount to £186 000 per tank and non-material costs amount to £149 000 per tank. Adding these costs together (186 000 + 149 000) we arrive at a total cost per tank of £335 000. Scaling this cost up by an assumed 500 tanks in scope we arrive at our mid-range estimate of £167 million (335 000 x 500).

Benefits of the Board's recommendations

87 We have used the information in the Competent Authority's regulatory impact assessments (RIA's) in its consultation documents on land use planning,[ref 34] containment policy[ref 35] and societal risk[ref 36] as the basis for our benefits estimates.

88 We have used the formula:

Valuation of risk reduction benefits = $(NV+E)R_1 - (NV+E)R_2$

Where: N = number of people exposed to risk
V = value per fatality
E = economic impact/cost
R = level of risk

89 The benefit of reducing risk of a major incident is the fall in external costs associated with moving from one risk level to another (fatalities averted). The bracketed term (NV+E) provides the valuation of life and property around a hypothetical site. R represents the level of risk faced. If the current level of risk (R_1) falls due to changes made on site, then we subtract the valuation of risk under the new level of risk R_2 from the current level of risk R_1 to find the valuation of risk reduction (the difference between the costs before, compared with the costs after, new measures are introduced).

90 The above equation assumes that everything remains constant apart from the level of risk, which changes in proportion to the reliability of the containment measures on site.

91 By substituting variables in the equation we get a crude estimate of the benefits of the Board's recommendations when applied at a hypothetical ten-tank site. Benefits, like the costs, are site-specific in nature but a site-by-site analysis is not feasible. In this analysis we focus upon the improved safety integrity that may occur on site as a result of the Board's recommendations to prevent tank overfilling.

92 Incidents such as that at Buncefield are infrequent and for this reason there is little historical data available to calculate failure frequencies. The lack of data combined with the variable nature of the risk (due to different on-site characteristics, off-site population densities, instrumentation etc) mean that the benefit estimates presented in this annex should be treated with caution. For the purposes of analysing benefits to a typical site we use a simple sensitivity analysis based on changes in risk levels which could possibly occur.

93 To carry out this exercise we have made the following assumptions:

- benefits will be indefinite but are appraised over a period of 50 years (the assumed life of a tank);
- our recommendations will be introduced quickly in line with the recent industry and Government statements to that effect;
- the discount rate for economic benefits is 3.5% for the first 30 years and declines thereafter in accordance with HM Treasury appraisal guidelines;
- the discount rate for health (ie safety) benefits is 1.5%;
- an incident would lead to an economic cost of £1 billion and a human cost of £40 million; and

- the current risk of an incident per site is 1 in 10 000 years

94 For the purposes of analysis we adopt a reasonable but hypothetical base case frequency per site of 1 event in 10 000 years at the time of the Buncefield incident.

95 We also make assumptions for a lowering of major incident risk from implementing the Board's recommendations:

- Benefit Scenario 1: level of frequency of a Buncefield-like event reduced from 1 in 10 000 years to 1 in 100 000 years;

- Benefit Scenario 2: level of frequency reduced to 1 in 1 000 000 years.

(Note: The above risk levels are calculated on an individual risk basis, ie do not take into account populations at risk because of the hypothetical nature of our 'typical site'.)

96 We have used the estimated total costs of the Buncefield incident (roughly £1 billion) as an indicator of future benefits if risk is reduced. This presents an estimate of benefits if the worst-case scenario (a vapour cloud explosion of similar magnitude to that of Buncefield) were to be avoided. This assumes that such an event would occur in an area surrounding a site such as Buncefield with similar population and industrial characteristics in the surrounding area.

97 We further assume (as in the Competent Authority's regulatory impact assessments for land use planning) that the number of people killed by a 'typical' incident will be 15 (this is the number of people killed by the incident at Texas City in March 2005). We also assume that for each fatality there will be seven major injuries (roughly equivalent to an additional 15 fatalities). We then multiply this by HSE's appraisal value of £1.5 million per fatality to provide an estimate of human costs of £45 million approximately (1.5 x 30). We have made these assumptions to account for the fact that the small human costs associated with the Buncefield incident are unlikely to occur in any future incident on the scale of Buncefield.

98 In our calculation we separate economic and human benefits to allow for more accurate discounting:

- To calculate the current annual expected economic cost of the risk posed by the hypothetical site we divide the assumed cost of an incident by the associated level of risk (if the level of risk is 1 in 10 000 years then the annual expected economic cost is £100 000 (1 billion/10 000)).

- To calculate the annual expected economic cost at the future level of risk (Benefit Scenario 1) we multiply by the estimated future level of risk (if 1 in 100 000 years after safety improvements. The annual cost falls to £10 000 (1 billion/100 000)).

- The difference between current and future economic costs is then calculated to provide the value of economic costs averted:
  - [(£1 billion/10 000 = 100 000) – (£1 billion/100 000 = 10 000)] = £90 000 per year.

- We discount over a period of 50 years at an initial rate of 3.5% (this declines over time in line with HM Treasury guidance) giving an average annual present value of £63 000. This is equivalent to £3.2 million over the 50-year appraisal period.

- The difference between current and future human costs is calculated in similar fashion to provide the value of human costs averted:
  - [(40 million/10 000 = 4000) – (40 million/100 000 = 400)] = £3600 per year.

- We discount over a period of 50 years at a rate of 1.5%, resulting in an average annual present value of £1700. This is equivalent to £85 000 over the 50-year appraisal period.

- Adding economic and human benefits together we estimate a total benefit from safety improvements on an average annual present value (PV) basis of £65 000 for the hypothetical site.

- This is equivalent to £3.2 million over the 50-year appraisal period in present value terms.

- Assuming there to be 50 ten-tank sites the total benefit from our recommendations would be in the region of £162 million on a present value basis.

