The Buncefield Incident
11 December 2005

The final report of the
Major Incident Investigation Board

Volume 2

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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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Cover photo: Courtesy of Chiltern Air Support

Contents

Foreword

This second volume of our final report brings together all of our previous eight reports in their original form. We have not abridged any of the reports because to do so would diminish their usefulness as an accurate record of the Buncefield Board's work over the thirty-four months of its existence. We expect this collection of reports to be useful for anyone with a responsibility for bringing into effect our recommendations or for understanding them, and for those with an interest in how the Board's thinking developed over the period of its tenure.

Each of our reports had a specific purpose. The first three reports were from me to the Board describing progress with the investigation in understanding the incident; the first confirming a vapour cloud explosion had occurred, the second describing the environmental impact, and the third describing what had happened, and how.

Our fourth report was the Board's own 'Initial Report' and discharged our fifth term of reference. It marked the stage at which the Board set out its main areas of concern and turned its full attention to making recommendations for improvements in these areas. Accordingly, the next four reports made recommendations on design and operation of fuel storage depots; on the emergency preparedness, response to and recovery from major incidents; on the mechanism of the Buncefield explosion; and on land use planning and the control of societal risk around major hazard sites. We placed extensive annexes, glossaries and references in all of our reports to enhance the understanding of the reports, to support the recommendations, and to direct the interested reader towards further information. All of theses annexes, glossaries and reference sections are included in their original form here in Volume 2.

As well as making our reports available as soon as we could, we tried to be accessible at all times to everyone via an open e-mail system and website. We placed all of our reports, public statements, key correspondence and other relevant information on our website. The website was recorded on CD, a copy of which is included here in Volume 2.

Taf Powell
Chief Inspector, Investigation Manager
Buncefield Major Incident Investigation Board

The Buncefield Investigation

Progress report

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Photographs are courtesy of the Chiltern Air Support Unit and Hertfordshire County Council

Foreword

At the first meeting of the Major Incident Investigation Board (MIIB) on 24 January I was asked to prepare, for the second (10 February) meeting, a progress report on the Buncefield Major Incident Investigation by the Health and Safety Executive (HSE) and the Environment Agency (EA). This was to bring together relevant background material and to cover progress with the investigation and such facts as have been established to this point.

The MIIB said that this progress report would not constitute the 'initial report' required by Terms of Reference 6, since some of the main facts have yet to be established. This progress report is a stepping stone towards the initial report.

The report describes the incident and the nature of the site and surrounding communities and the initial responses by EA and HSE. Importantly, the report describes the most likely nature of the explosion and fires that have so far been ascertained from eyewitness statements and CCTV records. The explanation of what the investigation team believes is most likely to have led to the devastation of the area is not yet verified by scientific modelling and other evidence but I have sufficient confidence in the evidence to believe on balance it should be made public.

The report does not describe how what happened occurred. This is because I am not in a position to say anything with sufficient confidence for it to be other than a line of inquiry amongst others. Speculating publicly on causation would be undesirable because I am not in a position to confirm the likelihood of the theory, nor to deal authoritatively with the implications arising out of the theory. It may also lead to nugatory remedial actions by depot operators. I believe verification is required from records of fuel movement and storage to confirm any theory related to loss of containment, not least of all because this may alter the balance between system and mechanical failure, and this knowledge is vital in formulating a competent response to the Buncefield incident.

Taf Powell
Buncefield Investigation Manager and Member of Buncefield Major Incident Investigation Board

Part 1 The Investigation so far

1.1 The incident

1 At around 06.00[1] on Sunday 11 December 2005, a number of explosions occurred at Buncefield Oil Storage Depot, Hemel Hempstead, Hertfordshire. At least one of the initial explosions was of massive proportions and there was a large fire, which engulfed over 20 large fuel storage tanks over a high proportion of the site.[2] There were 43 people injured in the incident, none seriously. There were no fatalities. Significant damage occurred to both commercial and residential properties in the vicinity and a large area around the site was evacuated on emergency service advice. About 2000 people were evacuated. Sections of the M1 motorway were closed.

[1] Preliminary analysis of seismic records published by the British Geological Survey indicates that the initial explosion event occurred at 06:01 GMT.

[2] Figure 5 on page 8 shows the damaged area. For a description of the site see Part 2.1 of this report.

Figure 1 This photograph shows the Buncefield site on the first day of the fire. The Northgate building can be seen burning towards the lower left corner of the photograph.

2 The fire burned for several days, destroying most of the site and emitting large clouds of black smoke into the atmosphere, dispersing over southern England and beyond. Large quantities of foam and water were used to control the fire, with risks of contaminating water courses and ground water (see Figure 2).

Emergency response

3 The emergency services (primarily the Fire and Rescue Service and the police) led the initial response to the incident and its immediate aftermath. As a Category 1 responder under the Civil Contingencies Act, EA worked closely with the Fire and Rescue Service, the police, the Health Protection Agency (HPA) and the Strategic Health Authority, including advising on the water pollution aspects of the fire-fighting activities. HSE is a Category 2 responder, so during the early phase of the incident stood ready to provide advice and expertise on request in support of the emergency services and EA.

4 Hertfordshire Police co-ordinated the emergency response and worked closely with other responders including the Hertfordshire Fire and Rescue Service, Hertfordshire County Council, Dacorum Borough Council, EA and HPA. The police

Figure 2 This photograph shows the fire-fighting operation in progress with the appliance in the avenue between bunds ‘A’ and ‘B’

set up an exclusion zone around the site which remained in position for several days. The Hertfordshire Fire and Rescue Service was supported by staff drafted in from many other brigades and used equipment and foam brought in from around the country. Shortly before Christmas the police were able to hand back the security of the site to the depot operators but the fire service retained a presence on site until the New Year as quantities of uncontained fuel remained on site.

5 At the peak of the incident – on Monday lunchtime, 12 December – there were 26 Hertfordshire pumps on site, 20 support vehicles and 180 firefighters. More than 250 000 litres of foam concentrate were used, together with 25 million litres of water and 30 km of high-volume hose.

6 The investigation team wishes to acknowledge the work of the emergency services and especially the invaluable support given to HSE and EA in securing vital evidence in the initial period when the site was dangerous and under the control of the emergency services.

Securing the site

7 Once the Buncefield fire had been extinguished, HSE issued formal notices on the two operators of the part of the depot that had suffered the greatest damage. Prohibition Notices were served on both Hertfordshire Oil Storage Ltd (HOSL)[3] and British Pipeline Agency Ltd (BPA) on 16 December 2005 prohibiting operations on site under their control unless appropriate risk assessments had been agreed with HSE. Each of these operators were also served with Notices requiring that the parts of the depot under their control were left undisturbed. The Notices were issued to ensure that key pieces of evidence remained in place for examination by the investigation team and that the clear up operations were carried out in a safe manner. The operators have co-operated with HSE and EA to achieve these goals.

Water pollution

8 EA worked with the Fire and Rescue Service to develop a plan that minimised the potential for firewater run-off. This included recirculating cooling water. The main concern was the containment of liquid on site due to the presence of a drinking water aquifer nearby. Some material did leave the site into Three Cherry Trees Lane. EA believe most of this was contained by the natural contours of the land, which prevented it reaching surface waters. Pollution of the River Ver is low and no impact on its fish and animal life has been seen.

9 From the start of the incident both the Meteorological Office (using a long-range pollution dispersion model) and EA (using a short-range model) worked to model the plume and provided data to HPA on likely plume direction and ground level concentrations. On the advice of HPA a number of schools were closed as a precaution.

10 Air pollution in London and the Home Counties was measured by four regional air quality monitoring networks managed by King's College, London, and comprising over 130 local authority monitoring sites. A number of parameters were measured including particulates. Air samples were sent for particulate analysis and the results are awaited.

[3] For more details of the HOSL and BPA sites see Part 2.1 of this report.

Social and economic impact

11 The Buncefield Depot is close to the Maylands Industrial Estate, home to some 630 businesses employing about 16 500 people. All businesses were disrupted by the explosions and fire, some severely. The premises of 20 businesses employing 500 people were destroyed; the premises of 60 businesses employing 3500 people are under repair and not yet usable. Most businesses face difficulties in delivering pre-incident levels of service from dispersed and temporary accommodation. Reduced trading and supply disruptions have affected businesses over a wider area. Impact on employment has been limited so far, but job losses could become significant over the next few months.

Figure 3 The smoke plume rising and spreading above the Buncefield site.

Figure 4 Depot and surroundings prior to incident

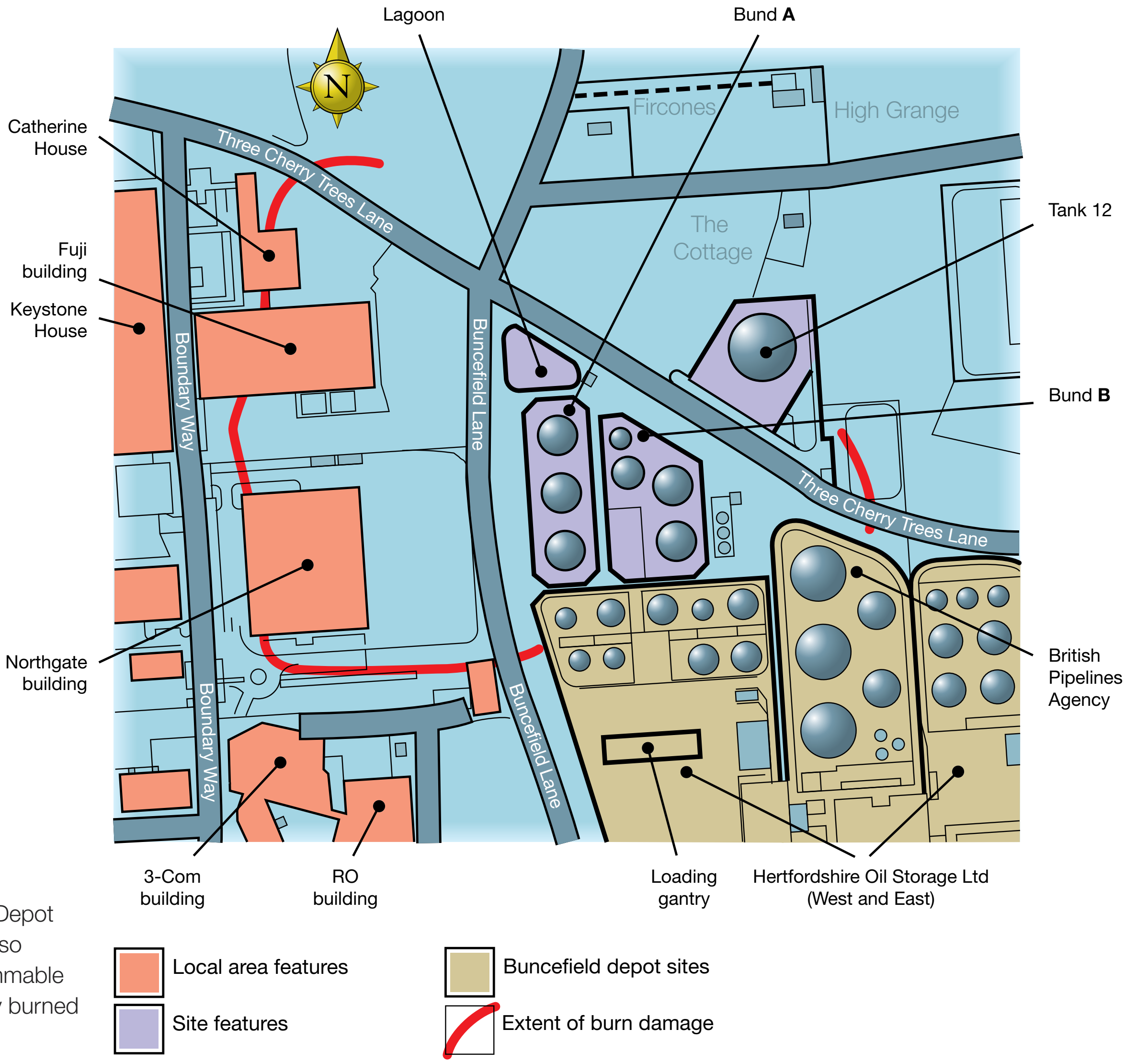


Figure 5 Layout of Depot and surroundings also showing limit of flammable mixture indicated by burned material

12 The incident also damaged nearby housing, mainly in Dacorum district, but also in St Albans district. Some houses closest to the site suffered significant structural damage; several families are living in temporary accommodation while their houses are repaired. At least 300 houses suffered lesser damage.

13 The incident disrupted fuel supply to London and South-East England. Remedial measures by the industry have restored supplies of road transport, commercial and domestic fuels generally back or close to pre-incident levels. However, supplies to Heathrow remain disrupted. This has required fuel rationing by the BAA to allow the airport to function normally, with no flight cancellations. For all supplies the industry is trying to find permanent solutions to replace the current transitional arrangements.

1.2 What is known about the explosions and fire

14 Evidence obtained so far points to the formation of a flammable mixture of petrol, or similar spirit, and air that ignited, leading to the explosions and fire. The flammable mixture appears associated with a visible mist. This evidence includes reports from eyewitnesses, CCTV records and forensic material, as briefly summarised below.

Eyewitness reports

15 On-site at the west side of the tanker loading gantry on HOSL West site:

- Witnesses describe seeing mist at about 05:50 GMT in the vicinity of one of the tanks in bund A[4] (see Figure 4). They also describe a mist variously between one and three feet in height rolling from bund A towards the tanker loading gantry. Witnesses also report a moving mist near the trees (along Buncefield Lane to the west of the site) about one and a half feet high and wisps of vapour on the ground near the end of the loading bay.
- These witnesses mention a strong smell at this time, variously described as petrol or aviation gasoline.
- None of the witnesses describe the flames reaching them as they moved from the tanker loading gantry towards the site exit. None of them report having suffered burn injuries.

16 Off-site in the vicinity of the Fuji building carpark to the west of the site:

- Witnesses describe a thick fog 'above head height' or 'between 15 and 20 feet high' between 05:50 and 06:00 GMT. This was first seen near the junction where Three Cherry Trees Lane meets Buncefield Lane. The fog continued to spread to the west towards Catherine House.
- These witnesses noticed a strong smell, but were not certain of its nature and in general there is a degree of disagreement among witnesses as to the nature of the smell. These witnesses also describe various responses from their car engines including 'revving uncontrollably', 'running rough' and 'stalling'.
- From the witness statements and lack of burn injuries, the flame does not appear to have travelled as far as Boundary Way.

CCTV records

17 Examination of CCTV images for the HOSL site and for the RO building off-site has provided the following evidence.

[4] A bund is an enclosure designed to contain fluids should they escape from the tank or vessel inside the bund.

18 HOSL West

- Before the event there was no evidence of mist or fog at ground level showing on any of the camera images. This includes the surface of the fire water lagoon in the north-west corner of the HOSL West site.
- The first unusual indication was at 05:38 GMT, 23 minutes before the explosion. At the north-west corner of bund A, a light mist is seen flowing from inside bund A towards the west. This is at the north-west corner of bund A. The mist is low-lying and about one metre deep. Its appearance is consistent with a mist that is denser than the surrounding air.
- During the next few minutes mist is seen flowing towards Three Cherry Trees Lane via the lagoon and flowing out of bund B at the north-east edge of the site, along the roadway on-site.
- Cameras at the eastern edge of the HOSL site adjacent to the BPA site first show the mist eight minutes after its first appearance crossing the wall of bund A.
- By this time, the cameras along the western edge of the site, along Buncefield Lane, show that the mist has thickened to about two metres deep. It is now so dense that it is not possible to see through it. It appears to flow away from bund A in all directions.
- There is no indication on the cameras that the visible mist has spread as far south as the tanker filling gantry.
- All the cameras stopped recording at the time of the explosion.

19 HOSL East

- There is no evidence of the mist seen on the HOSL West site having reached as far as any of the cameras on the HOSL East site. The cameras show evidence of the fire, but it is not possible to learn anything of significance.

20 RO building

- This building is to the south of the Northgate building, approximately level with the tanker loading gantry on the HOSL West site. There is no evidence of the mist having reached as far as any of the cameras at this building. The images show a flash of light at the time of the explosion, followed by evidence of explosion damage.

Figure 6 HOSL West gates

Initial forensic examination

21 Initial examination of the evidence of damage around the site by the Health and Safety Laboratory (HSL) allows the approximate extent of the flammable mixture to be judged from the effects of the flash fire on vulnerable surfaces:

- Scorched vegetation on a row of trees between the Northgate building and the 3-Com building.
- Scorched leaves underneath these trees.
- Scorched upholstery to unignited cars at this location.

22 In addition the north-east corner of the Northgate building has been on fire. There are burnt cars and trees between the Northgate building and the Fuji building.

23 Cars on Three Cherry Trees Lane near to Catherine House were set on fire and vegetation along the side of Three Cherry Trees Lane was scorched at this location.

24 Evidence of the extent of any flammable mixture over the HOSL site is masked by damage from the resulting tank and bund fires.

Initial conclusions regarding the extent of the flammable mixture.

25 The explosion(s) that caused the extensive damage on and off site, and the early fires, can probably be ascribed to the ignition of a flammable mixture that is thought to have been associated with the visible mist reported by eyewitnesses and visible on CCTV records.

26 Initial indications are that the flammable mixture of fuel and air extended to the west almost as far as Boundary Way in the gaps between the 3-Com, Northgate and Fuji buildings. To the north-west it extended as far as the nearest corner of Catherine House.

27 It may have extended to the north of the HOSL site as far as BPA tank 12. It may have extended across part of the HOSL site, but there is no evidence of it having spread as far south as the tanker filling gantry, although the visible mist had just started to reach this point. Figure 5 shows the most likely extent of the flammable mixture based on the investigation so far.

28 The visible mist seen in the CCTV records and described by witnesses is assumed to arise from the evaporation of the more volatile fractions of an escape of fuel. This evaporating fuel would be cold compared to the surrounding air, which is known from weather records to have had high humidity. The cooling would result in the condensation of water in the air. The visible mist thus indicates the approximate extent of the fuel air mixture.

29 The source of the fuel release is not yet known, although the CCTV records indicate that it was in the vicinity of bund A on the HOSL West site. The most plausible scenarios involve large-scale loss of containment of vessels or pipework within bund A. Resources are being directed to clarify these early indications and to find out what underlying causes there may have been.

Initial findings regarding the explosion

30 It is clear from the witness accounts and the evidence of damage both on and off site that there was a massive explosion early in the developing incident. There appear to have been several explosions, but the exact sequence of events has not yet been established. Initial indications from examination of the explosion damage are that the main explosion event appears to have been located in the area of the car parks between the HOSL West site and the Fuji and Northgate buildings. The heaviest damage can be seen in this area. This does not necessarily mean that the ignition of the flammable mixture occurred here, but that the highest flame speeds were in this location. The mechanism for this is not yet understood. This forms part of the ongoing investigation.

Initial advice to duty holders

31 In response to the incident HSE will advise duty holders what steps to take in the light of what is known so far about the nature of the Buncefield explosion. The advice will be systematically followed up with duty holders by HSE inspectors.

1.3 The continuing Investigation

32 Immediately after the incident HSE and EA set up a joint investigation team under the leadership of HSE. The Investigation team was tasked with finding out what had happened, including the factors leading up to it and the root causes. The full terms of reference are at Annex 3.

33 The team divided the Investigation into a number of strands and assigned specialist staff to take each one forward. The Investigation is led by specialists in inspection and investigation. The main technical strands are in mechanical engineering, process engineering, fire and explosion engineering, control and instrumentation, and environmental impact assessment. Human factors experts will be increasingly involved as more evidence becomes available concerning the operation of the site. The site has been segmented into areas to assist the early Investigation.

34 The team commissioned staff from the HSL to assess the damage caused by the explosion. This assessment has enabled the team to determine the approximate location and extent of the flammable mixture that had formed, and the probable sources of ignition that led to both the fire and the explosion.

35 Work is continuing to find out the exact nature and composition of the flammable mixture and to determine the precise mechanism which led to such a violent explosion. This includes establishing the nature and composition of the fuel from which the mixture was formed. Priority is being given to this work so that HSE's advice to local planning authorities about developments adjacent to Buncefield and other fuel storage sites can be reviewed and, if necessary, amended. Site surveys have been carried out to enable the team to determine the volume and physical and chemical properties of the flammable mixture; this important work is continuing.

36 Inspectors are continuing painstaking work to restore and view CCTV evidence from the site and adjacent premises. There is a large amount of electronic evidence relevant to the operation of the depot and much of this was contained in buildings severely damaged by the blast. As much of this as possible has now been secured and work continues to restore and then examine these highly specialist electronic records to determine the operating conditions before and at the time of the incident.

37 The Investigation team is also examining the detailed technical documentary records relating to plant design and operation. Examination of the damage to plant on site and forensic examination of key parts of tanks and pipework is only just commencing. Following the extensive damage and contamination of bunds with fuel products and run-off fire water, access to many parts of the site has been restricted. Priority has been given to making these areas safe and only recently have inspectors been able to turn their attention to this aspect of the investigation.

38 On environmental issues the team has focused on containment of products and fire-fighting materials on site and releases to the environment. It is working to identify pathways of pollutants into the environment and to quantify the scale of impact to the environment both on and off site with regard to land and water. As the clean-up operation has progressed samples have been taken from lagoons, boreholes and surrounding watercourses and gaining photographic evidence of the developing situation both on and off site. Staff are also obtaining documentary evidence of how containment was designed, constructed and maintained on site, including the provision for containing fire-fighting water.

39 The Investigation team continues to investigate the scale of environmental impact from the liquids released from the site, as well as closely monitoring the clean-up work. Team members are working to identify the root causes of any containment failings as well as identifying where measures on site have prevented greater impact.

Ongoing objectives

40 The Investigation is at a very early stage. The team has yet to start examining previous inspection reports and assessments of safety reports. This will be necessary to identify whether any issues linked to the root causes of this incident had been raised previously with the operators and if so what the operators had done about them. The investigation will also examine the on- and off-site emergency plans.

41 A critically important focus for the site Investigation is to find out why and where there was a release of hydrocarbons. It is therefore vital to continue work on the examination of pipework and storage tanks to ascertain the precise source of the release and the mechanism of formation of the flammable mixture and why preventive control measures were inadequate.

42 The Investigation still needs to establish whether the incident has caused serious danger to the environment, as set out in the definition of a 'major accident' affecting the environment in the Control of Major Accident Hazards Regulations 1999 (COMAH).

43 Work on all strands of the Investigation is continuing. Further work is needed before a clear and definitive picture will emerge, both of how and why there was a release of fuels on 11 December 2005 and of the underlying reasons for it.

44 As part of the Investigation, the team will also examine all this collective evidence against the standards required by the COMAH Regulations and other health, safety and environmental legislation.

Emergency plans

45 The COMAH Regulations require on- and off-site emergency plans for the Depot (see Part 2.2). HSE and EA are examining the adequacy of these plans in conjunction with the operators and the emergency services. The plans will be compared to the operational response and lessons drawn for the future.

Figure 7 The area prior to incident

Developments around the Buncefield Site

46 COMAH sites are subject to a special planning regime which is described in Part 2.2. At Buncefield this resulted in zones being drawn around the site within which HSE was consulted on developments by the local planning authorities. The outer zone (the 'consultation distance') was set at approximately 190 metres from the perimeter of the site. The investigation will examine the history of planning applications within the vicinity of the site and in particular, when the precise nature of the explosion and fire has been determined, will address the question of whether or not advice to local planning authorities at Buncefield and similar sites should be changed.