(This cost is comprised of human costs totalling £4.2 million for all 50 sites over the appraisal period and economic costs/impacts totalling £156 million, again discounted over the 50-year period for all sites in scope.)

99 The figures below shows the sensitivity of the hypothetical example to the assumptions we make by comparing estimated benefits under alternative assumptions about the level of risk posed by the example site assuming all sites are identical to the hypothetical example:

Change in the level of risk net present value of benefits:

Base case risk 1 in 10 000 years
Benefit Scenario 1 level of risk 1 in 100 000 years
Benefit Scenario 2 level of risk 1 in 1 000 000 years

From base case to Benefit Scenario 1: benefit = £162 million
From base case to Benefit Scenario 2: benefit = £178 million

100 In Table 12 we adjust the above estimates to show how benefit valuations are likely to fall if the total potential costs of the incident were not so high.

Table 12 Sensitivity of total benefits to the overall economic impact of the Buncefield incident (excluding human costs)

% change in total costs of incident	*change in risk level*	
	base case to Benefit Scenario 1	*base case to Benefit Scenario 2*
50%	£83 million	£91 million
25%	£44 million	£48 million
10%	£20 million	£22 million

Annex 4

Open flammable cloud explosions

1 The violent explosion at Buncefield was deemed to be unprecedented at the time, although a review of the literature revealed that this was not strictly correct. The event comes under the classification of an 'open flammable cloud explosion' (OFCE), a topic that attracted much debate in the 1970s and 80s after a series of major events which involved the release and subsequent ignition of large quantities of hydrocarbon vapour – such as propane.

2 At that time, they were referred to as 'unconfined vapour cloud explosions' to distinguish them from 'confined explosions' in which a flammable gas/air mixture is ignited in an enclosed space such as a building or an empty storage vessel. The heat released during the burning of the flammable mixture causes the gases contained within the structure to expand, leading to a rise in pressure above ambient atmospheric pressure. This will lead to the failure of the boundary of the enclosure at its weakest point. For example, ignition of flammable vapour/mixture in an empty storage tank will cause the roof to blow off thereby acting as a vent, relieving the pressure and protecting the rest of the structure.

3 This is what is thought to have happened in the case of Tank 910 in bund A on the HOSL site. This tank was immediately adjacent to Tank 912 from which the initial escape of fuel occurred and had stood empty, with an open inspection hatch close to ground level, pending completion of maintenance work. The percussive noise associated with such an event is created by the sudden failure of the enclosing structure which generates a shock wave.[35] Generating a shock wave by the ignition of a mixture that is 'unconfined' (ie there is no (or little) resistance to the expansion of the gases as the combustion process develops) cannot be explained in the same way. No 'overpressure' would be expected if free expansion was possible.

4 Nevertheless, in the case of an 'unconfined' flammable cloud, an overpressure can be generated, despite the fact that it appears that the hot gases are essentially free to expand. However, this does not take into account the rate at which the burning process is taking place. For flammable vapour/air mixtures,[36] the rate of burning is defined by the velocity with which the flame propagates through the unburnt mixture. If the gases are completely quiescent, the propagation velocity (with respect to the unburnt mixture) is of the order of 0.5 m/s. However, the rate of propagation of the flame is very sensitive to any turbulence in the mixture into which the flame is propagating. Turbulence will be generated as a flammable cloud burns if there are obstacles such as pipework, within the cloud itself. Because the gases behind the flame front expand, the unburnt mixture will be pushed past the obstacles, generating turbulence that will cause the flame to accelerate. This creates a feedback loop in which flame acceleration and turbulent intensity are coupled and can lead to very high rates of burning. The rate of flame propagation can

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35 The same effect is created by bursting an inflated paper bag, or over-inflating a balloon.

36 It should be noted that mixtures of a flammable gas (or vapour) and air will only burn (propagate flame) if the mixture lies within well-defined 'flammability limits'. For example, the lower and upper limits for n-butane are 1.8% and 8.4% (by volume) respectively. 'Ignition' can only occur if the ignition source is located where the mixture is within these limits.

become so high that the processes involved in expansion are overwhelmed and the gas ahead of the flame front is compressed, ultimately creating a shock wave, the strength of which will depend on the flame speeds that have been achieved. If there are very few obstructions within such a cloud, there will be no shock wave, but the combustion process might be heard as a 'whoosh'. At the other extreme, if there were extensive obstacles in the cloud a much more percussive sound would be heard, similar to the noise produced by a charge of high explosive.

5 The term 'unconfined vapour cloud explosions' is very rarely used now – the word 'unconfined' has been dropped in favour of 'open' to emphasise that for most (if not all) of the incidents there was some degree of confinement provided by obstacles which prevented the unhindered movement of the flammable cloud ahead of the flame as the combustion process developed.

6 Although there had been many earlier incidents in the USA and Europe, it appears that the Flixborough disaster of July 1974 was the first of its kind in the UK. This involved the catastrophic release of superheated cyclohexane from a series of chemical reactors.[37] A large cloud of cyclohexane vapour and liquid droplets was formed in the atmosphere. After a short delay, ignition occurred. The resulting explosion completely destroyed the plant and buildings within the site boundary and houses in the village of Flixborough c 800 m away were seriously damaged. The violence of the explosion was subsequently attributed to the obstructions afforded by the items of plant (pipework, reactor vessels etc). Other examples could be given, but in general OFCEs have two principal characteristics:

- release of a large quantity of material capable of forming a flammable 'cloud'; and

- a delay (of undefined duration) before ignition.

7 These are almost self-evident: if ignition occurs immediately, with no delay, there will be a fire at the point of release and any overpressure is likely to be small.[38] Moreover, there must be mixing of vapour and air to produce a significant volume of the cloud within the flammability limits. Rapid flame propagation will only occur through those regions of the cloud that are flammable. Attempts have been made to estimate the minimum amount of fuel that would have to be released for an OFCE to occur, but this is likely to be only of academic interest. It may prove that the actual quantity released is less important than the amount of fuel vapour within the cloud that lies within the flammability limits. The question of whether or not such an explosion 'in the open' (albeit with obstructions) could lead to detonation has also been considered in detail, but the general view is that very unusual circumstances would be required. There appears to be only one incident reported (Port Hudson) in which the investigation team came to the conclusion that detonation 'in the open' had occurred. This is discussed briefly in paragraph 9.

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37 The process involved the oxidation of liquid cyclohexane (normal boiling point 81 °C) at 150 °C and 8 bar pressure in a series of reaction vessels. Catastrophic failure of a temporary pipe released c 40 tonnes of cyclohexane, a large proportion of which vaporised, creating a large vapour cloud which ignited shortly afterwards.

38 A shock wave would be produced if the release is the result of the catastrophic failure of a pressure vessel. This type of event is known as a 'BLEVE' – a 'boiling liquid expanding vapour explosion'.

8 The vast majority of OFCEs have involved substantial releases of highly volatile fluids, either from a process train (eg Flixborough 1974), or from a pipeline or storage vessel. The incident at Lake Charles, Louisiana (August 1967) is a good illustration of the latter. A gate valve to an isobutane tank was accidentally opened, releasing approximately 10 te of isobutane (normal boiling point -7 °C). Ignition occurred after 15 minutes, creating a devastating explosion.

9 Two incidents involving fractured pipelines may be given:

- at Port Hudson, Missouri 1970, a fractured pipeline carrying LPG released approximately 57 tonnes of propane (720 bbl[39]) in 25 minutes. The vapour accumulated in a valley, finding an ignition source in a nearby reinforced concrete structure which was totally destroyed in the blast. Observers reported that they saw the entire cloud light up instantaneously – no one saw flame propagating through any part of the cloud. It is thought that this was a detonation, following a massive 'bang-box' ignition; and

- an explosion occurred near Ufa in the Soviet Union in June 1989, following the rupture of a liquefied petroleum gas (LPG) pipeline. The leak developed over a significant period of time (possibly days) and was recognised as a drop in pressure at the pumping station. The operators compensated by increasing the flowrate. The vapour cloud formed in the surrounding forest and it is believed that ignition occurred when two trains on the Trans-Siberian railway travelling in opposite directions passed each other within the cloud.

10 These are typical of the OFCE, involving the release of highly volatile or 'flashing' liquids where a large proportion of the liquid that has been released is converted to vapour.

Formation of vapour clouds

11 The key features that need to be considered when evaluating the potential for formation of a large vapour cloud which might lead to an explosive event are the mechanisms by which the vapour is formed (or released) and the mode and location of ignition. Regarding the formation of a vapour cloud, the examples given above relate to (a) the release of gas/vapour under pressure; and (b) the rapid conversion of a superheated flammable liquid to vapour (eg release of LPG from a pipeline or pressure vessel). The formation of vapour from a pool of a 'stable' flammable liquid such as petrol is very much slower, and not normally considered a significant source of a vapour cloud.

Ignition and burning of vapour clouds

12 The ignition source must be in part of the cloud that is flammable. Flame will then propagate through that part of the cloud that lies within the flammability limits, and then the remaining fuel from the rich part of the cloud will burn as the vapour mixes with air (burning as a 'diffusion flame').

13 Consider the extremes for vapour cloud formation:

- **Extreme 1**: Minimum mixing, then the volume of the 'flammable' part of the cloud will be small, effectively an envelope around the core of fuel-rich mixture. Such a 'cloud' would be formed by evaporation from a pool of a

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[39] 1 barrel = 42 US galls = 158.99 litres; 720 bbls = c 114.5 m^3.

highly flammable liquid which is stable at ambient temperature and pressure (eg petrol, acetone, alcohol etc). Ignition will be followed immediately by a premixed flame propagating through the flammable mixture at a rate that will be influenced by turbulence generation, followed by the relatively slow burning of the rich part of the cloud (a turbulent diffusion flame).

- **Extreme 2:** Complete mixing of vapour with air, giving a very large volume of flammable mixture. This would be associated with a high-pressure release of flammable gas, either from a broken pipe or a pressure burst of a vessel containing a 'flashing liquid', in which air is entrained into the gaseous fuel as it is released. Ignition will be followed immediately by flame propagating through a large volume of flammable mixture. The rate of burning will be influenced by the degree of turbulence generated in the unburnt flammable mixture ahead of the propagating flame.

14 Significant overpressures will be generated if the rate of flame propagation exceeds 100–150 m/s. A turbulent flame may accelerate to speeds greater than 400 m/s, capable of generating over-pressures well in excess of 1 bar, depending on the extent and structure of the obstacle field within the cloud. The generally held view at the time of Buncefield was that evaporation from a spillage of petrol would not be rapid enough to generate a cloud of sufficient size to exhibit this behaviour.

15 In broad terms, before Buncefield, the worst design event[40] associated with a tank farm was thought to be a large pool fire following the failure of a tank. The rationale behind ignoring the possibility of an open flammable cloud explosion is that petrol is a 'stable liquid' at ambient temperatures and pressures, albeit one that is classified as a 'highly flammable liquid' that can easily be ignited under ambient conditions. As discussed above, open flammable cloud explosions tend to be associated with 'unstable liquids' which vaporise rapidly when released to the atmosphere, the most common example being LPG which has a boiling point of -42°C and must be stored in pressure vessels at normal atmospheric temperatures.[41] If the pressure is suddenly released the liquid is no longer stable and will boil vigorously (throughout its volume), converting a significant proportion of vapour which will form a vapour cloud. The liquid that remains will be chilled to below its boiling point (for pure propane, this is -42°C), some of which will be dispersed with the vapour as airborne droplets, any remainder forming a pool of cold liquid on the ground where it will boil rapidly until the ground is chilled to the boiling point of the liquid.