1.4 Review of HSE/EA roles in regulating activities at Buncefield

47 Point 3 of the Buncefield Investigation terms of reference (Annex 3) requires the Investigation to examine HSE's and EA's role in regulating the activities on this site under the COMAH Regulations, considering relevant policy guidance and intervention activity. HSE and EA together form the Joint Competent Authority for the regulation of major hazard sites (such as Buncefield) under the COMAH Regulations.

48 This review will address both the nature of the compliance with policy and procedures for regulating health, safety and environmental matters, and the efficacy of the policy and procedures.

49 HSE and EA will initially conduct separate reviews, sharing findings and aligning outputs as necessary. The final product will be a single report of the regulation of the Buncefield site together with recommendations arising out of the review.

50 Review teams have been set up in both organisations, site visits undertaken and plans for reviewing documentation and previous regulatory involvement have been drawn up.

51 The review findings on the HSE and EA roles will be subject to full scrutiny by the independent members of the Major Incident Investigation Board (see Part 1.5).

1.5 Major Incident Investigation Board

52 On 12 January 2006 HSC appointed a six-person Board to oversee the formal Investigation. This Board comprises an independent non-executive Chairman, two independent experts, one in fire safety, the other in occupational and environmental medicine, and three senior regulatory operations managers, two from HSE and one from EA.

53 In broad terms the purpose of the Board is to oversee the Investigation and ensure that:

- the Investigation is carried out effectively and the best professional advice is used in establishing causation;
- the confidence of the public is maintained in the work and findings of the Investigation;
- the eight points of the terms of reference (Annex 3) are met, even if in some cases delivery is the responsibility of other parties;
- information is made public in a timely way, but subject to legal considerations.

Part 2 Background

2.1 Site description

54 Buncefield Oil Storage Depot is a large strategically important fuel storage site (known as a tank farm) operated by a number of companies. Figure 5 shows the layout of the site and its immediate surroundings.

55 The Depot receives petrol, aviation fuel, diesel and other fuels by pipeline. It stores and then distributes these fuels by pipeline and road tanker to London and South-East England, including to Heathrow Airport. The UK Petroleum Industry Association (UKPIA) reports that, prior to the events of 11 December 2005, Buncefield handled 8% of overall UK oil supplies into the market, including 20% of supply to consumers in the South East. The terminal acted as a main pipeline transit point to meet 40% of Heathrow's demand for aviation fuel. On 11 December the site held over 35 million litres of petrol, diesel and aviation fuel.

56 The Depot contains three sites which are so-called 'top-tier' sites under the COMAH Regulations (see Part 2.2 of this report on regulation of high-hazard sites), although the HOSL and BP sites did not acquire top-tier status until changes were made to the Regulations in July 2002. This required submission of safety reports for these sites by July 2003:

- Hertfordshire Oil Storage Ltd (HOSL) – a joint venture between Total UK Ltd (60%) and Texaco Ltd (40%). This site is in two sections, HOSL East and HOSL West. HOSL West was at the centre of the fire. The site had consent to store 34 000 tonnes of motor spirit and 15 000 tonnes of kerosene. The COMAH safety report assessment process had not been completed.
- British Pipeline Agency Ltd (BPA) – a joint venture between Shell and BP that operates the site and the pipeline system, while the assets are owned by UK Oil Pipelines Ltd (UKOP). This site is split between the 'North' (or 'Cherry Tree Farm') section and the main section. It was substantially damaged by fire. It had consent to store 70 000 tonnes of motor spirit and other fuels. The COMAH safety report assessment process had been completed.
- BP Oil Ltd. The BP facility to the south of the Depot was furthest from the fire and appears to have escaped with superficial damage. It is out of operation while the full extent of damage is assessed. It has consent to store 75 000 tonnes of motor spirit, all product being received from the BPA site pipelines. The COMAH safety report assessment process had been completed.

57 The fuels arrive at the sites in batches through a system of three pipelines, namely:

- One 10" diameter pipeline ('FinaLine') from Lindsey Oil Refinery, Humberside, terminating in the HOSL West site.
- One UKOP 10" diameter pipeline ('Mersey-Buncefield') from Stanlow refinery, Merseyside terminating in the BPA North site
- One UKOP 14" diameter pipeline ('Thames-Buncefield') from Shell Haven and Coryton Refinery terminating in the BPA main site.

58 After separation of the multi-fuel product entering the sites from the pipelines, the fuel is stored in tanks individually dedicated to specific product types. Product then leaves the sites either by road tanker or, in the case of aviation jet fuel, via two dedicated 6" and 8" pipelines from the BPA site into the West London Walton Gatwick pipeline system. Fuel leaving the site by road is loaded by dedicated vehicle loading facilities at HOSL West, BP and to a lesser extent BPA.

59 There are also fire-fighting facilities on site, some of which are shared. The site water treatment is operated by BPA, collecting run-off water from the whole site into a water treatment plant in the north-east corner of the Depot.

60 For land use planning purposes the Depot is surrounded by a consultation distance of 190 metres (see page 22). The local planning authority must consult HSE about developments within that distance, but not those outside it.

Site conditions at the time of the incident

61 Information provided by HOSL indicates that during the hours leading up to the explosion, the HOSL site was importing unleaded petrol through the FinaLine pipeline from the Lindsey Oil Refinery. In addition, unleaded petrol was being imported through the Thames pipeline and diesel through the Mersey line. Unleaded petrol was being exported from the site by filling road tankers at the gantry on the HOSL West site.

Weather conditions

62 Meteorological Office records have been obtained for two sites at Luton Airport (13 km to the east-north-east) and Northolt (24 km to the south). These indicate that during the early morning of 11 December 2005 the weather was calm, cold, stable and humid. Atmospheric stability at Northolt was stable (Pasquill stability category F). The relative humidity was recorded as 99%. The air temperature was –1.7 °C at Northolt and 1 °C at Luton. There was no wind recorded at Northolt, while Luton recorded an average wind speed of 6 knots (approximately 3 metres per second) during the 10 minutes before 06:00 GMT. The average wind direction was recorded as 280 degrees measured from true north (this is the direction from which the wind was blowing).

63 At Luton there was a light wind west to east. Further south there was no wind.

Geology

64 The Buncefield Depot and the immediate surrounding area are positioned on a variable layer of clay with flints over Upper Chalk. The clay with flints layer is classified as a low permeability surface deposit and is believed to be present at a variable thickness of between 2 m and 10 m. This layer should inhibit the vertical and lateral migration of contaminants and protect the chalk aquifer below where present in sufficient depth.

65 The Upper Chalk is classified as a major aquifer, which provides water supplies regionally. The Depot is located within the catchment of a ground water abstraction point located to the south and east of the Depot. Ground water is present typically at a depth of 45 metres below ground level and flow is generally towards the south-east. Natural holes in the chalk which allow quicker water flow than normal may be present, but none have been positively identified in the immediate area.

66 Within the Depot site boundary a layer of made-ground, comprising a sand clay dominated soil mixture, overlies the clay.

Water

67 A local ground water abstraction point that is used as cooling water is located approximately 500 m south of the Depot.

68 The River Gade is located approximately 3 km to the south-west and the River Ver approximately 3.5 km east of the Depot.

69 During normal operation, surface water from the Depot drains to the Depot effluent treatment plant. It is then pumped into the public surface water system at Pratts Dell to the north-west of the Depot. This in turn drains to the surface water-balancing pond at Redbourne Road and subsequently to the River Red, a tributary of the River Ver.

70 Maylands pond is another surface water-balancing pond situated to the south-west of the Depot. It was used as a source of fire-fighting water during the incident.

General background

71 Land to the west and north of the Depot is largely used for the growing of arable crops.

72 There are no listed buildings within 1 km of the Depot and no recorded monuments within 500 m of the Depot.

73 The Depot is not located within a 100-year flood plain as defined by the EA flood maps.

74 There are no sites of special scientific interest within 2 km of the Depot and the nearest site designated under the Habitats Directive is Ashridge Common Special Area of Conservation, approximately 8 km north-west of the Depot.

Figure 8 Buncefield Oil terminal - Immediate surroundings of the complex

2.2 Regulation of high-hazard sites

75 The regulatory framework for sites, such as Buncefield, which pose potential major accident hazards comprises requirements imposed on the site operators under both health and safety and environmental legislation, complemented by the requirements of planning law. In particular the COMAH Regulations apply.

Health and safety law

76 Operators in the process industries are subject to the requirements of the Health and Safety at Work etc Act 1974 (HSW Act) and the Management of Health and Safety at Work Regulations 1999 (MHSWR) which require, respectively, safety policies and risk assessments covering the whole range of health and safety risks.

Control of Major Accident Hazards Regulations 1999 (COMAH)

77 COMAH's main aim 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 COMAH 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. There are two thresholds, known as 'lower-tier' and 'top-tier'. Annex 1 gives a brief background to the origins of these Regulations. The requirements of COMAH are fully explained in *A guide to the Control of Major Accident Hazards Regulations 1999 (COMAH). Guidance on Regulations* L111 HSE Books 1999 ISBN 0 7176 1604 5.

78 The COMAH Regulations are enforced by a joint Competent Authority (CA) comprising HSE and EA in England and Wales, and HSE and the Scottish Environment Protection Agency (SEPA) in Scotland. Operators will generally receive a single response from the CA on all matters to do with COMAH. The CA operates to a Memorandum of Understanding which sets out arrangements for joint working.

79 The COMAH Regulations require operators of top-tier sites to submit written safety reports to the CA. Operators of top-tier sites must prepare adequate emergency plans to deal with the on-site consequences of possible major accidents and to assist with off-site mitigation. Local authorities for areas containing top-tier sites must prepare adequate emergency plans to deal with the off-site consequences of possible major accidents, based on information supplied by site operators.

80 The COMAH Regulations place duties on the CA to inspect activities subject to the Regulations and prohibit the operation of an establishment if there is evidence that measures taken for prevention and mitigation of major accidents are seriously deficient. The CA also has to examine safety reports and inform operators about the conclusions of its examinations within a reasonable time period.

Environmental legislation

81 Some of the establishments regulated under the COMAH Regulations are also regulated by EA and SEPA (the Agencies) under the Pollution Prevention and Control Act 1999 (PPC) or Part I of the Environmental Protection Act 1990 (EPA 90). The regime under EPA 90 is gradually being replaced by the PPC regime and will be fully replaced by 2007.

82 While the purpose of the COMAH Regulations (the prevention of major accidents) differs from that of IPC/PPC or LAPC (the prevention of pollution), the means to achieve them are almost identical. They require industry to have good management systems to control risk. PPC includes a specific duty to prevent and mitigate accidents to the environment which is complementary to the main COMAH duty. The Agencies manage this overlap between their different regimes following the principle that accident prevention work on COMAH sites is generally more significant because of the greater risks.

Land use planning

83 The land use planning aspects of the Seveso II Directive are given effect in the UK by the Planning (Hazardous Substances) Regulations 1992. Under these Regulations the presence of hazardous chemicals above specified thresholds requires consents from the Hazardous Substances Authority (HSA), usually the local planning authority. HSE is a statutory consultee on such occasions. The role of HSE is to consider the hazards and risks which would be presented by the hazardous substances to people in the vicinity, and on the basis of this advise the HSA whether or not consent should be granted. HSE will also supply a consultation distance around the site. Any future developments in these zones require HSE to be consulted.

84 The aim of health and safety advice relating to land use planning is to mitigate the effects of a major accident on the population in the vicinity of hazardous installations, by following a consistent and systematic approach to provide advice on applications for planning permission around such sites.

85 Historically, HSE has based its land use planning advice on the presumption that site operators are in full compliance with the HSW Act. Section 2 of the Act places a duty on an employer to ensure, so far as is reasonably practicable, the health and safety of his employees. There is a corresponding duty in Section 3 to ensure, so far as is reasonably practicable, that others (which includes the public) are not exposed to risks to their health and safety. These duties are goal-setting and operators are expected to determine the most appropriate means to comply with them, without the need for detailed approval from HSE.

86 Annex 2 sets out HSE's current approach to land use planning advice.

87 Under the General Development Procedure Order 1995, both HSE and EA are statutory consultees for:

- the development of a new major accident hazard site; or
- developments on an existing site which could have significant repercussions on major accident hazards; or
- other developments in the vicinity of existing establishments, where the siting or development is such as to increase the risk or consequences of a major accident.

Annex 1

Backgound to the COMAH Regulations

1 Certain industrial activities involving dangerous substances have the potential to cause accidents that give rise to serious injury to people or damage to the environment both close to and further away from the site of the accident. Such activities are known as major accident hazards.

Flixborough

2 In Great Britain, a disastrous explosion at a chemical plant at Flixborough in 1974 profoundly influenced the approach to regulating major hazards. There were 28 workers killed, the plant was destroyed and there was extensive damage to property off site. Following that accident, a committee of experts, the Advisory Committee on Major Hazards (ACMH), was appointed by the Health and Safety Commission to consider the problems of major accident hazards and make recommendations. They proposed a three-part strategy:

(a) identification of the sites;
(b) control measures to prevent major accidents; and
(c) mitigatory measures to limit the effects of any accidents which do occur.

European Union Directive

3 Other major accidents occurred in Europe during the 1970s, the most significant of which took place in Seveso, Italy in 1976. Here, the accidental production and release of a dioxin as an unwanted by-product from a runaway chemical reaction led to widespread contamination. Such incidents, and the recognition of the differing standards of controls over industrial activities within the European Community, led the European Commission to propose a Directive on the control of major industrial accident hazards. The three-part strategy proposed in the UK was highly influential in shaping the Directive. The Directive on the Major Accident Hazards of Certain Industrial Activities (82/501/EEC) was adopted on 24 June 1982, and is generally known as the Seveso Directive.

4 Following a complete review of the Directive by the European Commission a new one, now known as Seveso II, was adopted in 1996. The Seveso II Directive retained the basic principles of major accident hazard controls set out in the original Seveso Directive but addressed some weaknesses and omissions. The new Directive followed a review carried out by the European Commission in conjunction with the Committee of Competent Authorities for the Seveso Directive (made up of representatives of all Member States' governmental bodies enforcing the Seveso Directive). It came into force on 3 February 1997 and was implemented in Great Britain on 1 April 1999 by the COMAH Regulations, except for land use planning requirements (article 12) which were implemented by changes to planning legislation.

5 An amending Directive in 2003 was implemented by changes to the COMAH Regulations. These came into force on 30 June 2005.

Annex 2

HSE's current approach to land use planning

Policy and practice

1 Under the Planning (Hazardous Substances) Regulations, the presence of hazardous chemicals above specified threshold quantities requires consent from the Hazardous Substances Authority (HSA), which is usually also the local planning authority (LPA). HSE is a statutory consultee on all hazardous substances consent applications. HSE's role is to consider the hazards and risks which would be presented by the hazardous substance(s) to people in the vicinity, and on the basis of this to advise the HSA whether or not consent should be granted.

2 In advising on consent, HSE may specify conditions that should be imposed by the HSA, over and above compliance with statutory health and safety requirements, to limit risks to the public (eg limiting which substances can be stored on site, or requiring tanker delivery rather than on-site storage). HSAs should notify HSE of the outcome of all applications for consent and where consent has been granted should supply copies of the site plans and conditions.

3 HSE uses the information contained in consent applications to establish a consultation distance (CD) around the installation. This usually comprises three zones (or 'risk contour areas') – see paragraph 6. The CD is based on the maximum quantity of hazardous substance(s) that the site is entitled to have under its consent. HSE notifies the LPAs of all CDs in their areas. The General Development Procedure Order 1995 requires the LPA to consult HSE about certain proposed developments (essentially those that would result in an increase in population) within any CD.

4 HSE advises the LPA on the nature and severity of the risks presented by the installation to people in the surrounding area so that those risks are given due weight by the LPA when making its decision. Taking account of the risks, HSE will advise against the proposed development or simply note that it does not advise against it. This advice balances the ACMH principle of stabilising and not increasing the numbers at risk, with a pragmatic awareness of the limited land available for development in the UK.

5 HSE's role in the land use planning system is advisory. It has no power to refuse consent or a planning application. It is the responsibility of the HSA or LPA to make the decision, weighing local needs and benefits and other planning considerations alongside HSE advice, in which case they should give HSE advance notice of that intention. LPAs may be minded to grant permission against HSE's advice. In such cases HSE will not pursue the matter further as long as the LPA understands and has considered the reasons for HSE's advice. However HSE has the option, if it believes for example that the risks are sufficiently high, to request the decision is 'called in' for consideration by the Secretary of State, in England and Wales (a very rare situation). In Scotland, if the planning authority is minded to grant permission they have to notify the Scottish Ministers who can decide to call in the application.

Consultation distances and risk contours

6 Using consent information, HSE undertakes a detailed assessment of the hazards and risks from the installation and produces a map with three risk contours representing defined levels of risk or harm which any individual at that contour

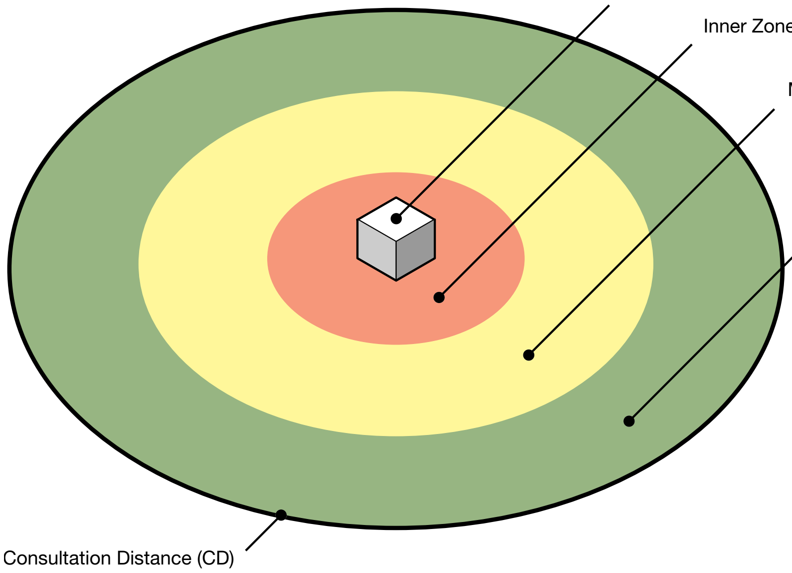
would be subject to. The risk of harm to an individual is greater the closer to the installation. In each case the risk relates to an individual sustaining the so-called ‘dangerous dose’ (see Figure 9) or specified level of harm. The three contours represent levels of individual risk of 10 cpm (chances per million), 1 cpm and 0.3 cpm per year respectively of receiving a dangerous dose or defined level of harm. The contours form three zones (see left), with the outer contour defining the CD around major hazard sites. The LPA consults HSE on relevant proposed developments within this CD.

Figure 9

Dangerous dose would lead to:

- severe distress to all;
- a substantial number requiring medical attention;
- some requiring hospital treatment; and
- some (about 1%) fatalities.

Figure 10



How HSE gives advice

7 When consulted, HSE firstly identifies which of the three defined zones the proposed development is in. Secondly, the proposed development is classified into one of four ‘Sensitivity Levels’. The main factors that determine these levels are the number of people at the development, their sensitivity (vulnerable populations such as children, old people) and the intensity of the development. With these two factors known, a simple decision matrix is used to give a clear ‘Advise Against’ (AA) or ‘Do not Advise Against’ (DAA) response to the LPA, as shown below:

The ‘PADHI’ system

8 The decision matrix above was developed taking into account the experience of 30 years of HSE advice on land use planning. It is built into a software tool known as PADHI (Planning Advice for Developments near Hazardous Installations) introduced in late 2002. PADHI deals with the vast majority of consultations and is operated by staff in local HSE field offices, significantly speeding up responses from previous arrangements which required some specialist HSE resource.

Figure 11

Level of sensitivity	Development in Inner zone	Development in Middle zone	Development in Outer zone
1	DAA	DAA	DAA
2	AA	DAA	DAA
2	AA	AA	DAA
4	AA	AA	AA

Sensitivity level 1	*Example*	Factories
Sensitivity level 2	*Example*	Houses
Sensitivity level 3	*Example*	Vulnerable members of society eg primary schools, old people's homes
Sensitivity level 4	*Example*	Football ground/large hospital

DAA means Do not Advise Against the development
AA means Advise Against the development

Technical assumptions underpinning HSE methodology for land use planning

9 **The installation** The quantities and properties of hazardous substances, and the descriptions of storage and process vessels, are assumed to be in accordance with the 'hazardous substances consent' entitlement for the site since this represents a duty holder's declaration of their entitlement to store such substances which could be introduced at any time. For each type of development HSE's advice to planning authorities will take account of the maximum quantity of a hazardous substance permitted by a hazardous substances consent and any conditions attached to it. Best cautious, but not pessimistic, assumptions concerning substances, locations, operating conditions and surroundings are used. For operations not described in the consent (eg numbers and sizes of road tanker operations, pipework diameters, pumps and other fittings) site-specific values are obtained as necessary.

10 **Hazardous events** All foreseeable major accidents are considered and a representative set of events which describe a set of circumstances which, for that installation, could lead to an accidental release of hazardous substances.

11 **Consequences** The previously described 'dangerous dose' concept is generally used to describe the extent of the impact of any hazardous event on the surrounding population. Protection provided to people by being sheltered within buildings is generally taken into account by the approach, as is the likelihood of people being outdoors at the time of the incident.

12 **Ambient conditions** Local weather data is used to provide wind and stability information around the installation. Further, the surroundings are generally assumed to be flat although ground roughness can be taken into account where circumstances require it.

13 **Risk assessment** The calculations produce contours of the frequency that a typical house resident would be exposed to a dangerous dose or worse. This is generally expressed in terms of 'chances per million per annum' or cpm for short, eg 10 cpm, 3 cpm and 0.3 cpm.

Annex 3

Investigation 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 duty holders 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.