16 Petrol can be stored as a liquid at normal atmospheric temperatures and pressures. If the liquid is spilt or otherwise released (eg catastrophic tank failure) it will form a pool of stable liquid on the ground. Its rate of evaporation will be relatively slow if compared with the rate of evaporation of chilled LPG, but it is not insignificant during the early stages as the more volatile components of the petrol (mainly n-butane) evaporate preferentially, coming out of solution. These are present in all petrol blends in quantities required to achieve the desired volatility which determines the efficiency of the fuel in the internal combustion engine. So there tends to be a higher proportion of the more volatile components in winter grades of petrol than in the summer grades. However, even with 10% butane, a winter grade of petrol is very unlikely to give rise to a large cloud of

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[40] A design event is one which is used as the basis of design for protective systems either in terms of engineered systems or emergency response arrangements or both.

[41] For example, at 25 °C liquid propane has a vapour pressure of 9.6 bar. It must be stored in a pressure vessel capable of withstanding much higher pressures to take into account natural atmospheric temperatures variations.

vapour, simply because the rate of generation is low and any air movement (wind) would aid its dispersal and dilute the cloud to below the lower flammability limits within a 'relatively' short distance. The rate of evaporation (ie the rate of formation of vapour) will depend on a number of factors, including the temperature of the petrol, but the free surface area of the liquid pool will be a major – indeed a limiting – factor. It was tacitly considered that the rate of evaporation of petrol which was leaking or spilling from a tank into a bund would ultimately be controlled by the free surface area of the pool of liquid petrol contained within the bund. At Buncefield, it seems likely that much higher rates of evaporation were achieved as a result of the manner in which the liquid was discharged from the tank.

Annex 5

Environmental update, Environment Agency November 2008

1 The contamination pattern under and around Buncefield has reduced since the original incident. However, ongoing monitoring is still detecting levels of fuel and fire water related products that would not normally be in the water environment.

2 By November 2008, only one borehole near Cherry Tree Lane still contained neat fuel/oil products that may be attributed to the Buncefield incident. The groundwater under the fuel layer in this borehole was contaminated with fuel and fire water related compounds (BTEX and PFOS). Other boreholes on site indicated contamination by PFOS, MTBE and/or BTEX (these acronyms are explained below). Contaminants appeared to be migrating in an east-south-east direction.

3 Contamination levels in perimeter and near off-site boreholes had stabilised, ie some contamination was still detected in perimeter boreholes. Migration of contamination in the direction of the Bow Bridge boreholes shows decreasing concentration of PFOS and BTEX. Contamination was, however, still being detected at very low levels all the way to Bow Bridge pumping station, near the River Ver.

4 By November 2008 the Environment Agency had taken and analysed over 1500 samples and validated the programme through duplicate sampling and analysis. The majority of the sampling was carried out with in-house trained staff. The oil companies continued to carry out their own monitoring and to install new boreholes to understand the extent of the contamination. The Environment Agency is satisfied that its own sampling and that of the oil companies are producing consistent results.

5 The Environment Agency aims to continue to work with the oil companies to ensure that the clean-up of the contaminated soils and groundwater is effective. All surface water from the Buncefield depot is collected at the on-site effluent treatment area and is treated to remove oils and PFOS before being tested and discharged.

Perfluorooctane sulphonate

6 Perfluorooctane sulphonates are a group of chemicals, collectively identified as PFOS, which have been shown to be hazardous (persistent, bioaccumulative and toxic). PFOS chemicals have been used in a diverse range of applications, including as an additive to aid the spreading properties of firefighting foam. Data obtained from those working in industries manufacturing perfluorochemicals have indicated that exposure to PFOS can have adverse impacts on liver function. PFOS does not appear to degrade in the natural environment. Due to this stability, it has now become widespread both in man and in the environment.

7 PFOS was not routinely monitored and analysed in surface water or groundwater prior to the Buncefield incident. Sampling and analysis for PFOS are not straightforward and until very recently there has been no recognised recommended limit for PFOS levels in drinking water against which to assess any results.

8 PFOS was present in some of the foam used to combat the Buncefield fire. At the start of the Buncefield incident, PFOS in the fire waters was recognised as an

important potential contaminant for land, surface water and groundwater. The Environment Agency and others have sampled groundwater and surface water extensively for PFOS and other contaminants both on and off site from soon after the explosion.

9 The Drinking Water Inspectorate (DWI) measures the level of contaminants in drinking water (as opposed to in groundwater and rivers) and regulates the quality of drinking water supplied to the public. This is not a function of the Environment Agency.

BTEX

10 BTEX is an acronym for benzene, toluene, ethyl benzene and xylenes – a group of volatile aromatic hydrocarbons. They are the primary toxins of soils and groundwater associated with petroleum products, being found in petroleum derivatives such as petrol (gasoline). Toluene, ethyl benzene, and xylenes have harmful effects on the central nervous system.

11 Contamination of soil and groundwater by BTEX compounds typically occurs near petroleum and natural gas production sites, and petrol stations and other areas with underground storage tanks or above-ground storage tanks containing petrol or other petroleum-related products.

12 The amount of 'Total BTEX', the sum of the concentrations of each of the constituents of BTEX, is sometimes used to aid in assessing the relative risk or seriousness at contaminated locations and the need of remediation of such sites.