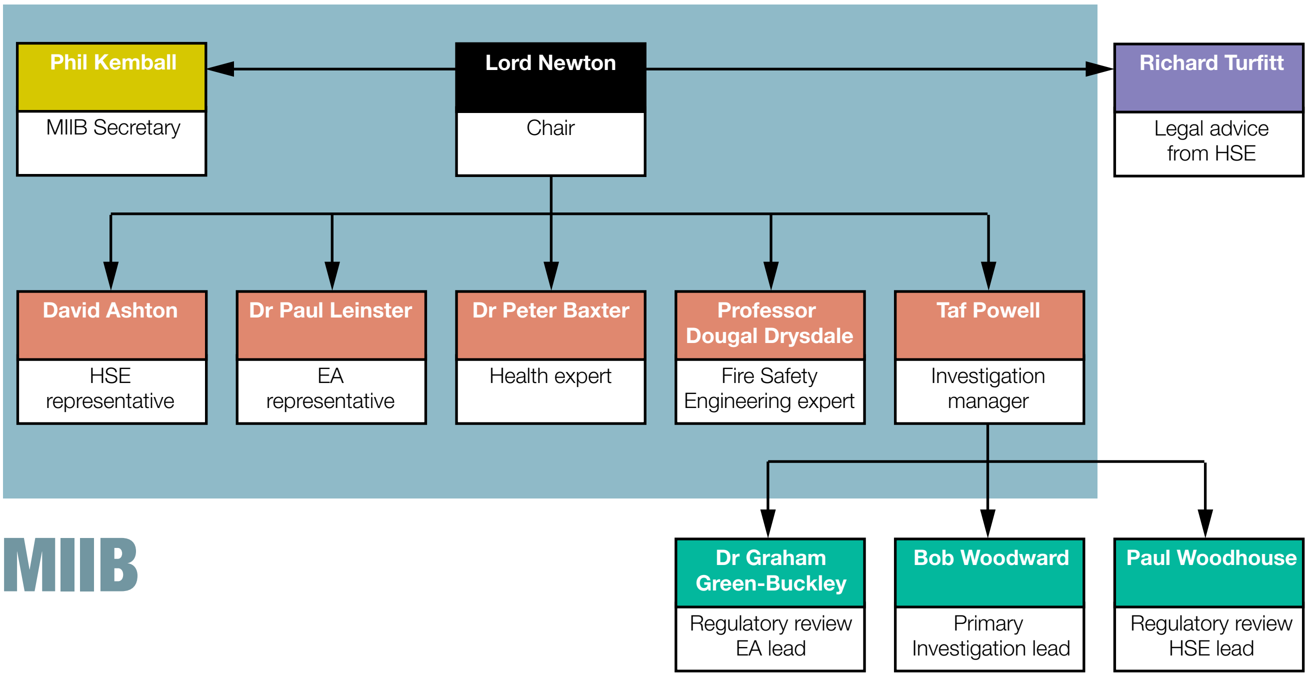
6 To produce an initial report for the Health and Safety Commission and the Environment Agency as soon as the main facts have been established. Subject to legal considerations, this report will be made public.

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

8 To make the final report public.

Annex 4

Major Incident Investigation organogram



Annex 5

Further information

Useful links

Dacorum Borough Council
www.dacorum.gov.uk
Tel: 01442 228000

St Albans District Council
www.stablans.gov.uk
Tel: 01727 866100

Hertfordshire County Council
www.hertsdirect.org
Tel: 01483 737555

Hertfordshire Chamber of Commerce
www.hertschamber.com
Tel: 01727 813680

Government links

Government Office for the East of England
www.go-east.gov.uk

Environment Agency
www.environment-agency.gov.uk

Department of Trade and Industry – Oil and Gas Directorate
www.og.dti.gov.uk

Health and Safety Executive
www.hse.gov.uk

Industry links

United Kingdom Petroleum Association (UKPIA)
www.ukpia.com
Tel: 020 72400289

Chemical Industries Association
www.cia.org.uk
Tel: 020 78343399

Useful sources of information

Dacorum Borough Council Digest newsletter, available monthly

Dacorum Borough Council Buncefield Update Newsletter

Glossary

The Health and Safety Commission (HSC) is responsible for health and safety regulation in Great Britain. The Health and Safety Executive (HSE) (and local authorities) are the enforcing authorities who work in support of the HSC. Both are statutory bodies, established under the Health and Safety at Work etc Act 1974 (the HSW Act).

HSC's statutory functions include conducting and sponsoring research; promoting training; providing an information and advisory service; and submitting proposals to Ministers for new or revised regulations and approved codes of practice. HSC has a chair plus nine members nominated by organisations representing employers, employees, local authorities and others. They are appointed by the Secretary of State for Work and Pensions.

HSE is a body of three people appointed by HSC with the Secretary of State's approval. HSE advises and assists HSC and has specific statutory responsibilities of its own, notably for enforcing health and safety law. HSE's staff of around 4000 (inspectors, policy advisors, technologists, scientific and medical experts etc) is collectively known as HSE.

HSE regulates health and safety in factories, farms, mines, nuclear installations, offshore installations, hospitals, schools and many other sectors. Local authorities are responsible for enforcement in offices, shops and other services.

The Environment Agency (EA) 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 (DEFRA) and the National Assembly for Wales (NAW). EA's prime responsibilities include flood risk management, tackling pollution incidents, reducing industry's impact on the environment, restoring and improving rivers, coastal waters, contaminated land, and wildlife habitats.

EA also advises on sustainable drainage, water conservation and management, planning issues, nature conservation and waste management.

The Control of Major Accident Hazards Regulations (COMAH) are enforced by a joint Competent Authority (CA) comprising HSE and EA in England and Wales, and HSE and the Scottish Environment Protection Agency (SEPA) in Scotland.

3-com	A business whose premises were effected by the Buncefield incident
ACMH	Advisory Committee on Major Hazards
Aquifer	A water-bearing stratum of porous rock, gravel or sand
BAA	BAA plc operate airports, including London Heathrow
Boreholes	A cylindrical shaft drilled into the ground, often for geological exploration or extraction of resources
Bund	An enclosure designed to contain fluids should they escape from the tank or vessel inside the bund
Catherine House	A building effected by the Buncefield incident

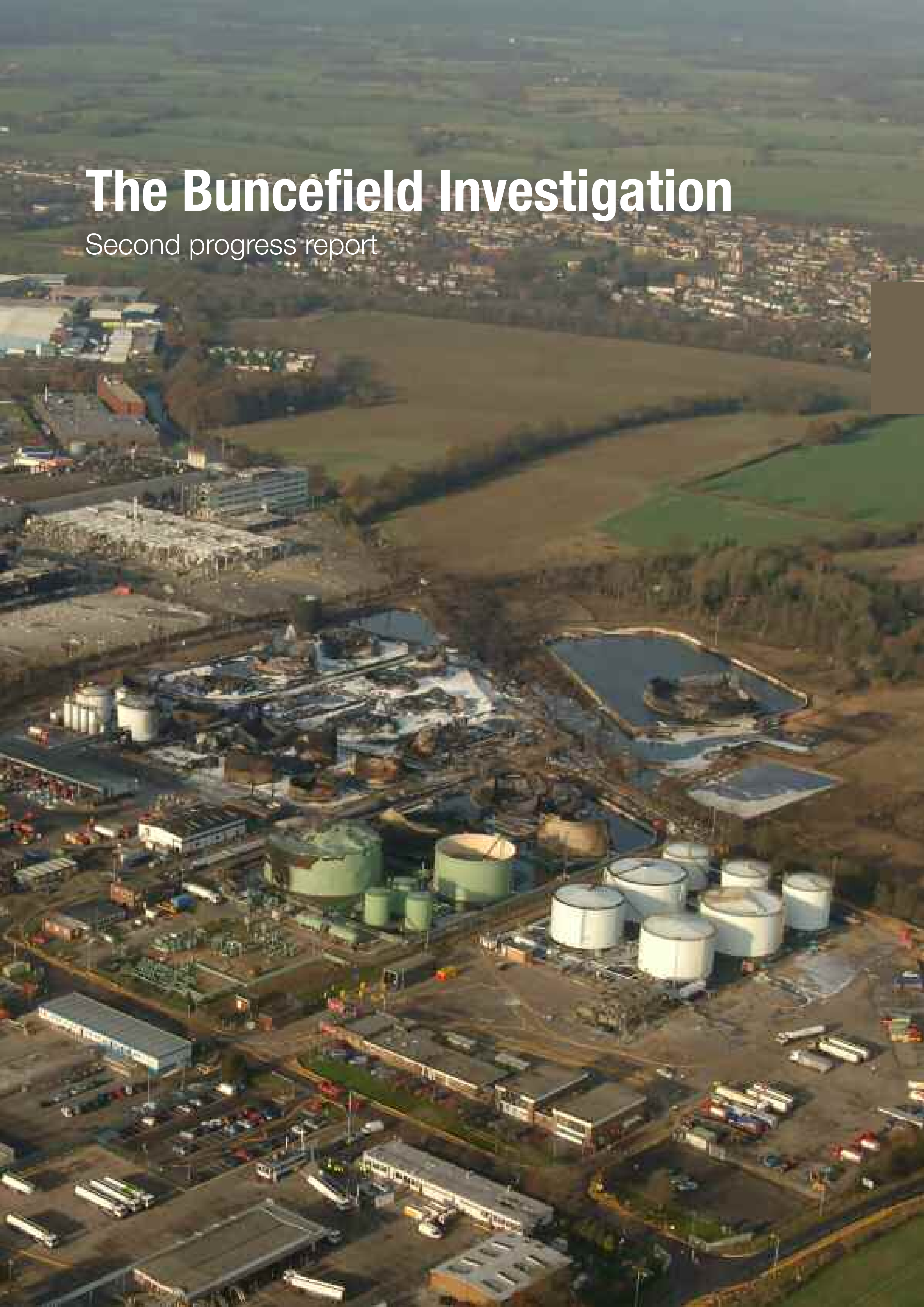
COMAH Regulations	The Control of Major Accident Hazards Regulations 1999 (COMAH). See annex 1
COMAH sites	A site to which the COMAH Regulations apply
Competent Authority	The COMAH Regulations are enforced by a joint Competent Authority (CA) comprising HSE and EA in England and Wales, and HSE and the Scottish Environment Protection Agency (SEPA) in Scotland. The CA operates to a Memorandum of Understanding which sets out arrangements for joint working
dangerous dose	A dose large enough to lead to: severe distress to all; a substantial number requiring medical attention; some requiring hospital treatment; and some (about 1%) fatalities
dioxin	Toxic chemical by-products of incineration and some industrial processes that use chlorine
duty holder	In the context of this report, any person or organisation holding a legal duty – in particular those placed by the HSW Act, the MHSWR, and the COMAH Regulations
fire water	Water stored for use during, and used during, fire-fighting operations
foam concentrate	In the context of this report, a concentrate used during operations to extinguish hydrocarbon fires
Fuji	A business whose premises were effected by the Buncefield incident
hazard	Anything with the potential to cause harm
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
Northgate	A business whose premises were effected by the Buncefield incident
on- and off-site and emergency plans	Operators of top-tier COMAH sites must prepare adequate emergency plans to deal with the on-site consequences of possible major accidents and to assist with off-site mitigation. Local authorities for areas containing top-tier COMAH sites must prepare adequate emergency plans to deal with the off-site consequences of possible major accidents, based on information supplied by site operators
particulates	Fine particles (liquid or solid) suspended in the air such as dust, smoke, fumes, and so on

Pasquill stability category	A category within a classification scheme used to describe the degree of atmospheric turbulence
pollution dispersion model	A model used to describe the transport and diffusion of pollutants in the atmosphere
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
responder	Under the Civil Contingencies Act 2004, EA 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
RO	A business whose premises were effected by the Buncefield incident
run-off	Uncontained liquid, either deposited on-site as rain, or in the context of the Buncefield incident, fuel and/or fire water not contained as part of the operation to control the incident
safety reports	The COMAH Regulations require operators of top-tier sites to submit written safety reports to the Competent Authority
tier	The COMAH Regulations apply where threshold quantities of dangerous substances identified in the Regulations are kept or used. There are two thresholds, known as 'lower-tier' and 'top-tier'. Annex 1 gives a brief background to the origins of these Regulations
volatile	A substance which evaporates readily, even below its boiling temperature
watercourses	A natural or man-made channel along which water flows

Published 02/06

The Buncefield Investigation

Second progress report



Contents

Foreword

I present a second progress report that focuses mainly on the environmental impact on land, surface water and ground water of the fuel and fire water that escaped from the Buncefield site. It is important, in my view, that the vital work being done by the Environment Agency and others is brought to public attention.

My report also contains for completeness a brief update on progress with the investigation into how fuel escaped, thereby breaching the primary containment barriers. It reveals that cloning of a number of important computer records has been successful and that vapour formation modelling is underway. Although briefly stated, this is important new information – it was quite possible that these disks would be too badly damaged for the information on them to be recovered.

The report is, as I say, mainly a description of loss of containment of fuel and fire water from bunds (secondary containment) and from the site itself (tertiary containment).

There are important early observations that sealant used in some bund walls was not capable of withstanding fires and/or the hydraulic pressure in bunds or adjacent tanks. Bund performance during the incident forms an important but as yet inconclusive aspect of the investigation.

There was massive loss of containment at the site boundaries and fuel and fire water escaped from the site to the surrounding lands. The report describes the monitoring work by the Environment Agency and others to identify whether or not short and long-term pollution of watercourses and ground waters has or is likely to occur, particularly potential contamination of the important chalk aquifer that underlies Buncefield. The pathways for pollutants are still being investigated. It is important to emphasise that if contamination of the aquifer occurs from the Buncefield incident, it could take months or years to materialise. However, we have been reassured by Three Valleys Water Company and the Drinking Water Inspectorate that drinking water is of a high quality and has not been affected by this incident.

A further report to the Board on the means of escape of the fuel and the formation of flammable vapours is suggested as possible within a month of this report, provided we are able to continue the good rate of progress that the investigation is making.

Taf Powell
Buncefield Investigation Manager and Member of Buncefield Major Incident Investigation Board

Part 1 Progress with the primary investigation

1.1 Loss of containment of fuel and contaminants

Background

1 Fuel depots such as Buncefield are strategic centres for the distribution of liquid fuels such as diesel, unleaded petrol and aviation fuel. Fuel comes to depots via pipelines from refineries and is stored according to fuel type before being distributed to other places (typically points of use, such as petrol stations and airports) either by road tanker, by rail, or by dedicated pipeline.

2 Fuel depots are designed to keep fuel within the vessels and pipework that store and distribute them. Should fuel escape, there needs to be provision for ensuring that fuels, and the contaminants associated with any emergency response to a fuel escape or fire, are prevented from running off site so as to protect the surrounding environment. The provisions for keeping escaped fuel and other contaminants within the site (referred to as containment) is described in the safety report that operators of large sites such as Buncefield must submit to the Environment Agency (EA) and the Health and Safety Executive (HSE) (the 'Competent Authority').

3 There are typically three levels of containment. **Primary containment** relates to the equipment and facilities that have direct contact with the products (eg tanks and pipework), and their operation and management.

4 **Secondary containment** relates to both the control of the product in the primary containment facilities (eg the provision of tank high-level alarms to prevent loss through overfilling) and any contingency provisions for the failure of the primary containment. The most important of these provisions are bunds, which are enclosures capable of holding liquids that may escape from the vessels and pipes within the bund wall.

5 There are a number of types of bunds across the Buncefield Depot, ranging from earth banks with earth bases to concrete walls with concrete bases. In the area most affected by the fire, the bunds were predominantly of concrete construction, although some had concrete walls and clay floors.

6 **Tertiary containment** relates to the site surface and associated drainage, boundary walls, roads, 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 ground water, or contaminate surface waters and land.

7 At Buncefield, the site slopes downwards in a north-easterly direction towards Cherry Tree Lane, a public road running between the main site and the British Pipeline Agency Ltd (BPA) tank 12, at the north of the depot. There is a general slope from west to east. Cherry Tree Lane has a depression about half way along its length near to the to BPA's tank 12 area, before sloping away to the east and the junction of Green Lane and Hogg End Lane.

Loss of fuel from vessel(s)

8 The first *progress report*[1] noted that the explosions and fires on 11 December 2005 were the result of a massive escape of fuel in the vicinity of bund A on the Hertfordshire Oil Storage Ltd (HOSL) West part of the site. This escaped fuel formed

[1] www.buncefieldinvestigation.gov.uk

Figure 1 Site map showing bunds

a flammable mixture with the air. Little was known about how primary containment was lost or how the escaping fuel formed into a flammable mixture. (Figure 1 shows a schematic of the bunds.)

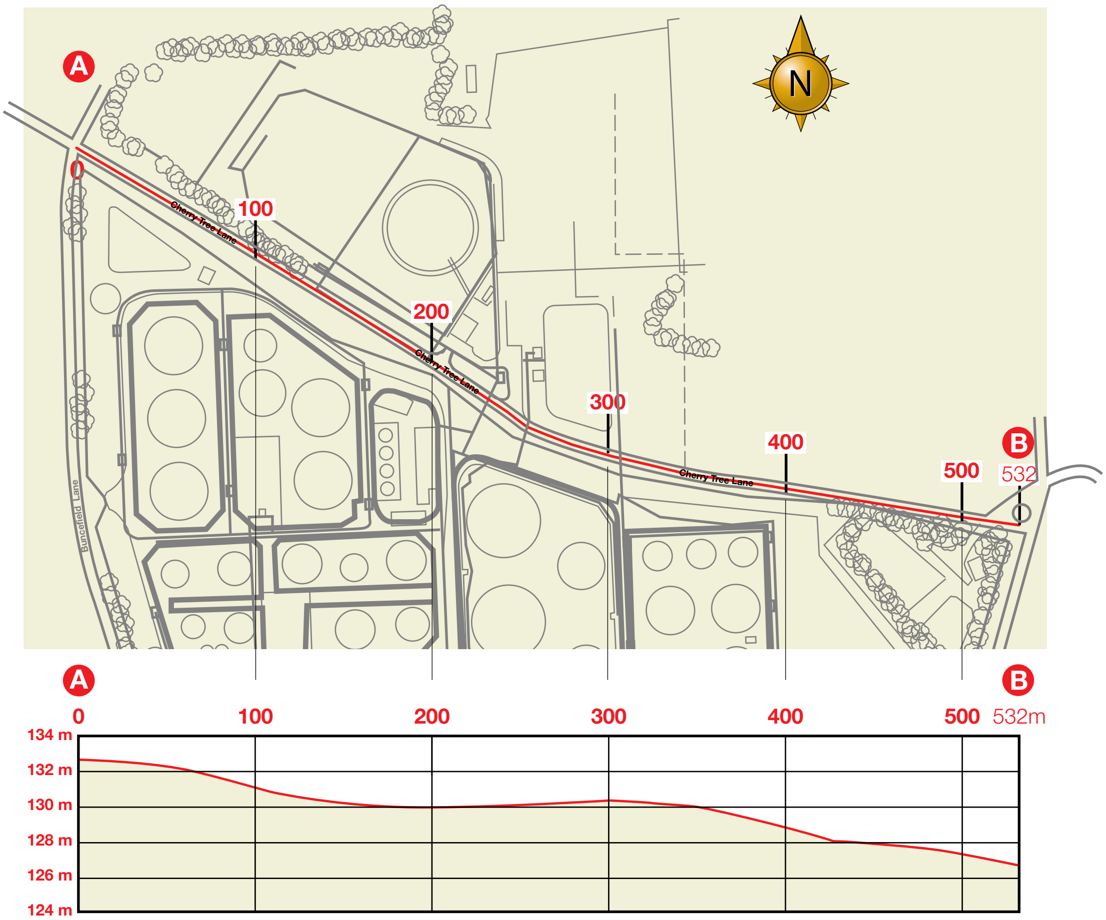
9 Progress has been made in determining the main source of escaped fuel. CCTV recordings recovered from the south side of the BPA site show the visible mist, associated with the loss of containment of the fuel, drifting eastwards onto the site from the adjacent HOSL West site shortly before the first explosion. This is consistent with the evidence obtained from other CCTV coverage and detailed in

the first *progress report,* and appears to confirm that the initial escape of fuel was from the HOSL West site. CCTV records from the Northgate building provide further confirmation of the spread of the flammable cloud away from the HOSL West site. This information also supports the initial forensic conclusions about the extent of the flammable cloud in this vicinity.

10 A significant amount of information has now been obtained from the extensive electronic equipment used to control and monitor the operations on site. Much of the equipment was housed in damaged buildings and great care had to be taken to ensure its safe removal and subsequent restoration and examination. This has revealed important information on key parameters such as fuel levels in tanks, flow rates and valve positions. Work is continuing to extract this information and to examine it in detail so as to conclude with confidence how the fuel escaped. It is hoped this work will be completed within five weeks of this report.

11 A key aspect of the investigation is to determine how the escaping fuel vaporised so rapidly. Work has been commissioned from the Health and Safety Laboratory (HSL) to assist with this. The work is being carried out as quickly as possible to enable feedback to the investigation team within the next month. In particular, priority is being given to the composition of the fuel and to modelling how the escaping fuel could have been vapourised under the prevailing weather conditions. This work should provide a link between the possible release events indicated by the control and instrumentation records and the clear evidence of mist formation coming from witness statements and CCTV records.

Figure 2 Schematic of topography at Cherry Tree Lane



Ground profile along Cherry Tree Lane (West to East)

12 In parallel with the work on vapour cloud formation, HSL is helping to determine the exact nature and composition of the flammable mixture and to determine the precise mechanism for generating such a violent explosion within an apparently unconfined vapour cloud. This work is supported by analysing other incidents from around the world and assimilating technical information from them.

13 Good progress on damage assessment, both on and off site, has given added momentum to the work to explain the high level of blast damage caused by the explosion.

14 A systematic fuel sampling programme is being carried out to confirm the composition of products being stored and transferred on site in tanks or pipes. This programme has had to be fitted into the remediation work being carried out on site by the operators, under the control of two Prohibition Notices issued by HSE.

Loss of fuel and contaminants from bunds

15 There was significant loss of secondary containment related to the bunds on the HOSL West and BPA sites. Investigators have not been able to gain access to every part of the sites, in particular to some of the bunded areas, because of continuing safety concerns. It has been possible, however, to identify some key issues related to the condition of the bunds after the fire. A more systematic examination of the bunds will be completed only when it is safe to do so, following final removal of product from a number of pipework sections.

16 While the bunds substantially remained standing throughout the incident, their ability to fully contain the fuel and fire waters was lost as a result of the explosion and subsequent fires. Figure 3 shows the damage caused to bund walls as a consequence of the incident. Pools of fuel were burning in the bunds as a result of loss of fuel from the tanks, along with fires from the tanks themselves. Figures 4 and 5 show a bund, where the concrete panels had been infilled with a joint sealant. This sealant has been lost as a result of the fire and/or hydraulic pressure within the bund.

Figure 3

Figure 4

Figure 5

Figure 6

17 Many of the bunds around the site have suffered varying degrees of sealant damage. Figure 6 shows fire water and product leaking from such a joint in the later stages of the incident.

18 Another two leakage mechanisms can be seen in Figure 7. Here a corner joint has opened up, releasing fire water and product. Visible along the lower edge of the bund wall, a 'tide mark' shows where liquids were seen to seep through the concrete itself.

19 Figure 8 shows the base of a bund where the concrete panels have undergone significant 'heave' which has resulted in the escape of product and fire water.

Figure 7

Figure 8

20 Figure 9 shows the inclusion of penetrating pipework in the construction. Here the sealing material surrounding the pipes has been lost.

Loss of contaminants from the site

21 There was extensive loss of tertiary containment and large amounts of contaminant went off site. The burning fuel formed an extensive plume of smoke. Ground and water contaminants include fuel and products of its degradation in the fire – hydrocarbons and polycyclic aromatic compounds (a group of chemicals commonly found in residues from burning coal, fuel and oil).

22 Some fire-fighting foam concentrate contains zinc (to act as a heat resistor) and a chemical called perfluorooctane sulphonate (PFOS), which is a surfactant to aid the spreading properties of the foam. Zinc and PFOS are useful tracers for the movement of fire-related contaminants off site.

23 There are lagoons on the site which provide a reserve of fire water for use in emergencies. One of the lagoons (to the north of bund A) shows evidence of significant damage to the lining that may have resulted from the explosion or the fire.

24 As a result of the breach to the lining, some of the liquids in the lagoon, which included contaminated run-off liquids from the bunds and fire fighting, may have escaped into the ground. The natural clay layer beneath the site would have helped to minimise the extent of any contamination of the ground from this source.