MTBE

13 MTBE (methyl tertiary-butyl ether) is a chemical compound that is manufactured by the chemical reaction of methanol and isobutylene. It is a member of a group of chemicals commonly known as fuel oxygenates. Oxygenates are added to fuel, predominantly petrol, to increase its oxygen content. MTBE is used in petrol to reduce carbon monoxide and ozone levels caused by vehicle emissions and to replace lead tetraethyl as an octane enhancer, ie to help prevent the engine from 'knocking'.

14 MTBE is a volatile, flammable and colourless liquid that is immiscible but reasonably soluble in water. As such it can migrate rapidly in surface and ground waters. MTBE has an unpleasant odour and taste in water.

References

1 *The public health impact of the Buncefield oil depot fire* HPA 2006

2 *Occupational Health Surveillance after the Buncefield Oil Depot fire, England, December 2005. Final Report: March 2007* Eastern Region Public Health Observatory 9 July 2007 www.erpho.org.uk

3 *Initial review of Air Quality aspects of the Buncefield Oil Depot Explosion* May 2006 Defra
www.defra.gov.uk/environment/airquality/buncefield/buncefieldreport.pdf

4 *Initial Report to the Health and Safety Commission and the Environment Agency of the investigation into the explosions and fires at the Buncefield oil storage and transfer depot* Fourth report Buncefield Major Incident Investigation Board 13 July 2006 www.buncefieldinvestigation.gov.uk

5 *Explosion Mechanism Advisory Group report* Seventh report Buncefield Major Incident Investigation Board 16 August 2007 www.buncefieldinvestigation.gov.uk

6 *The Buncefield Investigation: Progress report* First report Buncefield Major Incident Investigation Board 21 February 2006
www.buncefieldinvestigation.gov.uk

7 *The Buncefield Investigation: Second progress report* Second report Buncefield Major Incident Investigation Board 11 April 2006
www.buncefieldinvestigation.gov.uk

8 *The Buncefield Investigation: Third progress report* Third report Buncefield Major Incident Investigation Board 9 May 2006
www.buncefieldinvestigation.gov.uk

9 *COMAH Competent Authority: Initial report on the findings of the oil/fuel depot safety alert review* HSE, Environment Agency, SEPA 13 June 2006
www.hse.gov.uk/comah/buncefield/reviewjune06.pdf

10 *Safety Alert to operators of 'COMAH' oil/fuel storage sites and others storing hazardous substances in large tanks* HSE 4 July 2006
www.hse.gov.uk/comah/alerts/sa0106.htm.

11 *Initial report – recommendations requiring immediate action* Buncefield Standards Task Group 2006 www.hse.gov.uk/comah/buncefield/bstg1.htm

12 *Proposals for revised policies for HSE advice on development control around large-scale petrol storage depots and land use planning Objectives and Principles: Responses to an HSC/E Consultation Document* HSE 4 December 2007
www.hse.gov.uk/consult/condocs/cd211response.pdf

13 *Recommendations on the design and operation of fuel storage sites* Fifth report Buncefield Major Incident Investigation Board March 2007
www.buncefieldinvestigation.gov.uk

14 *COMAH Competent Authority: Report on the findings of the oil/fuel depot and environmental reviews* HSE, Environment Agency, SEPA 29 March 2007
www.environment-agency.gov.uk/commondata/acrobat/comahsafety__1769905.pdf

15 *COMAH Competent Authority Policy on Containment of Bulk Hazardous Liquids at COMAH Establishments Control of Major Accident Hazard Regulations 1999* Consultation Document Environment Agency, SEPA, HSE 2007

16 *Recommendations on the emergency preparedness for, response to and recovery from incidents* Sixth report Buncefield Major Incident Investigation Board 17 July 2006 www.buncefieldinvestigation.gov.uk

17 *Safety and environmental standards for fuel storage sites Buncefield Standards Task Group* (BSTG) Final report BSTG 24 July 2007 www.hse.gov.uk/comah/buncefield/bstgfinalreport.pdf

18 *Report on progress against the Buncefield Standards Task Group initial recommendations* HSE, Environment Agency, SEPA February 2008 www.hse.gov.uk/comah/alerts/buncefieldprogress.htm

19 *Recommendations on land use planning and the control of societal risk around major hazard sites* Eighth report Buncefield Major Incident Investigation Board 15 July 2008 www.buncefieldinvestigation.gov.uk

20 *The Buncefield Investigation: The Government and Competent Authority's Response* Cm 7491 The Stationery Office November 2008 ISBN 978 0 10 174912 1 www.dwp.gov.uk/publications/dwp/2008/buncefield.pdf

21 *The Buncefield Oil Depot Incident: Economic and Business Confidence Impact Study: Final Report* SQW 2006 www.dacorum.gov.uk/pdf/Buncefield%20Economic%20Impact%20reportfinal.pdf

22 *Risk criteria for land use planning in the vicinity of major industrial hazards* HSE Books 1989 ISBN 978 0 11 885491 7

23 *Developing process safety indicators: A step-by-step guide for chemical and major hazard industries* HSG254 HSE Books 2006 ISBN 978 0 7176 6180 0

24 BS EN 61511: 2004 *Functional safety. Safety instrumented systems for the process industry sector* British Standards Institution

25 *Buncefield Multi-agency Debrief Report and Recommendations* Hertfordshire Resilience Forum March 2007

26 *Buncefield: Hertfordshire Fire and Rescue Service's review of the fire response* Hertfordshire Fire & Rescue Service 2006 ISBN 978 0 11 703716 8

27 *Civil Contingencies Act 2004: Part 1 Emergency Preparedness* Chapter 7 'Communicating with the public' Cabinet Office 2004

28 *The Lead Government Department and its Role: Guidance and Best Practice* Civil Contingencies Secretariat 2004

29 Niall Ramsden report, issues identified for further consideration post-Buncefield (excluding those specifically addressed in 'review of Buncefield TOR 5 lessons learnt – phase 1 issue mapping'), P748 Other Issues, October 2006 not printed

30 *The economics of land use planning* HSE 2008 www.hse.gov.uk/economics/research.htm

31 *Buncefield social impact assessment: Final report January 2007* www.dacorum.gov.uk/PDF/Buncefield%20Social%20Impact%20Assessment_Final%20report.pdf

32 *Housing Market Background Paper* Dacorum Borough Council 2006 www.dacorum.gov.uk/PDF/Housing_Market_Study2006.pdf

33 *A review of high-cost chemical/petrochemical accidents since Flixborough 1974* WS Atkins Safety and Reliability 1997 www.hse.gov.uk/comah/lossprev.pdf

34 *Proposals for revised policies for HSE advice on development control around large-scale petrol storage sites* Consultation Document CD211 HSE 2007 www.hse.gov.uk/consult/condocs/cd211.htm

35 *Containment of bulk hazardous liquids at COMAH establishments: COMAH Competent Authority Policy on Containment of Bulk Hazardous Liquids at COMAH Establishments Consultation* Draft HSE, Environment Agency and SEPA 2007 www.environment-agency.gov.uk/yourenv/consultations/1696211

36 *Proposals for revised policies to address societal risk around onshore non-nuclear major hazard installations* Consultation Document CD212 HSE 2007 www.hse.gov.uk/consult/condocs/cd212.htm

Further reading

MacDonald DN, Murdoch JC and White HL 'Uncertain Hazards, Insurance, and Consumer Choice: Evidence from Housing Markets' *Land Economics* 1987 63 (4) 361–371

Clark DE and Allison T 'Spent nuclear fuel and residential property values: the influence of proximity, visual cues and public information' Papers in *Regional Science* 1999 78 (4) 403–421

McCluskey JJ and Rausser GC 'Estimation of Perceived Risk and Its Effect on Property Values' *Land Economics* 2001 77 (1) 42–55

Glossary

BAA British Airports Authority. BAA plc operates airports, including London Heathrow.

bioaccumulative literally, to accumulate in a biological system. It is commonly taken to measure the uptake over time of toxic substances that can stay in a biological system.

borehole a cylindrical shaft drilled into the ground, often for geological exploration or extraction of resources.

Buncefield Standards Task Group the joint Competent Authority/industry standards working group set up to review safety and environmental protection standards at fuel storage sites following the Buncefield incident. The Task Group published its initial recommendations on 12 October 2006.

bund an enclosure designed to contain fluids should they escape from the tank or vessel inside the bund, as well as any additional materials added to the container area such as firefighting water and foam etc.

Civil Contingencies Act (CCA) the Civil Contingencies Act was set up in order to deliver a single framework for civil protection in the United Kingdom. The act is divided into two parts. The first sets out the roles and responsibilities for those involved in emergency preparation and response at a local level, whilst the second updates the 1920 Emergency Powers Act, taking into account the developments over the years, as well as potential risk factors faced in the 21st century.

Civil Contingencies Secretariat (CCS) the Civil Contingencies Secretariat is housed within the Cabinet Office, and works alongside other Government departments, the devolved administrations and key stakeholders to assist with emergency preparation, response and recovery in the UK.

COMAH see Control of Major Accident Hazards Regulations 1999.

COMAH Regulations the Control of Major Accident Hazards Regulations 1999 (COMAH).

COMAH site a site to which the Control of Major Accident Hazards Regulations 1999 apply.

Competent Authority the COMAH Regulations are enforced by a joint Competent Authority comprising HSE and the Environment Agency in England and Wales, and HSE and the Scottish Environment Protection Agency (SEPA) in Scotland. The Competent Authority operates to a Memorandum of Understanding which sets out arrangements for joint working.

Control of Major Accident Hazards Regulations 1999 the main aim of these Regulations is to prevent and mitigate the effects of those major accidents involving dangerous substances, such as chlorine, liquefied petroleum gas and explosives, which can cause serious damage/harm to people and/or the environment. The Regulations treat risks to the environment as seriously as those to people. They apply where threshold quantities of dangerous substances identified in the Regulations are kept or used.

consultation distance the distance round major hazard sites set by HSE within which local planning authorities are required to consult HSE on all new planning applications.

containment barriers which, in the event of a spill, can prevent spilled materials from reaching the environment.

contaminants substances that have an adverse effect on air, water or soil.

dutyholder in the context of this report, any person or organisation holding a legal duty – in particular those placed by the Health and Safety at Work etc Act 1974, the Management of Health and Safety at Work Regulations 1999, and the COMAH Regulations 1999.

Environment Agency the Environment Agency is the lead regulator in England and Wales with responsibility for protecting and enhancing the environment. It was set up by the Environment Act 1995 and is a non-departmental public body, largely sponsored by the Department for Environment, Food and Rural Affairs and the National Assembly for Wales.

fire water water stored for use during, and used during, firefighting operations.

foam in the context of this report, a foam used during operations to extinguish hydrocarbon fires.

foam concentrate in the context of this report, a concentrate used during operations to extinguish hydrocarbon fires.

Gold Command the working name for the strategic command centre during a Major Incident – also known as the Strategic Co-ordinating Group (SCG).

groundwater all water below the water-table, as opposed to 'ground waters', which include groundwater but also sub-surface water above the water-table.

hazard anything with the potential to cause harm.

Health and Safety Commission the Health and Safety Commission (HSC) was a statutory body, established under the Health and Safety at Work etc Act 1974, responsible for health and safety regulation in Great Britain. It merged with the Health and Safety Executive on 1 April 2008. The roles and functions of the Commission have now transferred to the 'new' HSE.