25 The pumphouse to the north of bund A, adjacent to the lagoon, was destroyed by the explosions. The control of water on the site was dependent on the use of the pumps located within the pump house. Because the initial explosions destroyed all of the fire-fighting equipment in the affected area, the lagoons were never brought into use and the fire services had to establish alternative arrangements.

Figure 9

Figure 10

26 During the incident, the internal roadways were submerged by fire water and fuel flowing to the lowest point. Fire water and fuels flowed through the site drainage and along the roads within the site perimeter. At the low point on the site perimeter the flows overtopped the road edge, which was not kerbed, and flowed into Cherry Tree Lane.

Figure 11 The three parallel bars show where the pumphouse stood before the incident

Figure 12

27 A large pool of liquid, consisting of fire water and fuels that escaped from tanks and pipes, collected in Cherry Tree Lane. It is estimated that this pool was 200 m in length and between 10 and 20 m wide. Road tankers removed the liquids in the pool by the first week in January this year.

28 The investigation has highlighted a number of potential pathways by which fuel and contaminated water could have entered the environment. Within the site, shallow boreholes of 4-5 m depth exist within the terminal, and a deep borehole is located in the Chevron/Texaco tanker park, directly due south of the HOSL and BPA sites that were on fire. This borehole is 42 m deep, extending into the chalk layer.

29 A number of places where contaminants could penetrate the ground have been found around the perimeter of the site: on the northern and southern verges of Cherry Tree Lane; on the western verge of Buncefield Lane; and the southern verge of Hogg End Lane. These drains and chambers were either submerged in fire water and fuel or had drains connected to them that delivered such contaminants.

30 Cherry Tree Lane has a number of road drains, some of which are connected to deep chambers. At the bottom of one appears to be a borehole at least 40 m deep penetrating the chalk aquifer. For a description of the local geology and aquifer, see paragraph 41.

Figure 13

1.2 Monitoring environmental impact

Air quality

31 Monitoring air quality impact of the incident was carried out by a number of organisations. The Health Protection Agency was chiefly responsible for organising the air quality monitoring in the vicinity of the Buncefield site. The Agency received the support of HSL and, via the Hertfordshire Fire Brigade, the London Fire Brigade Scientific Advisers. A Meteorological Office (Met Office)/Natural Environment Research Council aircraft also sampled the plume. This was supplemented by local monitoring organised by the Department for Environment, Food and Rural Affairs (DEFRA). DEFRA's Automatic Urban and Rural Network (AURN) and local authority air monitoring networks monitored the impact on air quality over the wider region of southern England, including London. French regional air networks monitored potential impacts in northern France. In addition, the Met Office carried out modelling of the plume and DEFRA's air quality information service published regular reports on air quality. The Environment Agency also carried out modelling of the short range impacts in support of the Met Office, which was used by the Health Protection Agency in part to develop the strategy for subsequent sampling of grass and soil.

32 DEFRA is planning to publish a report on *Air quality impact of the Buncefield Oil Depot explosion* in May. This report will describe the monitoring carried out in England and France during the incident, and assess the air quality impacts. It will also describe the modelling of the plume and estimate the emission of pollutants released in the fire. This will inform the considerations as to whether the Buncefield incident will be designated a major accident to the environment (MATTE) under COMAH as a result of the impact of the smoke plume.

33 DEFRA is keeping the Board informed of progress with its findings. DEFRA's website can be found at www.defra.gov.uk. The Health Protection Agency is also keeping the Board informed of progress of its findings. HPA's website can be found at www.hpa.org.uk.

Surface water

34 Extensive sampling of surface and ground waters around the site has been carried out to assess the environmental impact of the incident. Samples of liquids and contaminated soils have been sent to Environment Agency laboratories around the country for analysis.

35 Surface water monitoring has concentrated on the River Ver, as it receives surface water from the Buncefield site. Two balancing tanks (which provide buffers to prevent uncontrolled surges of water), the Maylands and Redbourn lagoons, receive surface water from the site and the surrounding area, and subsequently discharge into the River Ver.

36 The River Ver was monitored daily in the first two weeks after the incident. Two sites, one upstream and one downstream of the Maylands tank outfall, were tested. The balancing tanks and outfalls were also subject to daily sampling and analysis. The initial focus was on potential fuel and fire-fighting foam contamination which could impact on the ability of fish and other organisms to live in the river and on drinking water.

37 Two additional monitoring sites were added at the end of December, both on the River Colne, which is a tributary of the River Ver. These were both south of St Albans, 7 and 11 km downstream of the Maylands outfall. All of these points were sampled for PFOS.

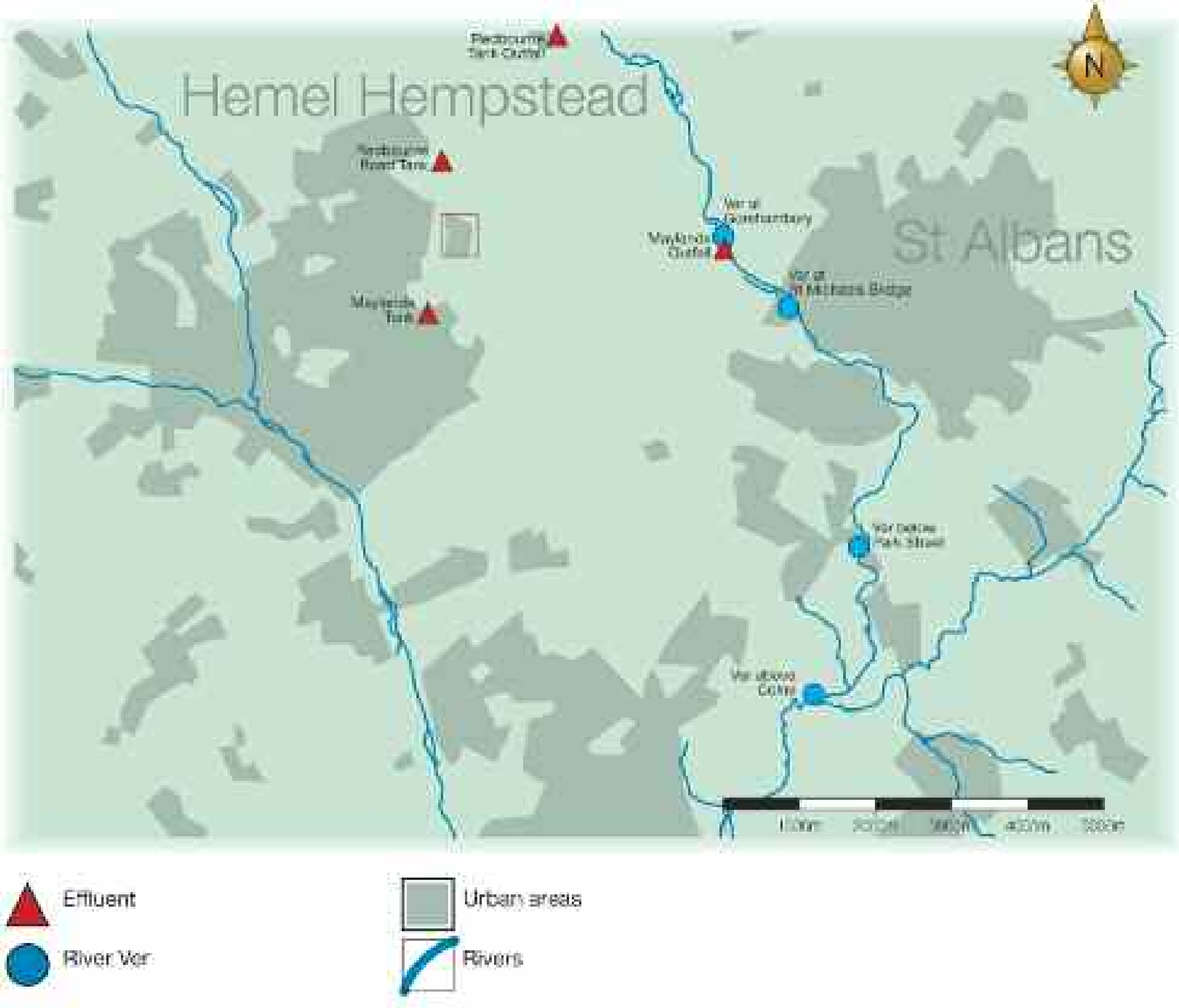


Figure 14

38 No direct impact of spills was found in the first days after the incident. By the third day of the incident, detectable but low concentrations of PFOS were noted in the balancing lagoons, at the Maylands outfall and in the River Ver downstream of the outfall. In addition, there was an increase in zinc above background concentrations.

39 PFOS was identified at all monitoring points, including in the River Colne. The PFOS concentrations, however, were less than the provisional water quality threshold concentration specified by the Drinking Water Inspectorate (DWI) and no identifiable environmental consequences have been observed in the river habitat.

40 Levels of PFOS started to drop in the River Ver in the middle of January, falling below detectable limits in February. The flow of water from the Maylands outfall stopped in February. However, the water that remains within this lagoon has low concentrations of PFOS.

Ground water

Geology

41 The Buncefield Depot and the immediate surrounding area are positioned on a variable layer of clay with flints over Upper Chalk. The clay with flints layer is classified as a low permeability surface deposit and is believed to be present at a variable thickness of between 2 and 10 m. This layer should inhibit the vertical and lateral migration of contaminants and protect the chalk aquifer below, where present in sufficient depth.

42 The Upper Chalk is classified as a major aquifer, which provides water supplies regionally. The Depot is located within the catchment of a ground water abstraction point located to the south and east of the depot. Ground water is present typically at a depth of 45 m below ground level and flow is generally towards the south-east. Natural holes in the chalk rocks, which allow quicker than normal water migration, may be present, but none have been positively identified in the Buncefield area. Ground water is water held naturally in the chalk rocks underground. This can be abstracted for drinking water and other purposes.

43 Regional ground water in the vicinity of the Buncefield site flows to the south east but there are possibly some local variations or preferential flow along dry valleys that may put Bow Bridge, Mud Lane/Holywell and Hunton Bridge pumping stations at a higher risk of contamination.

Monitoring

44 Ground water and ground water abstraction boreholes have been monitored up to 9 km surrounding the site. These include six pumping stations operated by Three Valleys Water Company, two private boreholes and a number of Environment Agency monitoring sites.

45 Three new observation boreholes have been drilled closer to the Buncefield site to provide early detection of any ground water pollution: Butlers Farm (between Buncefield and Bow Bridge Pumping Station); Breakspear House (south of Buncefield); and Hogg Lane (on the east boundary of Buncefield – see Figure 16). This is part of an ongoing monitoring regime that will provide further boreholes surrounding the site. They have each been sampled once, along with drinking water boreholes, and analysed for pollutants.

Figure 15 Picture of Maylands Tank outfall into River Ver

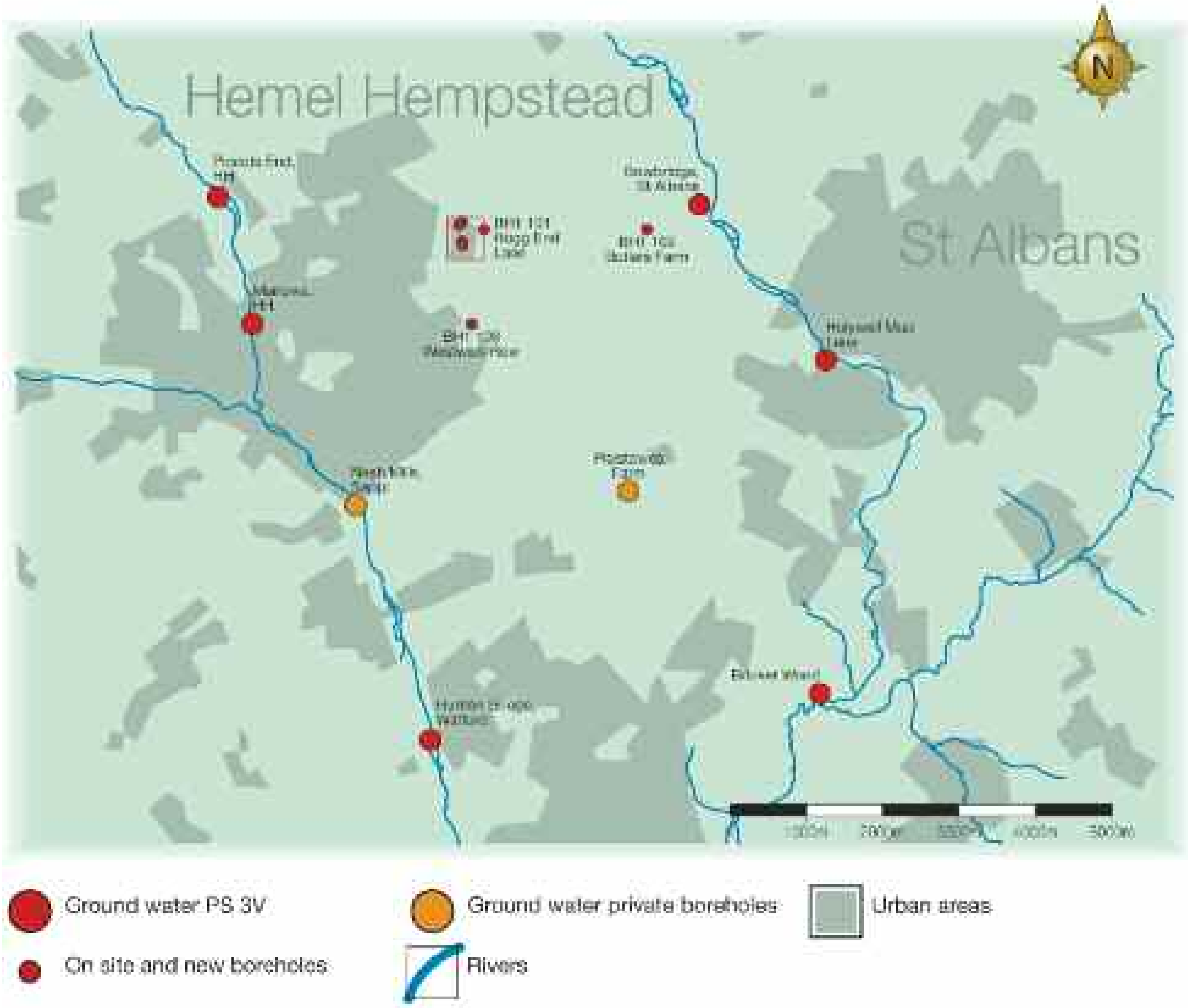


Figure 16 Map of ground water boreholes

Figure 17 A new borehole at Cherry Tree Lane

Results of monitoring

46 It is too early to rule out potential contamination of the ground water, as it can take many months or years for water to drain through the ground into the chalk aquifer. Overall, the results received to date do not suggest any identifiable contamination pattern which is directly attributable to pollution from the incident.

47 A limited number of results have indicated the presence, at limits just above detection, of PFOS and other contaminants such as oil or polycyclic aromatic hydrocarbons. These results need to be considered in relation to the overall picture for the whole of the aquifer, especially as the ground-water flow has not been established.

48 The 42 m deep borehole located on the Chevron/Texaco lorry park on the Buncefield site, south of HOSL West has been sampled (see paragraph 28). Initial results indicate fuel is present at low concentrations. It is not yet known if this contamination is historic or a result of the incident. Investigations continue.

49 The four points of ground penetration around the perimeter of the site reported in paragraph 29 are being investigated. Some of the chambers and deep boreholes associated with these entry points may contain contaminants from the incident.

Drinking water

50 The closest drinking water abstraction point to the Buncefield site is the Bow Bridge pumping station approximately 3 km due east. Drinking water was not being pumped from here prior to the incident and the station remains out of operation as a precautionary measure. As a further safeguard, non-return valves have been fitted to prevent any possible backflow of water from the site. Changes have also been made to the supply arrangements to ensure drinking water supplies are maintained. The other drinking water abstractions are located in a ring around Buncefield at a distance of more than 5 km.

51 Water supply in the area is the responsibility of Three Valleys Water Company which has the detailed operational knowledge required to manage the local response. The regulation of drinking water quality is the responsibility of DWI.

52 Three Valleys Water Company and DWI are working closely together to ensure that drinking water supplies remain of the highest quality. Water companies treat and monitor the quality of water before it is distributed to the public as drinking water, thus providing reassurance of its quality.

Land investigations

53 Investigations to assess the extent of land contamination started in February 2006 along Cherry Tree Lane. Trial pits were excavated at points along the Lane and on site and a number of samples taken for laboratory analysis. The locations of the trial pits are indicated in Figure 18.

54 The initial findings indicate that the surface layer of the soils, the top 30 cm approximately, was contaminated with fuel and fire-fighting products. No visible free product was detected in any of the trial pits at depth. PFOS, hydrocarbons and polycyclic aromatic hydrocarbons have been reported in the laboratory analysis.

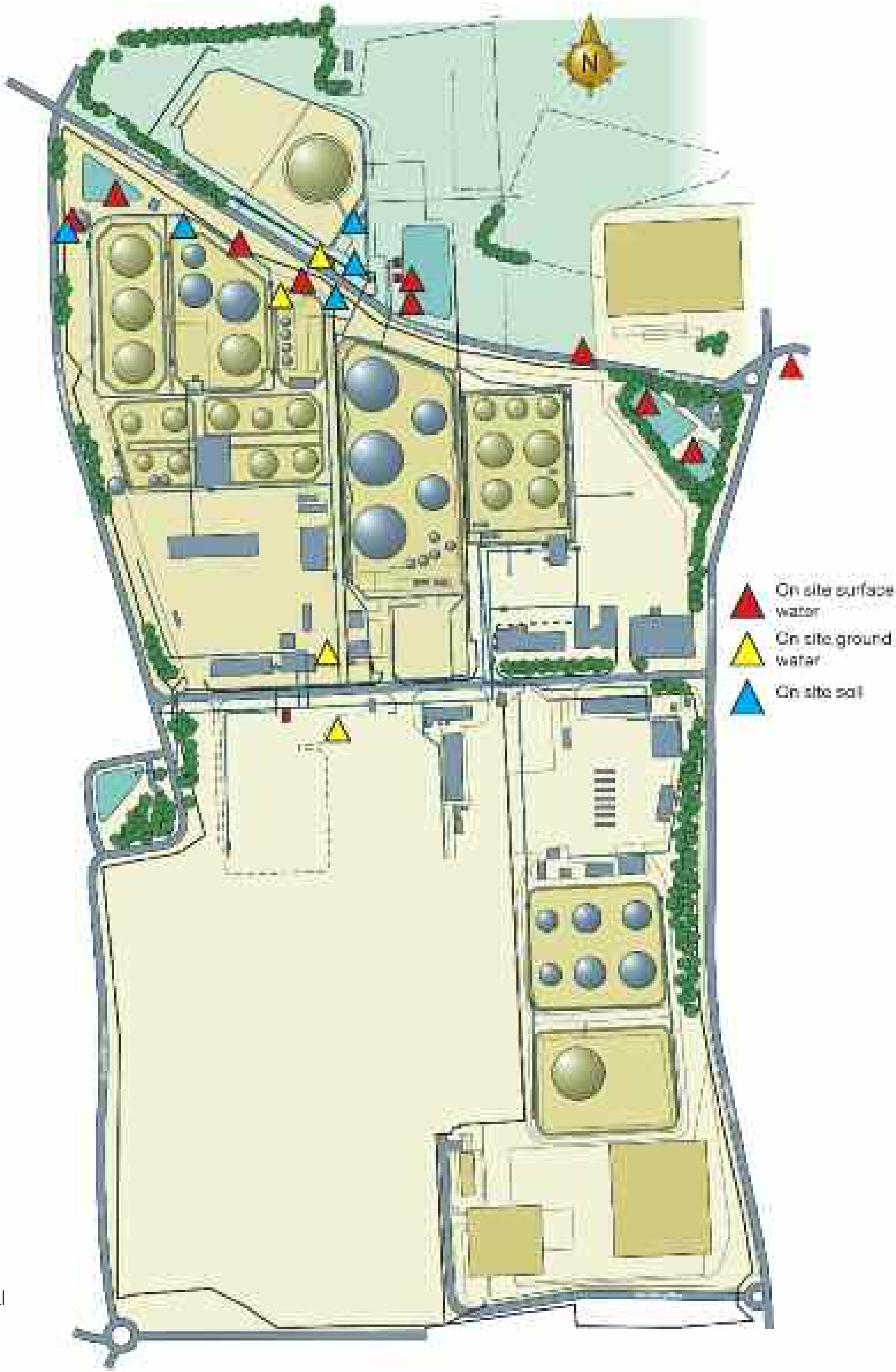


Figure 18 Location of trial pits

Disposal of fire water

55 All contaminated fire water has been removed from the site and is being safely and securely stored at a number of sites around the country. Thames Water holds the largest quantities. There are approximately twelve million litres at Maple Lodge Sewage Treatment works near Rickmansworth and four million litres at Blackbirds Treatment near Radlett.

56 The disposal of these fire waters is the responsibility of the oil companies. The Environment Agency await definitive risk assessments from the companies on their proposed best practicable disposal options to avoid risk of contamination of the environment.

57 Rainfall will give rise to more contaminated water within the Buncefield site. This will be contained on site before being safely removed.

1.3 Progress with other aspects of the major investigation

Acting on regulatory advice (Investigation term of reference two)

58 HSE issued an alert to fuel depot operators on 21 February 2006 in response to the first *progress report* to the Board, seeking a response from depot operators by Easter 2006. The Competent Authority has also begun a programme of depot inspections targeting the key findings in the first *progress report*. A report of the programme's findings is expected in late May. This will be of importance in improving the control of major hazards at fuel depots.

Working with others and communities (Investigation term of reference four)

59 Lord Newton has written to other agencies and authorities that may undertake reviews of the Buncefield incident. The investigation team is actively engaged with communities and businesses in the Buncefield area. See Part 2 of this progress report for further information on this aspect.

Report to the European Commission (Investigation term of reference seven)

60 A report has been sent to the European Commission by the Competent Authority to discharge a responsibility under the Control of Major Accident Hazards (COMAH) Regulations 1999.

Part 2 Current business and community issues

61 Four months on from the incident, the local community is still facing a variety of difficulties. In these challenging circumstances both individuals and businesses have demonstrated remarkable resilience.

62 The incident has had significant impact on some individuals' day-to-day lives, leading to changed circumstances, including in some cases unemployment. These factors contribute to heightened levels of stress and anxiety.

63 A number of properties that sustained significant structural damage are still being repaired, and in some cases residents are as yet unable to return home.

64 Many businesses forced to relocate away from Maylands Estate in the immediate aftermath of the incident are still facing challenges to deliver pre-incident levels of service. Some businesses based beyond Maylands have seen an associated drop in their levels of business.

65 The uncertain future of the Buncefield Oil Depot continues to cause concern to local businesses, employees and residents.

66 Dacorum Borough Council is working with community and voluntary sector organisations to provide a wide range of services, including advisory and training, to people affected by the incident. Business advice and support is being provided by both the Council and Hertfordshire Chamber of Commerce.

67 Board members have also met with local residents at Woodhall Farm and at Leverstock Green and will repeat the exercise at Adeyfield. A meeting with the Maylands business community will take place in April. The investigation team and Members of the Board have also met with representatives from Dacorum Borough Council, St Albans District Council and Hertfordshire County Council, as well as with Mike Penning (the local Member of Parliament), local councillors, Hertfordshire Police and Hertfordshire Fire and Rescue Service.