Health and Safety Executive the Health and Safety Executive was a statutory body, established under the Health and Safety at Work etc Act 1974, and an enforcing authority working in support of the HSC. It has now merged with the Health and Safety Commission, taking over its roles and functions. Local authorities are also enforcing authorities under the Health and Safety at Work etc Act 1974.

HSE see Health and Safety Executive.

human factors HSE has defined human factors (also known as ergonomics) as the environmental, organisational and job factors, and human and individual characteristics which influence behaviour at work.

hydrocarbon an organic chemical compound of hydrogen and carbon. There are a wide variety of hydrocarbons such as crude oil (basically a complex mixture of hydrocarbons), methane, propane, butane etc. They are often used as fuels.

improvement notice improvement notices are one of a range of means which enforcing authorities use to achieve the broad aim of dealing with serious risks, securing compliance with health and safety law and preventing harm. An improvement notice allows time for the recipient to comply.

inversion layer this is the boundary between layers of air of distinctly different temperature, often quite sharply defined, as at Buncefield. In a temperature inversion, the normal vertical temperature gradient is inverted such that the air is colder near the surface of the earth. This can occur when radiation from the surface of the earth is less than the amount of radiation received from the sun, which commonly occurs at night, or during the winter when the angle of the sun is very low in the sky.

overpressure for a pressure pulse (or blast wave), the pressure developed above atmospheric pressure is called the overpressure.

perfluorooctane sulphonates a group of chemicals, collectively identified as PFOS, which have been shown to be hazardous (persistent, bioaccumulative and toxic). PFOS chemicals have been used in a diverse range of applications, including as an additive to aid the spreading properties of firefighting foam.

PFOS see perfluorooctane sulphonates.

primary containment the tanks, pipes and vessels that normally hold liquids, and the devices fitted to them to allow them to be safely operated.

prohibition notice issuing improvement or prohibition notices are some of the range of means which enforcing authorities use to achieve the broad aim of dealing with serious risks, securing compliance with health and safety law and preventing harm. A prohibition notice stops work in order to prevent serious personal injury.

reasonable practicability risks are deemed as low as reasonably practicable (ALARP) where there is gross disproportion between the costs to the dutyholder of doing more, against the benefit gained (in terms of risk reduction) in doing it.

responder under the Civil Contingencies Act 2004, the Environment Agency is a Category 1 responder, and HSE is a Category 2 responder. These categories define the roles played by each body in response to a major incident.

risk the likelihood that a hazard will cause a specified harm to someone or something.

Safety Alert where the Competent Authority considers that an issue poses significant risk, it can choose to issue a Safety Alert to operators of COMAH sites, informing them of the issue and possibly requiring them to undertake certain activity.

safety integrity level (SIL) a safety integrity level (SIL) is a measure of safety system performance, in terms of the probability of failure on demand. There are four discrete integrity levels, SIL 1-4. The higher the SIL level, the higher the associated safety level and the lower the probability that a system will fail to perform properly.

safety reports the COMAH Regulations require operators of top-tier sites to submit written safety reports to the Competent Authority.

Scottish Environment Protection Agency the public body that is responsible for the protection of the environment in Scotland.

secondary containment enclosed areas around storage vessels (often called bunds), created usually by concrete or earth walls. Their purpose is to hold any escaping liquids and any water or chemicals used in firefighting.

SEPA see Scottish Environment Protection Agency.

SCG see Strategic Co-ordinating Group.

Strategic Co-ordinating Group representation of all agencies deployed to resolve the Buncefield incident was established through a meeting process known as the Strategic Co-ordinating Group, also known as Gold Command.

surface water water that sits or flows above land, including lakes, seas, rivers and streams.

tank farm a facility where hazardous substances, very often petroleum products, are stored in tanks.

tertiary containment the site surface and associated drainage, boundary walls, roads, containment kerbs and any features such as road humps that can provide some retention of liquids. Proper design of drainage systems will limit loss of product out of the site and prevent lost product permeating into the ground with the potential risk that it can migrate to groundwater, or contaminate surface waters and land.

volatile a substance which evaporates readily, even below its boiling temperature.

Further information

Useful links

Buncefield Major Incident Investigation
Desk 35 – GSW, Rose Court, 2 Southwark Bridge London, SE1 9HS
Tel: 020 7717 6909
Fax: 020 7717 6082
E-mail: buncefield.inforequest@hse.gsi.gov.uk
Web: www.buncefieldinvestigation.gov.uk

Community/business support

Dacorum Business Contact Centre
Tel: 01442 867 805
Business Link Helpline Tel: 01727 813 813

Hertfordshire Chamber of Commerce
Tel: 01727 813 680

Dacorum Borough Council
Tel: 01442 228 000
Web: www.dacorum.gov.uk

Dacorum Community Trust
Tel: 01442 231396
Web: www.dctrust.org.uk

Hemel Hempstead Citizens Advice Bureau
19 Hillfield Road, Hemel Hempstead HP2 4AA
Tel: 01442 213368

Local authorities and emergency services

Dacorum Borough Council
Tel: 01442 228 000
Web: www.dacorum.gov.uk

Dacorum Community Trust
Tel: 01442 231 396
Web: www.dctrust.org.uk

St Albans District Council
Tel: 01727 866 100
Web: www.stalbans.gov.uk

Hertfordshire County Council
Tel: 01483 737 555
Web: www.hertsdirect.org

Hertfordshire Fire and Rescue Service
Web: www.hertsdirect.org/yrccouncil/hcc/fire/buncefield

Hertfordshire Constabulary
Web: www.herts.police.uk/news/buncefield/main.htm

Hertfordshire Chamber of Commerce
Tel: 01727 813 680
Web: www.hertschamber.com

Government links

Cabinet Office
Web: www.cabinetoffice.gov.uk

Communities and Local Government
Fire and Resilience Directorate
Web: www.communities.gov.uk