68 The investigation team and Dacorum Borough Council are working to ensure progress with the investigation is widely available to residents and businesses. Details of the first *progress report* were explained in Council newsletters to residents and business, such as *Dacorum Digest, Buncefield Update* and *Business Update*. The investigation team will continue to look for new and more effective means of communicating with people and businesses affected by the Buncefield incident.

69 An Investigation website contains useful information about the Investigation and the Board at www.buncefieldinvestigation.gov.uk.

70 Further meetings with residents and businesses in these areas will be arranged as the investigation progresses.

Part 3 Further work

3.1 Explosion and fire

71 The investigation priority is to establish how the fuel escaped from the vicinity of the HOSL site, and vapourised to form a flammable mixture that subsequently ignited with devastating results. Digital and other records, physical tracing of control systems, valve positions and other work on site, analysis of fuel samples and modelling of vapour formation under the prevailing conditions are therefore top priorities.

72 It is hoped that enough of the work will be completed within a month of publishing this second *progress report* to enable a further, third *progress report* to be made to the Board that describes with confidence how the fuel escaped and vapourised.

73 In parallel, further lines of investigation have been established. These include:

- pursuing information on other incidents of an apparently similar nature to Buncefield from around the world;
- completing an assessment of the extent of damage off site;
- modelling the ignition mechanism that generated massive overpressure from an apparently unconfined vapour cloud;
- modelling the dispersion of the flammable vapours; and
- development and propagation of the explosion.

74 Separately, work to ascertain why control of fuel was lost forms a continuing and key part of the primary investigation.

3.2 Environmental impact

75 The site drainage system was initially built when the site was commissioned in 1968 and has developed over the intervening years. A system of surface water drains and porous land-drains is evident but not yet fully mapped. A detailed examination of the site drainage system is underway. This will help to better define the flows during the incident.

76 Sampling of surface water will continue to monitor the potential effects of the Buncefield incident on surrounding watercourses (eg rivers and ponds).

77 Ground water monitoring by sampling of drains, subsurface chambers, pits and boreholes will continue. New boreholes will be sunk as further improved knowledge emerges of the drainage pathways from the site.

78 Analysis of fuel samples to get a 'fingerprint' has not yet been completed but it is one of the key steps in ascertaining whether contamination is a result of the incident (eg in determining whether the low-level contamination in the borehole sited in the lorry park south of the HOSL West site is new or historic).

79 Off-site, sampling of soil, sediment, and other materials, and CCTV examination of the drains around the perimeter of the Buncefield site is also continuing to develop a greater understanding of drainage and contamination.

80 DWI and Three Valleys Water Company will continue to work together to maintain supplies of high-quality drinking water.

81 The site operators are developing plans for the safe and environmentally sound disposal of fire water and other pollutants that have been removed to storage off site.

Annex 1 Further information

Useful links

Buncefield Investigation

Buncefield Major Incident Investigation
Marlowe Room, 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

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

Resident's support

Dacorum Community Trust Mayors' Fund
To apply, call the freephone helpline on 0800 131 3351. Lines are open from 9 am – 6 pm, 7 days a week.

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

Citizens Advice Bureau

Hemel Hempstead Citizens Advice Bureau, based in Hillfield Road, offers free, impartial, practical and confidential advice on a range of subjects.

Local authorities and emergency services

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

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

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

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

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

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

Government links

Office of the Deputy Prime Minister
Fire and Resilience Directorate: www.odpm.gov.uk

Government Office for the East of England
www.go-east.gov.uk

Environment Agency
www.environment-agency.gov.uk

Department of Trade and Industry
Oil and Gas Directorate: www.og.dti.gov.uk

Health and Safety Executive
Hazardous Installations Directorate: www.hse.gov.uk/hid
Control of Major Accident Hazards: www.hse.gov.uk/comah

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

Health Protection Agency
www.hpa.org.uk

Food Standards Agency
www.food.gov.uk

Drinking Water Inspectorate
www.dwi.gov.uk

Industry links

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

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

Other useful sources of information

Dacorum Borough Council *Digest* newsletter, available monthly
Dacorum Borough Council *Buncefield Update* Newsletter

Annex 2 Investigation 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 duty holders 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.

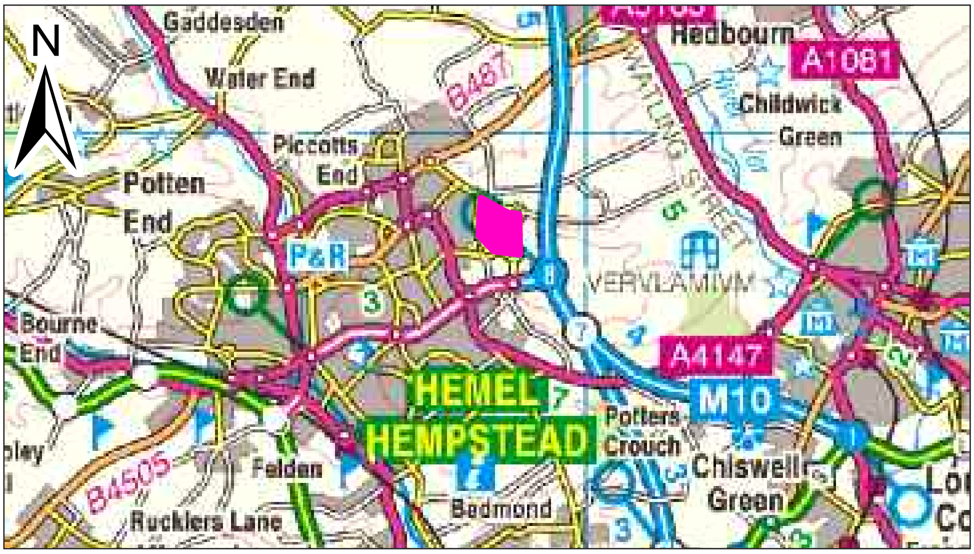
5 To make recommendations for future action to ensure the effective management and regulation of major accident risk at COMAH sites. This should include consideration of off-site as well as on-site risks and consider prevention of incidents, preparations for response to incidents, and mitigation of their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

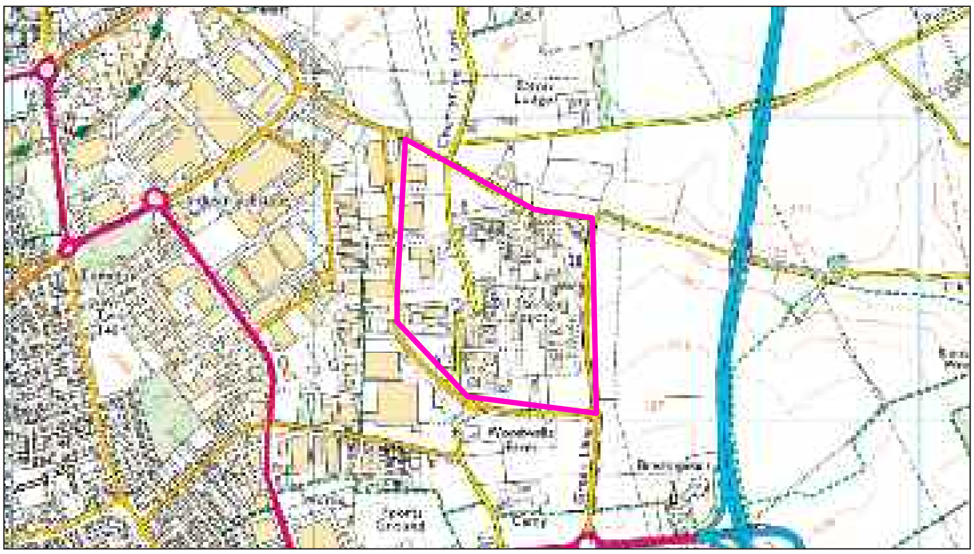
6 To produce an initial report for the Health and Safety Commission and the Environment Agency as soon as the main facts have been established. Subject to legal considerations, this report will be made public.

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

8 To make the final report public

Annex 3 Site maps





Glossary

The Health and Safety Commission (HSC) is responsible for health and safety regulation in Great Britain. The Health and Safety Executive and local authorities are the enforcing authorities who work in support of the HSC. Both are statutory bodies, established under the Health and Safety at Work etc Act 1974.

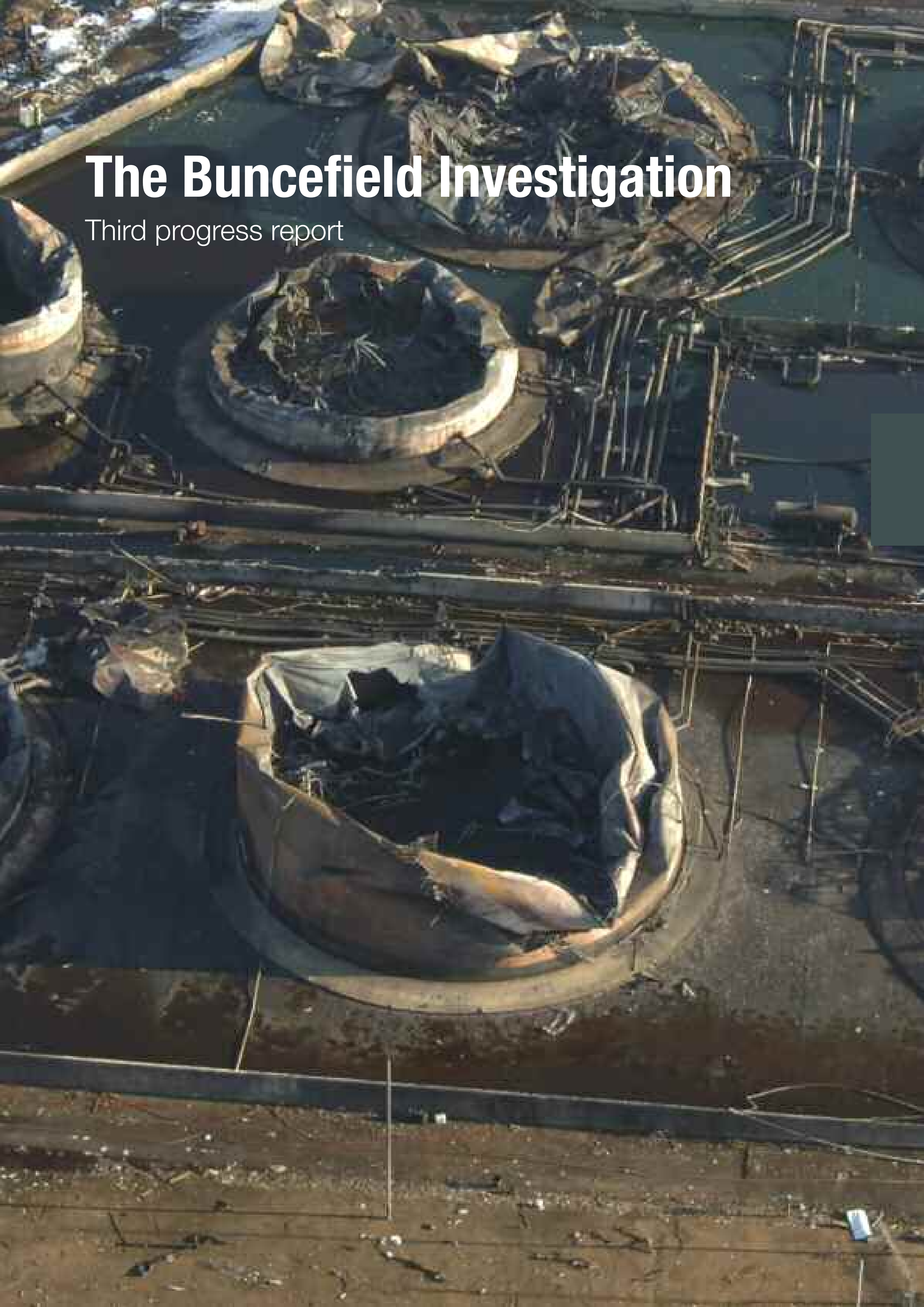
The Environment Agency is the lead regulator in England and Wales with responsibility for protecting and enhancing the environment. It was set up by the Environment Act 1995 and is a non-departmental public body, largely sponsored by the Department for Environment, Food and Rural Affairs (DEFRA) and the National Assembly for Wales (NAW). The Environment Agency's prime responsibilities include flood risk management, tackling pollution incidents, reducing industry's impact on the environment, restoring and improving rivers, coastal waters, contaminated land, and wildlife habitats. The Environment Agency also advises on sustainable drainage, water conservation and management, planning issues, nature conservation and waste management.

aquifer	A water-bearing stratum of porous rock, gravel or sand
borehole	A cylindrical shaft drilled into the ground, often for geological exploration or extraction
bund	An enclosure designed to contain fluids should they escape from the tank or vessel inside the bund
COMAH	The Control of Major Accident Hazards Regulations 1999 Regulations (COMAH). See Annex 1
COMAH sites	Sites to which the COMAH Regulations apply
Competent Authority	The COMAH Regulations are enforced by a joint Competent Authority comprising HSE and EA 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
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
foam concentrate	In the context of this report, a concentrate used during operations to extinguish hydrocarbon fires
fire water	Water used during fire-fighting operations
hazard	Anything with the potential to cause harm
hydraulic pressure	Pressure exerted by water
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

Northgate	A business whose premises were affected by the Buncefield incident
outfall	The point of discharge of water into a river, stream, pond, sea or other water body
PFOS	Abbreviation of perflourooctane sulphonate, a surfactant added to fire-fighting foam to aid it spreading
Polycyclic aromatic hydrocarbons and compounds	A group of chemicals commonly found in residues from burning coal, fuel and oil
pool fire	A fire over a pool of fuel and/or water or other liquids
primary containment	The equipment and facilities which have direct contact with the products under normal containment (eg tanks and pipe work), and their operation and management
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
risk	The likelihood that a hazard will cause a specified harm to someone or something
safety reports	The COMAH Regulations require operators of top-tier sites to submit written safety reports to the Competent Authority
secondary containment	The control of the product in the primary containment facilities (eg the provision of tank high-level alarms to prevent loss through overfilling) and any contingency provisions for the failure of the primary containment. The most important of these provisions are bunds
surface water	Water that sits or flows above land, including lakes, seas, rivers and streams
surfactant	A chemical added to fire-fighting foam which allows the foam to form a thin sealing film over the burning fuel
tertiary containment	The site surface and associated drainage, boundary walls, roads, 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 ground water, or contaminate surface waters and land
watercourses	A natural or man-made channel along which water flows

The Buncefield Investigation

Third progress report



Contents

Photograph on front cover shows Tank 912 and is courtesy of the Chiltern Air Support Unit

Foreword

This is my third progress report into the explosions, fires and aftermath at Buncefield. In this report I am able to explain with reasonable clarity and confidence that Tank 912 in bund A on the Hertfordshire Oil Storage Ltd (HOSL) West site overflowed at around 05.30 hours on 11 December while being filled at a high rate.

The environmental conditions, flow rate of fuel, and physical configurations of the tank top and wall provide a suitable mechanism for rapid formation of a fuel-rich vapour that flowed off site following the ground topography.

As the vapour flowed off site, driven by gravity and the formation of more vapour in bund A, it would have mixed with more air and by the time it reached the Fuji and Northgate car parks, may have become an almost ideal flammable mixture.

Several likely sources of ignition are discussed, a primary one on site and another in the Northgate car park. The explosion sequence is also discussed, but here there is far less confidence in the mechanism for the high overpressures seen and modelling of this may take some time. Nonetheless I believe the most important facts leading up to the explosions at Buncefield are known with reasonable confidence and they are presented below.

Updates are also given on environmental issues, and on further contacts with local businesses and residents, though the main focus is on the important information about how fuel escaped and vaporised leading to the explosions.

The ongoing investigation and other work are briefly described.

Taf Powell
Buncefield Investigation Manager and Member of Buncefield Major Incident Investigation Board

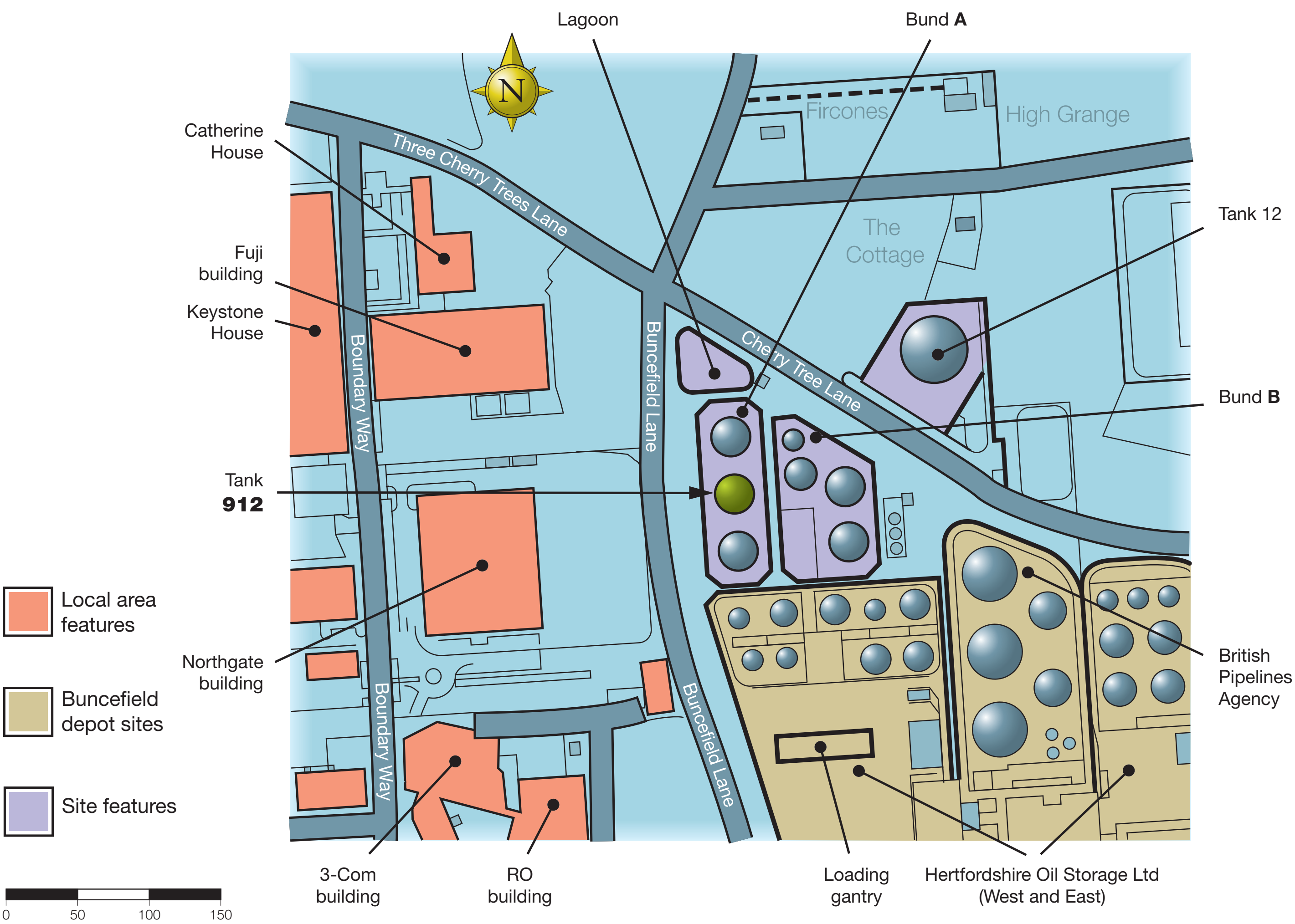
Introduction

1 This report describes where and how fuel escaped from storage at the Buncefield Oil Storage Depot on 11 December 2005 and how it vaporised, forming a flammable mixture that subsequently ignited at around 06.00 that morning with devastating consequences. It summarises the work carried out to analyse the electronic records that were recovered from site and experimental work undertaken by the Health and Safety Laboratory (HSL) to explain what happened to the fuel after it was released. So the heart of this report is a narrative, setting out the sequence of events leading up to the explosions.

2 For the complete picture of what is now known, this report should be read in conjunction with its predecessors, the details of which are not repeated here (see www.buncefieldinvestigation.gov.uk). The first progress report, published on 21 February, described in some depth the incident and emergency response. It concluded that the escape of fuel came from the area around bund A at the north west of the site and set out what was then known about the nature of the explosions and fire. The second progress report, published on 11 April, focused mainly on the environmental impact of the incident, and reported on the failure of some of the bunds to contain the fuel, foam and fire run-off water. It also set out the measures in hand to monitor any potential pollution levels.

3 The values and other data presented in this report are subject to ongoing rechecking as is usual in an investigation of this kind. They are presented as indicative and should be used in that context.

Figure 1 Layout of depot and surroundings



Timeline of events

10 December 2005

Around 19.00, Tank 912 in bund A at the HOSL West site started receiving unleaded motor fuel from the T/K South pipeline, pumping at about 550 m^3/hour (flow rates are variable within limits).

11 December 2005

At approximately midnight, the terminal was closed to tankers and a stock check of products was carried out. When this was completed at around 01.30, no abnormalities were reported.

From approximately 03.00, the level gauge for Tank 912 recorded an unchanged reading. However, filling of Tank 912 continued at a rate of around 550 m^3/hour.

Calculations show that at around 05.20, Tank 912 would have been completely full and starting to overflow. Evidence suggests that the protection system which should have automatically closed valves to prevent any more filling did not operate.

From 05.20 onwards, continued pumping caused fuel to cascade down the side of the tank and through the air, leading to the rapid formation of a rich fuel/air mixture that collected in bund A.

At 05.38, CCTV footage shows vapour from escaped fuel start to flow out of the north-west corner of bund A towards the west. The vapour cloud was about 1 m deep.

At 05.46, the vapour cloud had thickened to about 2 m deep and was flowing out of bund A in all directions.

Between 05.50 and 06.00, the pumping rate down the T/K South pipeline to Tank 912 gradually rose to around 890 m^3/hour.

By 05.50, the vapour cloud had started flowing off site near the junction of Cherry Tree Lane and Buncefield Lane, following the ground topography. It spread west into Northgate House and Fuji car parks and towards Catherine House.

At 06.01, the first explosion occurred, followed by further explosions and a large fire that engulfed over 20 large storage tanks. The main explosion event was centred on the car parks between the HOSL West site and the Fuji and Northgate buildings. The exact ignition points are not certain, but are likely to have been a generator house in the Northgate car park and the pump house on the HOSL West site.

At the time of ignition, the vapour cloud extended to the west almost as far as Boundary Way in the gaps between the 3-Com, Northgate and Fuji buildings; to the north west it extended as far as the nearest corner of Catherine House. It may have extended to the north of the HOSL site as far as British Pipelines Agency (BPA) Tank 12 and may have extended south across part of the HOSL site, but not as far as the tanker filling gantry. To the east it reached the BPA site.

Part 1 Loss of fuel containment

1.1 Overview of Buncefield operations

4 Fuel products were supplied by three discrete pipeline systems:

- 10" pipeline (FinaLine) from Lindsay Oil Refinery on Humberside, which terminates in the HOSL West site;
- 10" pipeline from Merseyside via Blisworth, (M/B North), which terminates in the BPA's Cherry Tree Farm site;
- 14" pipeline from Thameside via a tee junction close to the site – the Hemel Tee (T/K South), which terminates in the BPA main site.

5 The three pipelines all operated in a similar way by transporting fuel oils and motor spirit in discrete batches, of known volume, under pressure. These batches were separated by an interface or buffer, which are small amounts of mixed product. The volume of this interface mix varies dependant on the flow rate and operating conditions prevalent while the product batches are being transported through the pipeline.

6 On arrival at site, the batches of product were diverted into dedicated tanks for each product type. The interface mix when it entered the site system, being a mix of two products, was either re-injected in small quantities into the large tanks of specific product if the product specification allowed, or it was transported back to a refinery as 'slops' for reprocessing.

7 The fuel stored in the tanks at Buncefield was then either transported off site in road tankers for distribution, or in the case of the majority of aviation fuel, via two BPA-operated 6" pipelines to London airports.

1.2 The escape of fuel

8 Evidence from CCTV footage reported in the first progress report pointed clearly to the vapour mist emanating from bund A on the HOSL West site. The investigation has therefore concentrated on finding out how the site was operating in the crucial period leading up to the explosion and what was happening in the vicinity of bund A.

9 At the time of the incident, approximately 06.00 on 11 December 2005, the pipelines were transporting the following products into the HOSL West site:

- FinaLine was delivering unleaded petrol at a flow rate of approximately 220 m^3/hour into Tank 915 at HOSL West (also in bund A);
- M/B North line was delivering diesel oil at a flow rate of approximately 400 m^3/hour into Tank 908 in bund D;
- T/K South line was delivering unleaded petrol at a flow rate of approximately 890 m^3/hour into Tank 912.

10 All reasonable avenues of investigation have been and continue to be explored but information obtained to date allows stating with some confidence that the initial loss of containment occurred from Tank 912 in bund A, and that this was most likely due to an overfill of unleaded petrol.

11 In order to appreciate the way the fuel escaped, it is important to understand how the tank and its control and instrumentation systems functioned at the time.

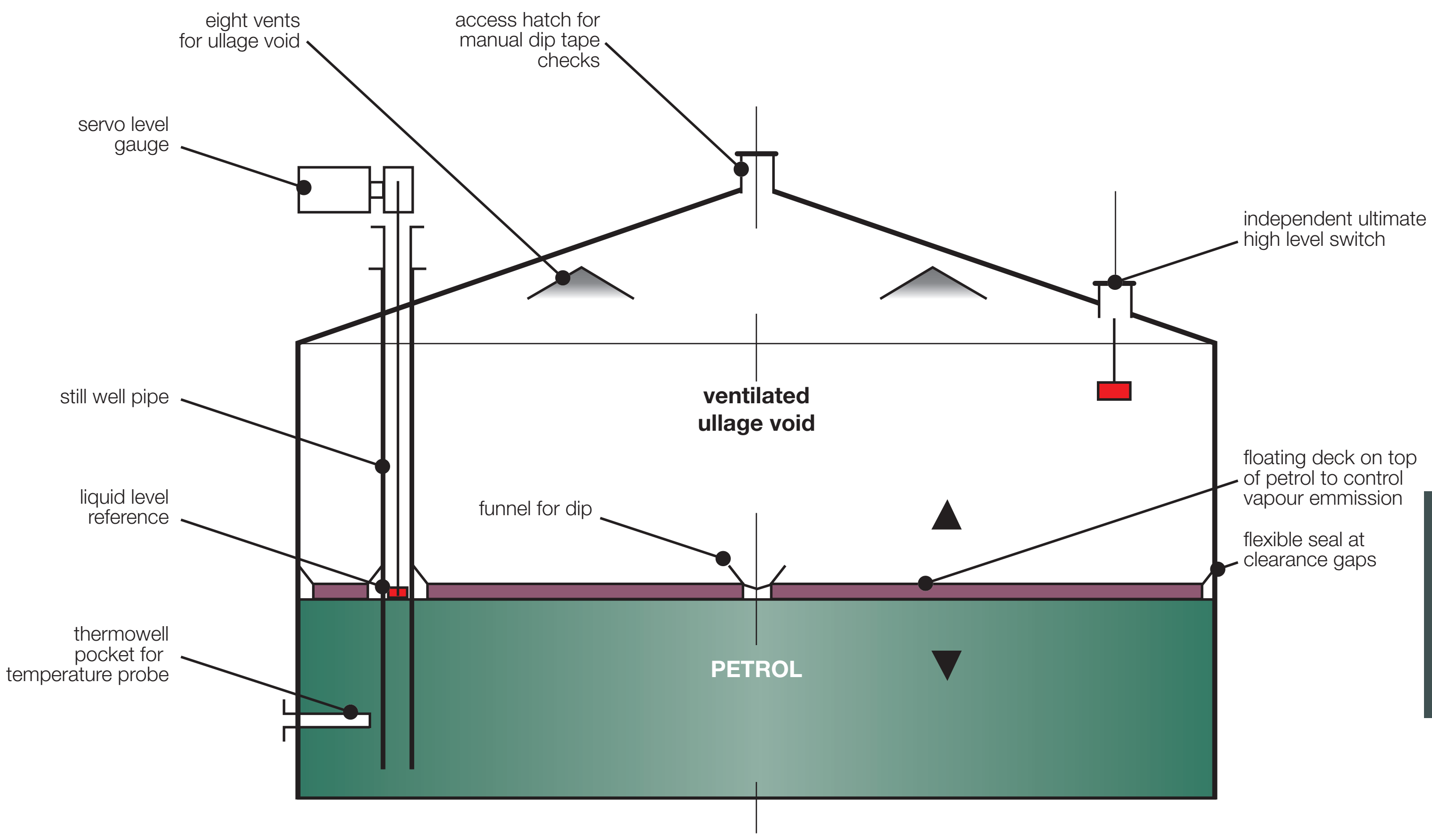


Figure 2 Basic layout of Tank 912

12 Figure 2 depicts the basic layout of Tank 912. This was a floating deck tank whereby in addition to the fixed roof, there is a deck inside the tank which floats on the fuel, thus minimising the emission of vapour from the fuel surface.

1.3 Instrumentation and control systems

13 Tank 912 was fitted with instrumentation that (among other things) measured and monitored levels and temperatures of the liquid in the tank. The instruments were connected to an automatic tank gauging (ATG) system in common with all the other tanks on the site. Tank levels were normally controlled from a control room using the ATG system.

14 A servo level gauge measured the liquid level. The temperature of liquid in Tank 912 was measured using a temperature sensor.

15 The ATG system enabled the operator to monitor levels, temperatures and tank valve positions, and to initiate the remote operation of valves all from the control room on HSOL West site. The ATG system was also able to trend data and had an event logging system, integrated with the alarm system. The ATG contained a large database which recorded levels, temperatures, alarms, valve positions, and other related information indexed against times and dates for a user-configurable period, which can be several months. The records from this database are providing valuable information for the investigation.

16 The tank also had an independent safety switch, which provided the operator with a visual and audible alarm in the control room when the level of liquid in the tank reached its specified maximum level (the 'ultimate' high level). This alarm also initiated a trip function to close valves on relevant incoming pipelines. The ultimate high level safety switch on the tank sensed when the liquid reached its specified maximum level, should all other alarms and controls fail to prevent this. Its purpose was to provide an alarm to operators in the control room and to initiate automatic shutdown of delivery once the maximum level was reached. The switch was intended to alert the control room operator via a flashing lamp (one for each tank) and an audible buzzer. In addition, the ultimate high level safety switch alarm signal from any overflowing tank in HOSL West would be sent to computer control and instrumentation relating to both the FinaLine and BPA pipelines.

17 When the BPA site received an alarm/trip signal from the HOSL West site, the BPA computer control system should have closed the relevant pipeline manifold valve feeding in product to the tank(s) on the HOSL West site. BPA also had a high-level supervisory control and data acquisition (SCADA) system, which had the facility for alarm and event logging both locally at Buncefield and remotely at the BPA control centre at Kingsbury, Warwickshire.

18 An override keyswitch in the HOSL West control room could be used to inhibit the alarm/trip signal to BPA during testing of the ultimate high level safety switches. Putting the keyswitch in the override position would illuminate a red lamp on the annunciator panel.

1.4 Evidence from control systems records

19 Examination of the records for Tank 912 from the ATG system suggest an anomaly. A little after 03.00 on 11 December, the ATG system indicated that the level remained static at about two thirds full. This was below the level at which the ATG system would trigger alarms.

20 However, the printouts from the BPA SCADA systems indicate that the T/K South line was delivering a batch of 8400 m^3 of unleaded petrol, starting around 19.00 the previous evening (10 December). The delivery was being split between Tank 912 at the HOSL West site and BPA's site at Kingsbury, giving a flow rate to Tank 912 of around 550 m^3/hour. These SCADA printouts further indicate that approximately seven minutes before the incident, the Kingsbury line was closed, leading to a sharp increase in the flow rate to Tank 912 to around 890 m^3/hour.

21 At the time of the incident, automatic shutdown did not take place.

22 Examination of the valve positions shown by the ATG database confirm that the inlet valve to Tank 912, which was connected to the BPA petrol manifold, was open at the time of the incident. Based on this evidence, it is concluded that Tank 912 was still filling after 03.00.

23 Temperature records also provide evidence that the inflowing fuel was warmer than the tank contents. Records for Tank 912 show the tank temperature continuing to rise after 03.00, supporting the above conclusion that the product was still feeding into the tank from the pipeline.

24 The evidence to date is consistent with continued filling of Tank 912 after 03.00, despite the ATG system showing a static level reading. On the basis of calculations, Tank 912 would have been completely full at approximately 05.20, overflowing thereafter. This timing is entirely consistent with CCTV evidence and eyewitness accounts reporting on a dense vapour cloud at various times between 05.38 and 06.00. The overflow of unleaded petrol would therefore have been in the order of over 300 tonnes by 06.00.

1.5 Alarm systems testings

25 Simulation of the ultimate high level tank alarms (from the relevant electrical substation on site) and tests on the annunciator panel and the link to BPA prove that they worked normally. Tests on the override switch found that it had no effect on the audible and visual alarms from the annunciator, but it did, when switched to override, inhibit the alarm/trip signals being sent to BPA.

26 Information from the BPA SCADA system indicates that no ultimate high level alarm was received from HOSL West, but it has not been possible to test the ultimate high level safety switch or intervening wiring between Tank 912 and the substation, as they have been damaged in the fire. However, the switch has very recently been located, but it has not yet been possible to recover it. When it is, it will be subject to forensic examination.

Part 2 Creation of the vapour cloud

2.1 Liquid behaviour during overfilling

27 The investigation considered the effect of the floating deck arising from overfilling of Tank 912. This deck is constructed from relatively lightweight alloy tubes. It is unlikely that the integrity of the tank would have been breached when this floating deck became pressed up against the top of the tank by the rising liquid. Drawings of it show several places where fluid could flow upwards through it with minimal backpressure. These locations include freely hinged man-ways, the dip-tube diaphragm and the accommodation plate around the level gauge pipe.

28 Therefore overfilling of Tank 912 would have resulted in flow from the breather holes at the top of the tank. There were eight of these, each triangular in section with an area of 0.07 m^2, as can be seen in Figure 3 which is a photograph of one of the tanks in bund A taken shortly after construction.

Figure 3 Tank top details before the incident

29 CCTV records from the HOSL West site show the first appearance of a mist from Bund A at about 05.38, supporting the view that the overflow began at around 05.20. For most of the time between the onset of loss of containment and ignition, the flow rate from vents would have been around 550 m^3/hour. Approximately seven minutes before the incident, shutting down of the flow from the BPA line to Kingsbury led to a sharp increase in the rate of delivery to Buncefield with a corresponding increase in the overflow rate.

30 To simulate a loss of containment from Tank 912, a full-scale model of one eighth of the whole tank top, including one of the breather vents, has been built at HSL in Buxton, Derbyshire (see Figure 4). It includes a 'deflector plate' at the edge of the tank top, visible in the third and fourth pictures in Figure 4. The original plate was designed to direct water from sprinklers on the top of the tank onto the sides of the tank to provide cooling in the event of fire engulfment. Liquid running off the top of the tank strikes this plate and is directed back onto the side of the tank.

31 Considerable work has been carried out on this model, pumping water through the breather hole at a flow rate equivalent to 550 m^3/hour for an entire tank top. These flows are sufficiently high that differences in viscosity and surface tension between water and petrol will make little difference to the results as regards observing initial flow behaviour.

Figure 4a-d Liquid flow from the breather holes on the tank top

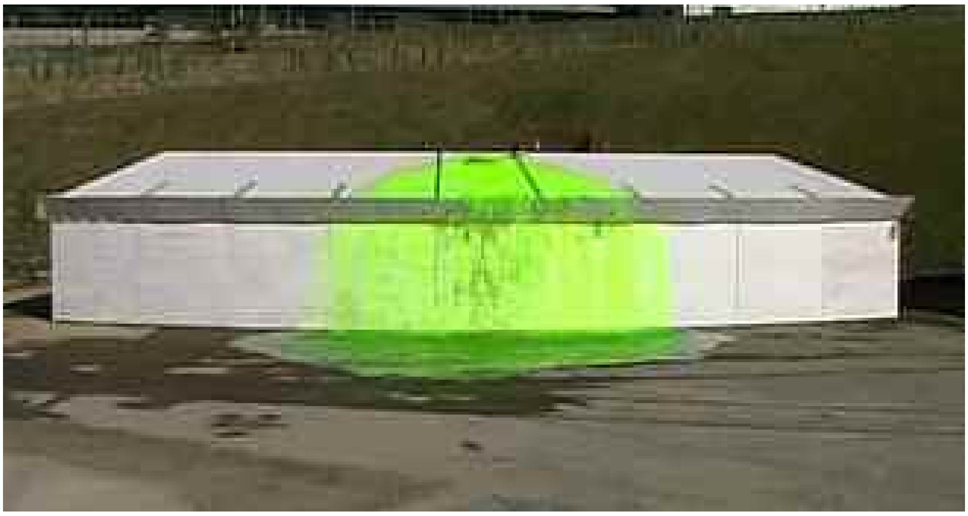


Figure 4a

Figure 4b

32 These tests demonstrate that the deflector plate was effective in channelling the majority but not all of the liquid onto the tank wall, but only spread it laterally over approximately one third of the wall. Images captured from video records are shown in Figure 4.

2.2 Generation of hydrocarbon-rich vapour

33 The differences in physical characteristics between water and petrol become more important for processes of droplet formation and additional work with petrol will be needed to investigate the subsequent behaviour of the escaped fuel. These tests are therefore a less reliable indicator of behaviour. However, it seems likely that the proportion of the liquid flowing over the top of the deflector plate will not reattach to the wall. This free cascade of liquid will naturally divide into small droplets.

34 Much of the liquid directed back to the wall by the deflector plate will hit the wind girder which can be seen running round the tank about a third of the way down in Figure 3. It is likely that this liquid flow will be further fragmented on impact with this girder to form a second free cascade.

35 There would be an impact zone in the bund where there is further splashing of falling liquid. There is also likely to have been a vigorous mixing of the heavy downward vapour flow with air.

Figure 4c

Figure 4d

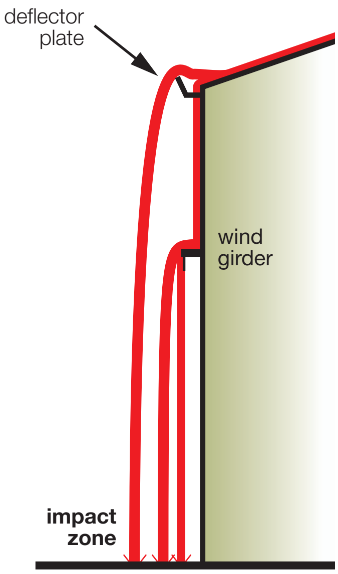


Figure 5 Liquid flow during overfilling of a tank with deflector plate and wind girder

36 The general features of these processes during an overflow are illustrated schematically in Figure 5.

37 The conclusion of this work is that the flow is likely to be very efficiently fragmented, and would create relatively small droplets falling freely through air around the tank. These conditions would promote the evaporation of the lighter chemical components of petrol, eg butanes, pentanes and hexanes.

38 The free fall of fuel droplets through the air also leads to entrainment of air and mixing between the air and fuel vapour. Calculations based on a simplified composition of unleaded petrol suggest that the ambient air already at 0 °C and fully saturated with water vapour, would have cooled below zero by a further 7-8 °C from fuel evaporation. As a result, roughly half the initial water content of the air would precipitate as an ice mist, and this mist would persist even as the vapour is diluted. This is consistent with the cloud of mist highly visible on CCTV cameras. It supports the contention that the mist can be used as an indicator for determining the size of the fuel/air vapour mixture created by the overfilling and how it was dispersed.

2.3 Dispersion of vapour

39 Aerial pictures of the site have confirmed preliminary conclusions about the extent of the burn damage shown in Figure 5 of the first progress report. This is also shown by the dotted line in Figure 6. This is indicative of the extent of the flammable vapour cloud.

40 As described in the first progress report, eyewitness accounts and CCTV footage show a white mist or thick fog on the north and west sides of the HOSL West site, spreading out from bund A (around Tanks 910, 912 and 915). By the time of the main explosion, the edge of this cloud had almost reached Boundary Way to the west of bund A and wisps of mist had just started to arrive at the tanker loading gantry to the south. To the north, it had flowed beyond Cherry Tree Lane. To the east, the mist can be seen on CCTV at the BPA site, but not further east at the

Figure 6 Extent of burn damage (indicated by dotted line)

HOSL East site. This is a little way beyond the extent of the burn damage shown in Figure 6. According to witnesses, the depth of the visible mist varied from about 1 m in the area between bund A and the loading gantry to between 5 and 7 m in Three Cherry Trees Lane.

41 In addition to defining the overall extent and location of the flammable vapour cloud, dispersion modelling is being used to analyse how concentrations of hydrocarbons vary within the cloud. In the meantime some features of dispersion of the hydrocarbon-rich vapour can be deduced from observations of burn damage at the site. Figures 7 and 8 illustrate this.

42 The telegraph pole shown in Figure 7 is in Buncefield Lane relatively close to the wall of bund A containing Tank 912. The bottom part of the pole shows soot blackening, characteristic of objects exposed to burning of a very rich vapour mixture. Video records of the fire confirm that this area was not affected by the smoke plume during the fire.

43 The tree trunk in the Northgate car park shown in Figure 8 is much further from the site and has been exposed to an explosion propagating in a more dilute vapour mixture with a composition close to the optimum for complete combustion. There is no soot on exposed surfaces but the left-hand side facing the camera has been deeply abraded by grit driven into it at high speed by the explosion. Examples of this kind of damage were found across most of the area covered by the Northgate and Fuji car parks.

44 Such observations of burn damage support the conclusion that additional air mixed with the rich vapour as it flowed out across the Northgate and Fuji car parks. This reduced the vapour concentration to the point where it could support an explosion.

Figure 7 A telegraph pole in Buncefield Lane, showing sooting on lower half

Figure 8 Part of a tree trunk in the Northgate car park showing abrasion

Part 3 The explosions

3.1 Description

45 From analysis of seismic records, the British Geological Survey (BGS) has calculated that the main explosion occurred at 06.01:32. Eyewitness accounts and media reports refer to a very large explosion followed by a number of lesser ones. The other explosions were not detected seismically, confirming that they were significantly smaller than the main explosion. Because of this it is not possible to say how many smaller explosions occurred, or much about their timing. The first of the smaller subsequent explosions was probably some minutes after the main explosion and probably all occurred within about half an hour. It cannot be ruled out that there were one or more smaller explosions immediately before the main explosion.

46 The delay of some minutes between the main and subsequent explosions suggests the latter were more likely to be due to internal tank explosions or further release of fuel from damaged tanks and pipework, rather than further explosions of parts of the vapour cloud.

47 For instance, part of a tank roof believed to come from Tank 910 in bund A was found in the Northgate car park. This is consistent with an internal explosion in the tank. It is understood that this tank was empty of liquid fuel and not in use at the time. Internal explosions in other empty tanks or tank ullage spaces could have accounted for the remaining explosions.

3.2 Ignition sources

48 The dispersion of vapour mixture is described earlier in Part 2.3. The extent of the visible mist cloud by the time of the main explosion very closely matches the extent of visible burning to vulnerable surfaces. Within this extensive area of about 80 000 m^2 there would have been a number of potential ignition sources. It is not possible to identify the ignition source for this explosion with any degree of certainty, because of the resulting destruction of evidence. However, there are some potential candidates.

49 There is some evidence of an internal explosion in the fire pump house, located on the east side of the lagoon on the HOSL West site. This is indicated by the doors, which are the only remaining part of the cladding. The left-hand door has been blown open, and the top half of the right-hand door folded outwards. It is believed that the pumps should have started when the emergency fire alarm was activated just before the explosion occurred.

50 There is also evidence of an internal explosion in the emergency generator cabin located on the south side of the Northgate Building. It is understood that there were thermostatically controlled heaters in the cabin and the air intakes for the diesel generator would have allowed vapour to enter the cabin. If the heaters were switched on, the spark generated at any electrical contacts would have been capable of igniting a surrounding flammable atmosphere. Like the pump house, the venting of an internal explosion within the generator cabin would have also been a very powerful ignition source.

51 Car engines are another potential source. A number of witnesses describe how their cars began to run erratically. For at least one vehicle in Three Cherry Trees Lane, the engine continued to race even after the ignition had been turned off and the driver had left the vehicle.

52 Other sources of ignition cannot be ruled out, given that off site there would have been no precautions in place to control ignition sources. There is also the possibility that there were near-simultaneous ignitions at a number of locations.

3.3 Explosion development and magnitude

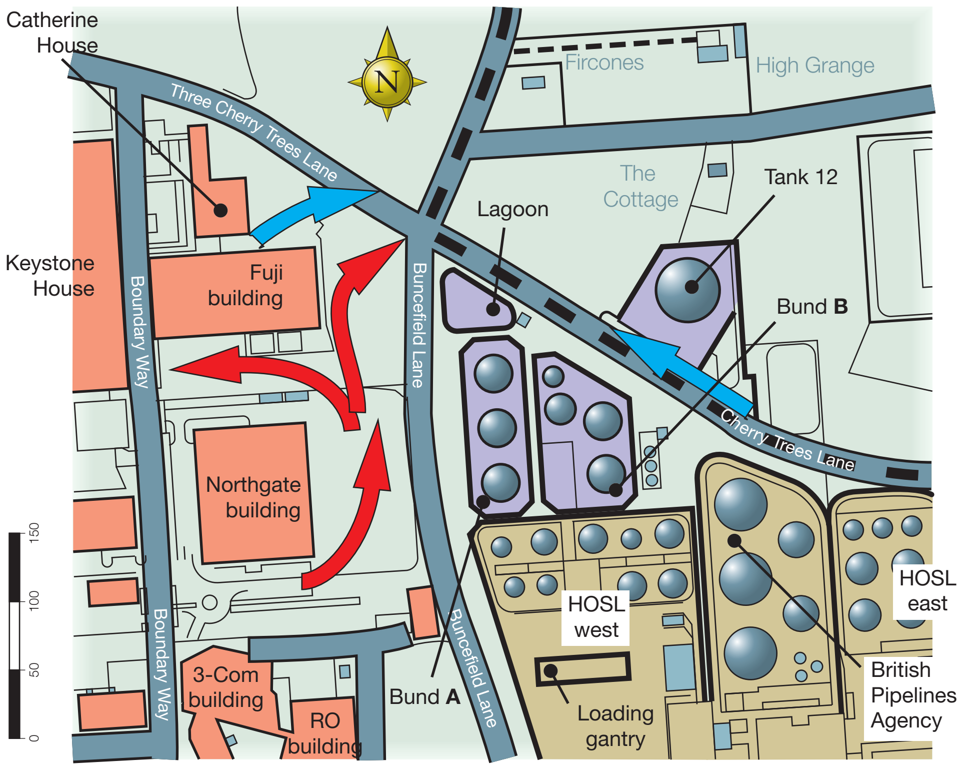
53 A preliminary assessment of the blast damage has been carried out. Estimates have been made of the overpressures required to cause the observed damage, based on the published tables derived from wartime bomb damage and solid explosive and nuclear bomb testing. Due to the very different characteristics of a blast wave produced by a vapour cloud explosion, there is considerable uncertainty in the estimated overpressures, and work is ongoing to resolve these uncertainties. But it is clear from a purely qualitative assessment of the damage that the highest overpressures were generated in the area of the Northgate and Fuji car parks.