Government Office for the East of England
Web: www.goeast.gov.uk

Environment Agency
Web: www.environment-agency.gov.uk

Department for Business, Enterprise and Regulatory Reform
Oil and Gas Directorate
Web: www.og.berr.gov.uk

Health and Safety Executive
Hazardous Installations Directorate
Web: www.hse.gov.uk/hid

Control of Major Accident Hazards
Web: www.hse.gov.uk/comah

Department for the Environment, Food and Rural Affairs
Web: www.defra.gov.uk

Health Protection Agency
Web: www.hpa.org.uk

Food Standards Agency
Web: www.food.gov.uk

Drinking Water Inspectorate
Web: www.dwi.gov.uk

Scottish Environment Protection Agency
Web: www.sepa.org.uk

UK Resilience
Web: www.ukresilience.info

Scottish Executive Justice Department – Civil Emergencies
Web: www.scotland.gov.uk/Topics/Justice/emergencies/guidance

Wales – Local Resilience
Web: http://new.wales.gov.uk/resilience/regional-local-resilience1/?lang=en

Northern Ireland Central Emergency Planning Unit
Web: http://cepu.nics.gov.uk

Process Safety Leadership Group (replaced the Buncefield Standards Task Group)
Contact: colette.fitzpatrick@hse.gsi.gov.uk

National Recovery Working Group
Contact: Rhiannon.harries@communities.gsi.gov.uk

Industry links

United Kingdom Petroleum Industry Association (UKPIA)
Tel: 020 7240 0289
Web: www.ukpia.com

Chemical Industries Association
Tel: 020 7834 3399
Web: www.cia.org.uk

Three Valleys Water
Tel: 0845 782 3333
Web: www.3valleys.co.uk

United Kingdom Onshore Pipeline Operators' Association (UKOPA)
Tel: 01773 852003
Web: www.ukopa.co.uk

Tank Storage Association
Tel: 01244 335627
Web: www.tankstorage.org.uk

Investigation reports

Buncefield Major Incident Investigation:

- Progress report published 21 February 2006
- Second progress report published 11 April 2006
- Third progress report published 9 May 2006
- Initial Report published 13 July 2006
- Recommendations on the design and operation of fuel storage sites published 29 March 2007
- Recommendations on the emergency preparedness for, response to and recovery from incidents published 17 July 2007
- Explosion Mechanism Advisory Group report published 16 August 2007
- Recommendations on land use planning and the control of societal risk around major hazard sites published 15 July 2008

Available from www.buncefieldinvestigation.gov.uk

Defra: Initial review of Air Quality aspects of the Buncefield Oil Depot Explosion
Main report: www.defra.gov.uk/environment/airquality/publications/buncefield/buncefield-report.pdf
Appendices: www.defra.gov.uk/environment/airquality/publications/buncefield/buncefield-append.pdf

Buncefield: Hertfordshire Fire and Rescue Service's review of the fire response
Hertfordshire Fire and Rescue Service November 2006 ISBN 978 0 11 703716 8

Angus Fire, Buncefield Oil Terminal Incident December 2005: Review of part played by Angus Fire and lessons learned
www.angusfire.co.uk

Other related reports/information

East of England Development Agency – report by SQW, Economic Developments Consultants *The Buncefield Oil Depot Incident: Economic and Business Confidence Impact Study* June 2006
www.eeda.org.uk

Swiss Fire Service: *Quick Look Report – Buncefield Fire 11 December 2005*

Buncefield social impact report Dacorum Borough Council January 2007
www.dacorum.gov.uk/default.aspx?page=4191

Contract research reports for HSE

WS Atkins Science and Technology *Derivation of fatality probability functions for occupants of buildings subject to blast loads Phases 1, 2, & 3 147/1997 and Phase 4 151/1997*

Biomedical Sciences Chemical and Biological Defence Sector Defence Evaluation and Research Agency: *Review of blast injury data and models 192/1998*

Available from: www.hsebooks.com

Government advisory bodies

Committee on mutagenicity of chemicals in food, consumer products and the environment (COM)

Committee on carcinogenicity of chemicals in food, consumer products and the environment (COC)

Committee on toxicity of chemicals in food, consumer products and the environment (COT)

www.advisorybodies.doh.gov.uk/coc/

Printed and published 12/08 C20

The Buncefield Incident 11 December 2005

The final report of the Major Incident Investigation Board

Volume 1

In the early morning of Sunday 11 December 2005, a series of explosions followed by a large fire destroyed large parts of the Buncefield Oil Storage and Transfer Depot and caused widespread damage to homes and businesses surrounding the site.

The then Health and Safety Commission (now Health and Safety Executive) appointed a Major Incident Investigation Board with an independent chair, Lord Newton of Braintree. This was a new departure in major incident investigation which allowed the Board to contact individuals and organisations who were affected or who had expert knowledge and experience, and to keep the public informed of progress with frequent reports.

This is the ninth and final report of the Buncefield Major Incident Investigation Board. It is made to the Boards of the Health and Safety Executive and the Environment Agency that together form the joint Competent Authority responsible for regulating the Buncefield site.

Volume 1 draws attention to some of the ways the Board has set about its business. It explains the significance of the Buncefield Depot and describes briefly how the explosions and fires happened and the damage they caused. It also summarises all the Board's recommendations to regulators, industry and government.

Volume 2 brings together all the Board's previous reports in a single publication for the public record and for future reference: three progress reports; an Initial Report; a report into the explosion mechanism; and reports giving recommendations on design and operation of fuel storage sites, emergency preparedness for, response to and recovery from incidents, and land use planning and the control of societal risk around major hazard sites.

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