54 Subject to these uncertainties, the current best estimates of the overpressures are of the order of:

- 700–1000 mbar in the Northgate and Fuji car parks, leading to extensive damage to adjacent buildings;
- decaying to 7–10 mbar at 2 km distant, causing breakage of some windows in local homes and premises.

55 The magnitude of the overpressures generated in the open areas of the Northgate and Fuji car parks is not consistent with current understanding of vapour cloud explosions. For example, a method in current usage would predict overpressures in this sort of environment of 20–50 mbar. The investigation has, so far, been unable to establish why the ignition of the vapour cloud and the explosion propagation in the relatively uncongested environment of the adjacent car parks caused significant overpressures that produced the severe damage to property.

Figure 9 Showing main and secondary explosion propagation



56 Furthermore there is evidence, from erosion/abrading on just one side of posts and tree trunks, of a powerful explosion having propagated northwards across the Northgate and Fuji car parks, as shown in Figure 8. The movement of objects like fence posts, tree branches etc indicate explosions of lesser magnitude having propagated through other areas bordering on the Buncefield site. The directions of explosion propagation are shown on Figure 9. The main explosion propagation is shown in red with secondary effects in blue.

Part 4 Environmental monitoring

4.1 Air quality and health surveillance

57 The second progress report explained that the Department for Environment, Food and Rural Affairs (DEFRA) is planning to publish a report on *Initial review of air quality aspects of the Buncefield Oil Depot explosion* in May, and this is still the case. The Health Protection Agency (HPA) is also closely involved with this work. DEFRA and HPA are continuing to keep the Investigation Board informed of progress with their findings.

4.2 Water quality monitoring

58 In the period from 12 December 2005 and up until 19 April, 125 river water samples and 76 ground water samples have been taken as part of a monitoring programme. On site, 190 solid and liquid samples from bunds, tanks, boreholes, lagoons and outfalls have been taken.

59 These samples were monitored for fuels and fire-fighting foam, or other chemicals which act as indicators for them. The indicators for foam include fluoro-surfactants including perfluorooctane sulphonate (PFOS) and zinc.

4.3 Ground water monitoring

60 Ground water and ground water abstraction boreholes have been monitored up to 9 km from the site, including six pumping stations operated by Three Valleys Water Company. Private boreholes have been sampled in a wider survey of the ground water for contamination, but not as part of the routine programme.

61 Three new observation boreholes have been drilled closer to the Buncefield site to provide an early detection of any ground water pollution: Butlers Farm (between Buncefield and Bow Bridge pumping station); Breakspear House (south of Buncefield) and Hogg End Lane (on the east boundary of Buncefield). This is part of an ongoing regime of monitoring that will provide further boreholes in the vicinity of the site.

62 In addition to the observation boreholes, two new ones have been installed in the vicinity of Tank 12, in the northern part of the site, to determine the level of ground water and any contamination. The first of these has been installed adjacent to the Cherry Tree Lane deep road drain. A second new borehole has been installed to the north west of Tank 12, which is believed to be upstream of the Cherry Tree Lane road drain.

63 The location of the monitoring borehole network was provided in the second progress report.

Results of ground water monitoring

64 Some results from the samples, taken from the ground water monitoring network, have shown very low levels of PFOS. Follow-up samples however, have not always shown PFOS to be still present. It is therefore not possible to draw conclusions as to the extent and origin of the PFOS. Further monitoring is continuing to establish if the results are directly attributable to the incident.

65 The Drinking Water Inspectorate (DWI) has established an advisory level for PFOS in drinking water of no greater than 3 micrograms/litre. This advice follows consultation with health professionals at HPA. HPA has stated that: ‘It appears unlikely that a lifetime’s consumption of drinking water containing concentrations up to 3 micrograms/litre would harm human health’. In all cases, the levels at which PFOS has been detected has been below this advisory level.

66 Fuel products, fuel-related contaminants and surfactants have been detected in soakaways, boreholes and chambers in the verges of Cherry Tree Lane.

67 Latest results suggest that the fuels and fire waters that formed a large pool in Cherry Tree Lane during the incident have passed into the deep road drain, and from there into the underlying water table. The extent of the movement of this pollution off the site will be the focus for the continuing investigations.

68 Work is continuing to characterise the contaminants found to establish if they relate to the loss of containment during this incident.

4.4 Surface water

69 Extensive sampling of surface water around the site continues to assess the environmental impact of the incident. The samples have been sent to Environment Agency laboratories around the country for analysis.

70 Monitoring of surface water has concentrated on the River Ver as it received surface water from the Buncefield site. Two balancing tanks which provided a buffer to prevent uncontrolled surges of water, known as the Maylands and Redbourn lagoons, received surface water from the site and the surrounding area. These tanks subsequently discharged into the River Ver and River Red respectively.

71 The River Ver was monitored daily in the first two weeks after the incident. Two sites were tested, one upstream and one downstream of the Maylands’ tank outfall. Additionally, the balancing tanks and outfalls were subject to daily sampling and analyses. The initial focus was directed to oil contamination and fire-fighting foam, which could have caused oil pollution and as the foam degraded, oxygen depletion. This could have impacted on the ability of fish and other organisms to live in the river.

72 Two additional monitoring sites were sampled routinely on the River Ver at the end of December, downstream of St Albans, 7 and 11 km downstream of the Maylands’ outfall.

73 These sites were sampled for oils and fluoro-surfactants such as PFOS.

Results of surface water monitoring

74 No direct impact of the loss of containment was found in the first days after the incident. By the third day of the incident, low concentrations of PFOS were noted in the balancing lagoons, at the Maylands’ outfall and in the River Ver downstream of the outfall. In addition, there was an increase in zinc levels above background concentrations (zinc is often used together with PFOS in fire-fighting foams).

75 PFOS concentrations started to drop in the River Ver in the middle of January, one month after the incident, to below detectable levels in February. Occasionally, low concentrations of surfactants are found in the River Ver. The flow of water from the Maylands' outfall stopped in February. The Redbourn outfall started to flow in February, with low concentration of PFOS, feeding into the River Ver. The Maylands' tank contains low PFOS concentrations. Results to date indicate the levels to be generally below the DWI advisory limit (3 micrograms/litre).

76 PFOS has been identified at all monitoring points, including during a survey on the River Colne. The PFOS concentrations, however, have not exceeded the DWI advisory limit and no identifiable environmental consequences have been observed in the river habitat. More recently, fluoro-surfactants (other than PFOS), which may be associated with fire-fighting foam, have been detected in the river at low concentrations.

4.5 Impact on the environment and drinking water

77 Although there have been elevated levels of surfactants and other contaminants found in the surface waters in the proximity of the Buncefield site, there has been no evidence (to date) of an adverse impact to the environment. The results from the monitoring to date are below levels that would cause concern to the health of humans or wildlife. Monitoring will continue for the foreseeable future.

78 Public drinking water supply in the area is the responsibility of Three Valleys Water Company, which has the detailed operational knowledge required to manage the local response. The regulation of public drinking water quality is the responsibility of DWI. Both Three Valleys Water Company and DWI are working closely together to ensure that drinking water supplies remain of the highest quality.

79 The monitoring boreholes that have shown evidence of fuel and fire water contamination are not used to abstract water for drinking water purposes. The nearest drinking water abstraction point operated by Three Valleys Water Company, some 3 km from the Buncefield site, has not been used for abstraction since the incident in December.

80 The purpose of the Environment Agency monitoring is to determine the severity and extent of ground water contamination and advise on any remediation that may be necessary. The Environment Agency is in regular contact with Three Valleys Water Company and should there be evidence that pollution is migrating towards any of its abstraction boreholes, the Environment Agency will advise Three Valleys Water Company so that they can put in place appropriate measures to safeguard the quality of drinking water supplies.

4.6 Disposal of contaminated fire waters

81 The contaminated fire waters have been removed from the site and are being safely stored at a number of sites around the country. The largest single storage site is at the Thames Water Maple Cross Sewage Treatment Works.

82 The fire waters are a mixture of water, oils and fire-fighting foam.

83 The oil companies are responsible for the safe disposal of the fire waters. They are continuing to investigate suitable techniques. The Environment Agency is responsible for ensuring that any proposals will provide proper protection of the environment.

84 The current storage does not present a significant environmental risk and measures are in place to protect the environment.

85 In response to the significant loss of primary and secondary containment after the incident, the Environment Agency issued specific advice to its officers to ensure that operators have assessed and provided suitable containment, primarily bunding (secondary containment) at fuel depots over the next three months. Some of these investigations will take place at the same time as Competent Authority (HSE and Environment Agency) investigations, following the safety alert issued to industry by HSE following publication of the first progress report (see www.buncefieldinvestigation.gov.uk). A copy of the Environment Agency advice is at Annex 1.

Part 5 Continuing business and community issues

86 Both local residents and businesses affected by the incident continue to a face a variety of difficulties.

87 At this time a number of residents have still not been able to return to their homes. The continuing uncertainty about the future of the depot is a cause of anxiety and stress to those living in the area. Businesses and residents are also concerned to know the root causes of the explosions and fires as soon as possible.

88 Investigation Board members met the Maylands Business Network in April, to listen to views and concerns of the local business community. Some businesses continue to have challenging operating conditions and face difficult decisions about whether to reinstate their premises.

89 According to a recent report, around 100 official redundancies have occurred since December, although it is likely that further jobs have been lost but have been unreported. A variety of agencies are working towards the recovery of the area. The Maylands Task Force, a group of key business leaders and local agencies, is seeking to rejuvenate and develop the area. A number of high profile companies have committed to remain while longer-term decisions about whether to rebuild their previous buildings are made.

90 In late May, Board members will be meeting with local residents in Adeyfield, and follow-up meetings with residents at Woodhall Farm and Leverstock Green will be arranged in the near future. In June, Board members will be represented at the Young People’s Forum to hear the views and concerns of local school children.

Part 6 The continuing Investigation

91 The investigation team will continue investigation of the computer records and testing and examination of the wiring and instrumentation circuits that remain after the fire. In particular, the team wish to establish why the safety switch and associated trip instrumentation of Tank 912 did not prevent an overfill. The team will then be looking at factors that may have contributed to any underlying causes to the incident.

92 Additional work will be carried out at HSL to measure what proportion of the liquid flows over the deflector plate and what proportion is brought back to the wall, and to investigate other factors associated with vapour cloud formation and dispersion.

93 Further detailed work is still being considered in order to ascertain why the ignition of the vapour cloud and explosion propagation in the relatively uncongested environment of the adjacent car parks caused significant overpressures that produced the severe damage to property.

94 Investigations into the loss of control of the fuel in Tank 912 continue apace.

95 The evidence obtained to date supports the initial conclusions regarding the physical process and the mechanisms that led to the explosions, while not yet understanding why the main explosion was so violent. Term of Reference 5 requires recommendations to be made for future action to ensure the effective management and regulation of major accident risk at COMAH sites. The investigation is in a position, subject to ongoing inquiries, to direct attention to the effective management and regulation of both the on-site and off-site major accident risks presented by such sites. This work will include the prevention of incidents, preparation for response to incidents, and mitigation of their effects. The investigation will pursue those issues in order to assist the Investigation Board to make its Initial Report to the Health and Safety Commission and the Environment Agency in line with its Terms of Reference.

Annex 1

Memo to Area PIR Team Leaders from Martin Bigg, Head of Industry Regulation, Environment Agency dated 10 April 2006

BUNCEFIELD INVESTIGATION UPDATE – 11 April 2006
ENVIRONMENT REVIEW AT OIL/FUEL STORAGE SITES

Introduction
On 11 April 2006 the Buncefield Major Incident Investigation Board (BMIIB) will publish its second progress report on the investigation. This memo identifies actions to be taken by Environment Agency staff with responsibility for the regulation of oil/fuel storage sites under the COMAH Regulations.

At this stage nothing can be said in relation to the causes leading to the loss of primary containment. Some information relating to issues of secondary and tertiary containment will be made available, though it is recognised that not all the details, which would be normally be used to inform inspections, will be available.

Given this situation, at this stage, our actions should be limited to a basic risk assessment of the secondary and tertiary containment measures across the sector, with the aim of identifying those sites with obvious basic deficiencies. This basic risk screening will inform further inspection and actions when conclusions from the Buncefield investigation are known.

Second progress report
In summary the BMIIB second progress report raised the following points regarding secondary and tertiary containment:

Secondary containment

- While the concrete bunds substantially remained standing, their ability to contain fuel and fire water was lost due to damage to the sealant in the construction and expansion joints;
- sealant around penetrating pipework was also lost resulting in leakage;
- seepage through the walls of the concrete bunds also occurred; and
- the concrete panels forming the floor of the bunds underwent significant heave, opening up holes and cracks which acted as a pathway for fuel and fire water into the environment.

Tertiary containment

- Following loss of containment, fuel and fire water found numerous pathways into the environment. These included a number of shallow boreholes and one deep borehole within the site and flow across site roadways and overtopping of kerbs onto public roads and consequent escape via surface water gullies.

Implications for the programme of sector inspections
The key issues to be addressed by Environment Agency staff within the next three months are listed below. Where inspections have already taken place, either by joint teams of inspectors from the HSE and the Environment Agency or unilaterally by either, please review the findings of these inspections against the key issues.

- Are the tanks holding oil/fuel within a bund or bunds of such integrity that they would contain any leak of the tank and fire water, and prevent loss including into the ground?

- Is the bund capacity at least 110% of largest tank in the bund or at least 25% of all the tanks in the bund?
- Is the bund capable of holding the significant volumes of imported fire water used during an incident for either direct fire fighting and/or cooling of adjacent tanks?
- Is the bund design sufficiently robust to remain serviceable following a pool fire that may last for a considerable period of time? This assessment should take account of whether sealants[1] and waterstops[2] have been used as part of the construction and expansion joints.
- Is there any pipework penetrating the bund which could cause the containment to fail including when subject to fire?
- Given that pumps and powered valves will be lost if site power is lost due to fire or explosion, the behaviour of liquids flowing under gravity should be considered. This includes the loss of liquids from secondary containment. Has a study been made of the directions and volumes of flow and are provisions in place to contain these liquids within the boundaries of the site?
- Has an assessment been made of drainage paths to the environment and are the plans available to the off-site emergency response teams? This should include all on-site and near-off-site drainage and its relationship to the surface water systems, geology and hydrogeology.

Please contact Mark Maleham (Tel: 0117 914 2813) if clarification is required.

Martin G Bigg
Head of Industry Regulation

1 British Standard BS 6213: 2000 *Selection of construction sealants. Guide* (First published May 1982 Second edition July 2000) British Standards Institution ISBN 0 580 33168 7

2 Waterstops are preformed strips of durable impermeable material that are wholly or partially embedded in the concrete during construction. BS 8007: 1987 *Code of practice for design of concrete structures for retaining aqueous liquids* British Standards Institution ISBN 0 580 16134 X

Annex 2 Further information

Useful links

Buncefield Investigation

Buncefield Major Incident Investigation
Marlowe Room, 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

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

Residents' support

Dacorum Community Trust Mayors' Fund
To apply, call the freephone helpline on 0800 131 3351. Lines are open from 9.30 am – 4.30 pm, Monday to Friday.

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

Citizens Advice Bureau

Hemel Hempstead Citizens Advice Bureau, based in Hillfield Road, offers free, impartial, practical and confidential advice on a range of subjects.

Local authorities and emergency services

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

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

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

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

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

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

Government links

Office of the Deputy Prime Minister
Fire and Resilience Directorate: www.odpm.gov.uk

Government Office for the East of England
www.go-east.gov.uk

Environment Agency
www.environment-agency.gov.uk

Department of Trade and Industry
Oil and Gas Directorate: www.og.dti.gov.uk

Health and Safety Executive
Hazardous Installations Directorate: www.hse.gov.uk/hid
Control of Major Accident Hazards: www.hse.gov.uk/comah

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

Health Protection Agency
www.hpa.org.uk

Food Standards Agency
www.food.gov.uk

Drinking Water Inspectorate
www.dwi.gov.uk

Industry links

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

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

Other useful sources of information

Dacorum Borough Council *Digest* newsletter, available monthly
Dacorum Borough Council *Buncefield Update* Newsletter

Annex 3 Investigation 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 duty holders 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.

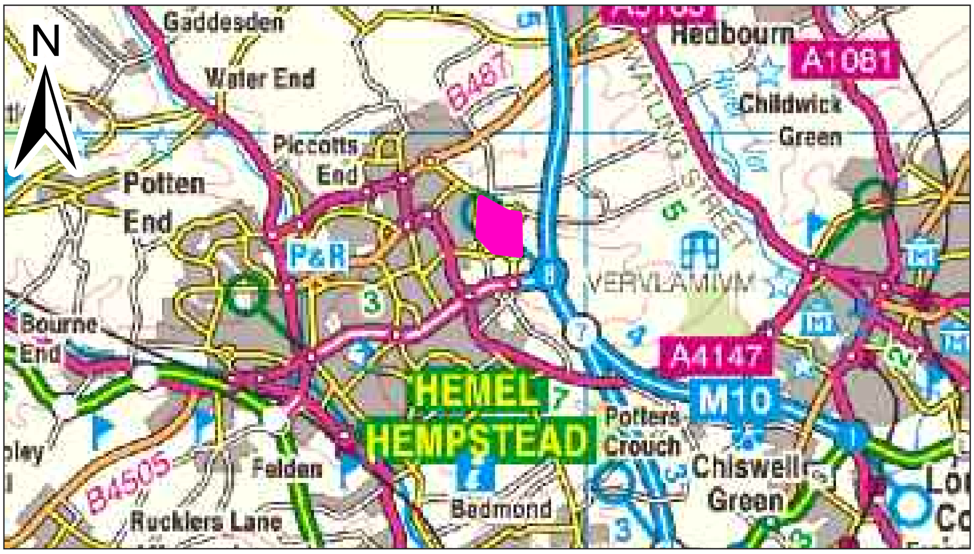
5 To make recommendations for future action to ensure the effective management and regulation of major accident risk at COMAH sites. This should include consideration of off-site as well as on-site risks and consider prevention of incidents, preparations for response to incidents, and mitigation of their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

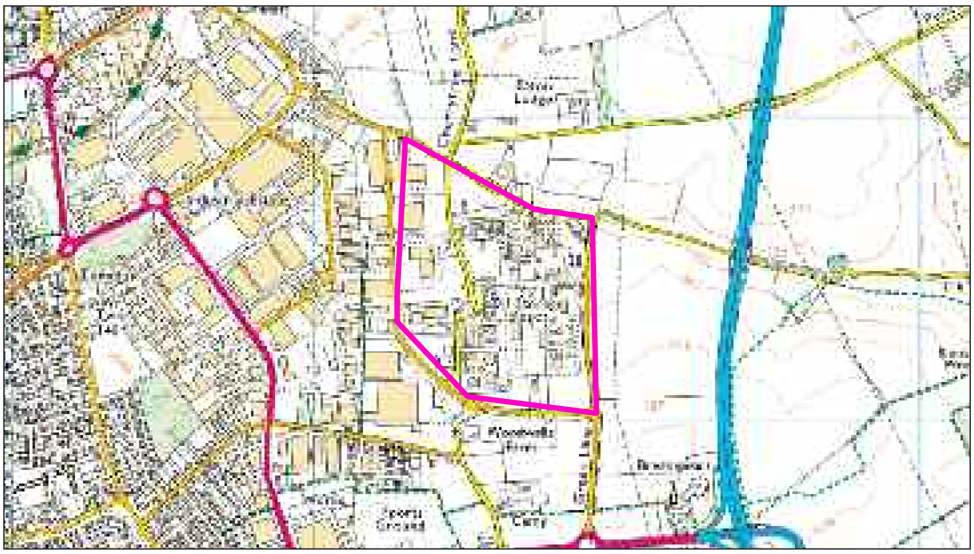
6 To produce an initial report for the Health and Safety Commission and the Environment Agency as soon as the main facts have been established. Subject to legal considerations, this report will be made public.

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

8 To make the final report public.

Annex 4 Site maps





Glossary

The Health and Safety Commission (HSC) is responsible for health and safety regulation in Great Britain. The Health and Safety Executive and local authorities are the enforcing authorities who work in support of the HSC. Both are statutory bodies, established under the Health and Safety at Work etc Act 1974.

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 (DEFRA) and the National Assembly for Wales (NAW). The Environment Agency's prime responsibilities include flood risk management, tackling pollution incidents, reducing industry's impact on the environment, restoring and improving rivers, coastal waters, contaminated land, and wildlife habitats. The Environment Agency also advises on sustainable drainage, water conservation and management, planning issues, nature conservation and waste management.

ATG	Automatic tank gauging system
bund	An enclosure designed to contain fluids should they escape from the tank or vessel inside the bund
COMAH Regulations	The Control of Major Accident Hazards Regulations 1999 (COMAH)
COMAH sites	Sites to which the COMAH Regulations apply
Competent Authority	The COMAH Regulations are enforced by a joint Competent Authority comprising HSE and EA 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
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
fire waters	A mix of waters, oils and fire-fighting foam
hazard	Anything with the potential to cause harm
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
Northgate	A business whose premises were affected by the Buncefield incident
Overpressure	For a pressure pulse (or blast wave), the pressure developed above atmospheric pressure is called the overpressure
PFOS	Perfluorooctane sulphonate

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
risk	The likelihood that a hazard will cause a specified harm to someone or something
safety reports	The COMAH Regulations require operators of top-tier sites to submit written safety reports to the Competent Authority
SCADA system	High-level supervisory control and data acquisition system
servo level gauge	Measures the liquid level in tanks
ullage	The volume in the tank between the normal maximum operating volume and when the tank is completely full of liquid
wind girder	Structural stiffening ring attached to the tank side wall

BUNCEFIELD MAJOR INCIDENT INVESTIGATION

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, Hemel Hempstead, on 11 December 2005

Buncefield Major Incident Investigation Board

BUNCEFIELD MAJOR INCIDENT INVESTIGATION

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, Hemel Hempstead, on 11 December 2005

Buncefield Major Incident Investigation Board

Contents

Executive summary

The terms of reference of the Investigation directed by the Health and Safety Commission into the explosions and fires at the Buncefield oil storage and transfer depot, Hemel Hempstead, on 11 December 2005 require an initial report to be produced for the Health and Safety Commission and the Environment Agency when the main facts of the incident have been established.

The independent Board set up to supervise the Investigation has previously published three Progress Reports submitted to the Board by the Investigation Manager. The Initial Report presents the Board's view that enough of the facts have been established, as described in the Progress Reports, to set out with reasonable confidence the sequence of events leading to the incident on 11 December. This also allows the Board to identify several issues of concern for the effective regulation of fuel storage sites such as Buncefield.

Summary of the incident and subsequent investigation

The Initial Report summarises and updates material from the Progress Reports on the nature of operations at Buncefield, the timeline of key events, the emergency response and the progress of the Investigation. Evidence shows that the main explosion probably resulted from the ignition of a vapour cloud emanating from Tank 912 in Bund A in the Hertfordshire Oil Storage Limited West site, most likely resulting from an overfill of unleaded petrol. The probable mechanism for the creation of the vapour cloud is described, though uncertainty remains about why the explosion was so violent.

Main findings since the publication of the Third Progress Report relate to the functioning of the systems used to shut down fuel delivery when a tank is full; the likely composition of the fuel released from Tank 912; and the ongoing monitoring of the environmental impact of the incident, particularly in relation to groundwater contamination. In this last regard, the incident has now been declared a Major Accident to the Environment (MATTE). The Investigation continues.

Issues of concern arising from the Investigation to date

Though knowledge of the Buncefield incident is still incomplete, enough is known for the Board to draw broad conclusions about the need for action in three areas:

- Design and operation of storage sites.
- Emergency response to incidents.
- Advice to planning authorities.

Design and operation of storage sites

The Buncefield incident involved failures of the means provided to contain fuel and water used in fire-fighting (known as 'fire-water') at three levels: primary, secondary and tertiary. The paramount need is to ensure the integrity of the primary means of containment, ie to make sure that fuel does not escape from the vessels in which it is normally contained. Further precautions need to be considered to prevent this happening and, should it still occur, to inhibit the formation of a flammable vapour.

This does not however lessen the need for effective secondary and tertiary containment (bunds and drains, mainly) that prevent pollutants from escaping the site and contaminating the environment should primary containment be lost.

Emergency response to incidents

Overall, the response to the incident was very impressive. The incident has highlighted the need to have effective emergency arrangements, both on and off site, in the event of a major incident of this kind. Lessons from Buncefield provide a very important opportunity to bring about improvements in emergency preparedness of resilience groups throughout Britain, and further afield. There are a number of reviews into the effectiveness of the emergency response to Buncefield being carried out by the agencies concerned, and the Board intends to return to this important area in the future.

Advice to planning authorities

The Buncefield incident poses fundamental questions about residential and commercial developments around sites like Buncefield. Continuing uncertainty in this area creates serious problems for local communities, particularly those directly affected by the Buncefield incident. This is a complex issue requiring a balance to be made between the risks and benefits of development. The Board intends to address these issues in detail once the preliminary conclusions of HSE's current review of its advice to planning authorities are known.

A measured approach is justified since the likelihood of a similar explosion remains low, and should be made lower still by a programme of actions designed to increase the reliability of primary containment. In our view, the importance of reaching conclusions that are considered, costed and sustainable greatly outweighs any benefit that might be derived from coming to summary judgements.

Introduction

1 This report is the 'initial report' required by the terms of reference of the Investigation into the explosions and fires at the Buncefield oil storage and transfer depot, Hemel Hempstead, Hertfordshire on 11 December 2005.[1] The Investigation was directed by the Health and Safety Commission (HSC) using its powers under section 14(2)(a) of the Health and Safety at Work etc Act 1974.

2 The Investigation is being carried out jointly by the Health and Safety Executive (HSE) and the Environment Agency. HSC appointed an independent Investigation Board, chaired by Lord Newton of Braintree, to supervise this investigation.[2] This report has been prepared by the Investigation Board, based on information arising from the continuing HSE/Environment Agency Investigation. Throughout the Investigation, the Board has been supplied with Progress Reports from the Investigation Manager, Taf Powell, which the Board has published.[3]

3 This report does not repeat all the material contained in the Progress Reports, which should be read for a fuller understanding of the Investigation up to May 2006. Part 1 summarises, and updates where necessary, key points of the Investigation for completeness and to aid in understanding the Investigation Board's initial conclusions set out in Part 2. The Board has included significant new findings from the Investigation that have emerged since the publication of the Third Progress Report on 9 May. Other new material is contained in the annexes to this report.

4 The Investigation terms of reference require an initial report to be submitted to HSC and the Environment Agency as soon as the main facts of the incident have been established. The Investigation is still continuing. Nevertheless, the Investigation Board considers that, with publication of the Third Progress Report in May, enough facts have been established to set out with reasonable confidence the sequence of events leading to the incident on 11 December. In particular, enough is known for the Board to be able to identify several issues of concern for the effective regulation of fuel storage sites such as Buncefield. As well as the main facts of the incident, the Board has included in Part 2 of this report its emerging thoughts about future action to address these issues of concern.

5 The Investigation Board plans to give further consideration to these issues.

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1 The full terms of reference are reproduced in Annex 1. Term of reference 6 requires an initial report.

2 The Members of the Investigation Board are listed in Annex 2.

3 Details of the three published Progress Reports are contained in Further information.

Part 1 - Summary of the incident and subsequent investigation

6 This section summarises information contained in the three Progress Reports to the Board published between February and May 2006. Full details can be found in the reports, which are available on the Investigation website.[4] Where necessary, this information has been updated in this report and supplemented by new findings from the Investigation. Other new information is contained in the annexes, referenced as appropriate in the text below.

Overview of Buncefield operations

7 The Buncefield oil storage and transfer depot is a large tank farm occupied by three companies. These are: Hertfordshire Oil Storage Limited, a joint venture between Total UK Limited and Chevron Limited; United Kingdom Oil Pipelines Limited and West London Pipeline and Storage Limited, whose site is operated by British Pipeline Agency Limited; and British Petroleum Oil UK Limited.[5] Each site is classified as a 'top-tier' site under the Control of Major Accident Hazards (COMAH) Regulations 1999.[6]

8 Figure 1 shows the layout of the Buncefield depot and its surroundings. The Buncefield depot forms part of a national petroleum refinery, pipeline and storage system, described in Annex 4. Fuel products were supplied to Buncefield by three pipeline systems:

- 10" pipeline (FinaLine) from Lindsey Oil Refinery on Humberside, terminating in the Hertfordshire Oil Storage Limited West site;
- 10" pipeline from Merseyside to Buncefield (M/B pipeline), terminating in the British Pipeline Agency Limited-operated Cherry Tree Farm site;
- 14" pipeline from Thames (Coryton) to Kingsbury, Warwickshire, with a spur line to Buncefield (T/K pipeline), terminating in the British Pipeline Agency Limited-operated main site.

9 The three pipelines all transported fuel products in discrete batches, separated by an interface or buffer of mixed product. At the terminal, the operators monitored the arrival of the various grades of fuel and separated them out into dedicated tanks by fuel type. The interface of mixed fuel was diverted to special small tanks to be reinjected into the main large storage tanks, if the fuel specification allowed, or transported back to the refinery as 'slops' for re-refining.

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4 Details of the three published Progress Reports are contained in Further information. These reports have not been revised to take account of more recent findings.

5 Texaco Limited became Chevron Limited on 3 July 2006.

6 The regulatory framework for high hazard sites, including the main requirements of COMAH, is summarised in Annex 8.

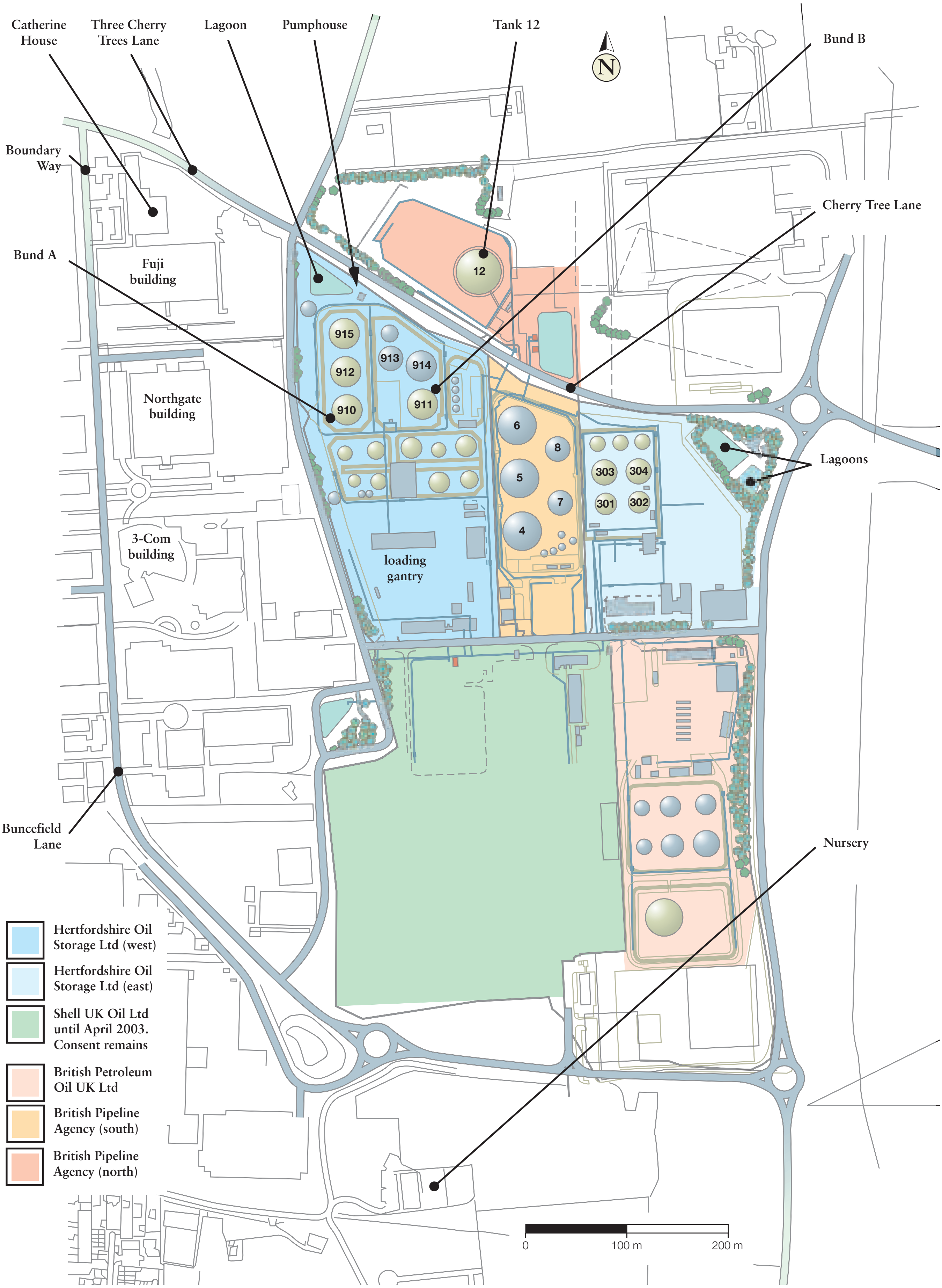

Figure 1 Pre-incident layout of Buncefield depot and immediate surroundings

10 The separated products left the depot either by road tanker or, in the case of the majority of aviation fuel, via two dedicated pipelines from the British Pipeline Agency Limited main site into the West London Pipeline system, which supplies Heathrow and Gatwick Airports. Tankers operating from Buncefield were of 44 or 18 tonnes capacity and were increasingly operated by specialised transport operators.

Timeline of key events

10 December 2005

- Around **19.00**, Tank 912 in Bund A at the Hertfordshire Oil Storage Limited West site started receiving unleaded motor fuel from the T/K pipeline, pumping at about 550 m^3/hour (flow rates are variable within limits).

11 December 2005

- At approximately **midnight** (**00.00**) the terminal was closed to tankers and a stock check of products was carried out. When this was completed at around **01.30**, no abnormalities were reported. From approximately **03.00**, the level gauge for Tank 912 recorded an unchanged reading. However, filling of Tank 912 continued at a rate of around 550 m^3/hour.

- Calculations show that at around **05.20** Tank 912 would have been completely full and starting to overflow. Evidence suggests that the protection system which should have shut off the supply of petrol to the tank to prevent overfilling did not operate. From this time onwards, continued pumping caused fuel to cascade down the side of the tank and through the air, leading to the rapid formation of a rich fuel/air mixture that collected in Bund A.

- At **05.38** vapour from the escaping fuel is first visible in CCTV footage from a camera looking down the western edge of Bund A, flowing out of the north-west corner of Bund A towards the west.[7]

- At **05.46** the vapour cloud had thickened to a depth of about 2 m and was flowing out of Bund A in all directions.

- By **05.50** the vapour cloud had started flowing off site near the junction of Cherry Tree Lane and Buncefield Lane, following the ground topography. It spread west into Northgate House and Fuji car parks and towards Catherine House.

- Between **05.50** and **06.00** the pumping rate down the T/K pipeline to Hertfordshire Oil Storage Limited West, and onwards to Tank 912, gradually rose to around 890 m^3/hour.

- By **06.01** the vapour cloud extended to the west almost as far as Boundary Way in the gaps between the 3-Com, Northgate and Fuji buildings; to the north-west it extended as far as the nearest corner of Catherine House. It probably extended to the north of the Hertfordshire Oil Storage Limited site as far as Tank 12, operated by British Pipelines Agency Limited, and probably extended south across part of the Hertfordshire Oil Storage Limited site, but not as far as the tanker filling gantry. To the east it reached the British Pipeline Agency Limited site.

- At 06.01 the first explosion occurred, followed by further explosions and a large fire that engulfed over 20 large storage tanks. The main explosion event appears to have been centred on the car parks between the Hertfordshire Oil Storage Limited West site and the Fuji and Northgate buildings.

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[7] Timings deduced from CCTV footage have been corrected for any inaccurate setting of the CCTV timers.

- At **06.08** an emergency services major incident was declared and operational command and control was set up near the incident site within minutes.

- At **09.00** Strategic Co-ordinating Group ('Gold' command') convened for the first time.

- An extensive plume of smoke from the burning fuel dispersed over southern England and beyond.[8] The plume could be seen from many kilometres away, and was also clearly identified in satellite images.

12 December 2005

- **Noon.** Peak of the fire. 25 Hertfordshire pumps were on site with 20 support vehicles and 180 fire-fighters.

- There was some loss of secondary containment, as the bunds were unable to fully contain the escaped fuel and water used in fire-fighting (known as 'fire-water'), which 'overtopped' (ie spilled over the top of) the bund walls.

14 December 2005

- HSE assumed control of the Investigation from Hertfordshire Constabulary.

- Damage to bunds caused by the intense heat of the fire caused significant loss of secondary containment on the Hertfordshire Oil Storage Limited West and British Pipeline Agency Limited sites. There was also extensive loss of tertiary containment at the site boundaries and large amounts of contaminated liquids escaped off site. The fire service recovered as much of the contaminated run off as possible, but was unable to prevent contamination of groundwater and surface water.

15 December 2005

- 'Fire all out' declared by the Fire Service.

- 786 000 litres of foam concentrate and 68 million litres of water (53 million 'clean' and 15 million recycled) were used overall to contain the incident during the period of fire-fighting operations.

- Strategic Co-ordinating Group ('Gold' command) convened for the last time.

16 December 2005

- The on-site investigation started (the preliminary planning and information gathering had commenced earlier). HSE issued notices to secure the site, to ensure both that evidence was left undisturbed and that clean up operations were conducted safely. Key parts of the site remained too dangerous for investigators to access for weeks or months.

18 December 2005

- Hertfordshire Oil Storage Limited started surveying roads and buildings on the site.

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[8] Monitoring by the Meteorological Office showed that the visible plume was mainly black carbon (soot). Full details of the plume and related air quality monitoring arrangements are given in the Department for the Environment, Food and Rural Affairs' *Initial review of the air quality aspects of the Buncefield oil depot explosion*, available at www.defra.gov.uk/environment/airquality/buncefield/index.htm.

20 December 2005

- HSC formally directed HSE and the Environment Agency to investigate the incident and to make a special report. HSE appointed Taf Powell, Director of HSE's Offshore Division, to be the Investigation Manager. HSC also announced the appointment of an independent Board to supervise the Investigation.

- The control room on the Hertfordshire Oil Storage Limited West site was sufficiently structurally sound to allow entry for gathering records and other evidence.

23 December 2005

- The Investigation team, with assistance from Hertfordshire Constabulary and Hertfordshire Fire and Rescue Service, recovered computers from damaged offices and placed them in safe storage.

5 January 2006

- Hertfordshire Fire and Rescue Service handed control of the site over to the Investigation team. Hertfordshire Constabulary and Hertfordshire Fire and Rescue Service continued to give invaluable support to the Investigation team that was working to gather and secure evidence.

12 January 2006

- HSC appointed Lord Newton of Braintree to chair the independent Board.

February 2006

- All fire-water had been removed from site and stored, pending safe disposal. The area around the loading gantry had been made safe for access and tankers, which were present at the time of the incident, were removed.

- Investigating personnel gained access to Bund A for the first time.

- Internal roadways were cleared and limited work started on removing debris from Bund A. Sampling of fuel in pipework was carried out prior to safe disposal. As fuel residues still remained in interconnecting pipework and damaged tanks, monitoring for flammable vapour was routinely carried out.

Emergency response to the Buncefield incident

11 The co-ordination and management framework at any incident identifies three levels of interlinked leadership and co-ordination.[9] They are:

- **Strategic** - Gold
- **Tactical** - Silver
- **Operational** - Bronze

12 The emergency services (primarily the Fire and Rescue Service and the police) led the initial response to the incident and its immediate aftermath. 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. This included the Environment Agency as a Category 1 responder under the Civil Contingencies Act 2004.[10] The Strategic Co-ordinating Group made decisions to ensure that the implementation of strategic aims was delivered by the tactical (Silver) and operational (Bronze) commands.

13 The Strategic Co-ordinating Group had its first multi-agency meeting at 09.00 on 11 December at Hertfordshire Police Headquarters, chaired by the Police Strategic Co-ordinating Group Commander. A decision was made at this meeting to evacuate those with damaged homes and workplaces, and to tell everyone in the immediate vicinity to shelter – ‘go in, stay in, tune in’.

14 The Strategic Co-ordinating Group remained in place until 18:30 on Thursday 15 December.

Disposal of fire-water

15 The contaminated fire-water was removed from the site during the first three weeks following the fire, although an unknown quantity contaminated the surface waters and groundwater. Following the event, further contaminated water resulting from rainfall or cleaning operations was removed from the site by tanker and stored along with the fire-water in a number of locations around the country.

16 The fire-water remains in temporary storage, and it is important for this matter to be resolved. The Board understands that the decontamination of fire-water on such an unprecedented scale may require the use of several processes to render the water suitable for its return to the environment. The oil companies are developing options to achieve this, which will be assessed by the Environment Agency to ensure that they have the minimum impact possible on the environment.

17 On 21 June 2006, the Environment Agency was informed that some 800 000 litres of this contaminated water had been released inadvertently from storage into a sewage treatment plant and thereafter into the River Colne, a tributary of the River Thames. The Environment Agency launched an investigation with the assistance of Thames Water Utilities Limited, who operate the storage facility and associated sewage treatment works. This investigation has yet to be concluded.

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9 *UK Resilience. Management and co-ordination of local operations*, available at www.ukresilience.info/ccact/errpdfs/err_chap_04.pdf.

10 Other Category 1 responders included the Health Protection Agency (HPA) and the Strategic Health Authority. The Environment Agency’s role was to minimise the risks of environmental damage. HSE is a Category 2 responder, so during the early phase of the incident stood ready to provide advice and expertise on request.

The Investigation

18 Progress Reports 1-3 detail four key aspects of the Investigation, briefly summarised below:

- Loss of fuel containment.
- Formation of the vapour cloud.
- The explosions.
- Environmental monitoring.

Loss of fuel containment

19 The first Progress Report indicated that the explosion probably resulted from ignition of a vapour cloud emanating from the vicinity of Bund A in the Hertfordshire Oil Storage Limited West site. The Investigation Manager was sufficiently confident in the investigation findings to state in the Third Progress Report that the initial loss of containment which created the vapour cloud occurred from Tank 912 in Bund A, most likely resulting from an overfill of unleaded petrol.

20 To understand how the fuel escaped, the Investigation examined how Tank 912 and its instrumentation and control systems functioned at the time. This examination suggested further lines of inquiry, involving aspects of the automatic tank gauging system, and the high-level alarm system. Investigators wanted to ascertain how the gauging system performed and why automatic shutdown of delivery did not take place as intended when the tank's 'ultimate high level' (ie the specified maximum capacity) was reached.

21 The Third Progress Report detailed findings about instrumentation and control systems on Tank 912. These include the product monitoring systems both for level and temperature, and the 'ultimate high-level switch', which was part of the system to prevent overfilling of the tank. As the Third Progress Report explained, from about three hours before the incident, the level gauge remained static, although the tank continued to fill.

22 The ultimate high-level switch should, if triggered, cause an alarm to sound and shut down the supply of fuel to the tank. Since publication of the Third Progress Report, most of the ultimate high-level switch from Tank 912 has been recovered, along with other parts of the instrumentation systems on this and other tanks, for examination.

23 Further investigation into the design of the ultimate high-level switch indicated that the position of a test lever or plate fitted to the switch is critical to ensure continued effective operation. While the relevance of this feature to the Buncefield incident has still to be determined, one of the issues that has arisen from these enquiries relates to the reliance on this type of switch at many similar installations throughout the UK and worldwide.

24 The Competent Authority has taken action to bring this issue to the urgent attention of operators of similar sites in the UK through a Safety Alert.[11] The Alert applies to a particular kind of switch used in ultimate high-level alarm systems. Improvement Notices have also been issued, requiring the suppliers to contact users or installers of these switches to alert them to this issue and provide revised instructions and labelling on the safe use, setting, cleaning and maintenance of the switches. The Board notes the continuing co-operation of the suppliers in that process.

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[11] Sites like Buncefield are regulated by a 'Competent Authority', as detailed in Annex 8. The full text of the Safety Alert can be found on HSE's website at www.hse.gov.uk/comah/alerts/sa0106.htm.

Formation of the vapour cloud

25 The Third Progress Report described extensive tests undertaken to model the behaviour of fuel escaping from Tank 912 during overfilling. Tank 912 was fitted with a deflector plate, installed to direct water from sprinklers on the tank's top to its sides to provide cooling in the event of fire. The tests demonstrated that the deflector plate channelled some of the escaped fuel onto the tank wall, but the rest ran over the top of the plate, fragmenting into droplets that cascaded through the air. Most of the fuel running down the wall hit a wind girder (a structural stiffening ring) and detached from the tank wall, creating a second cascade of droplets.

26 These conditions would promote the evaporation of the lighter components of petrol, eg butanes, pentanes and hexanes. The free-fall of droplets leads to entrainment of air and mixing between the air and fuel vapour, and the formation of a rich fuel/air mixture. Cooling of the surrounding air, already saturated with water vapour by the evaporation, would cause some of the water content to precipitate as an ice mist, which is consistent with the cloud of mist visible on

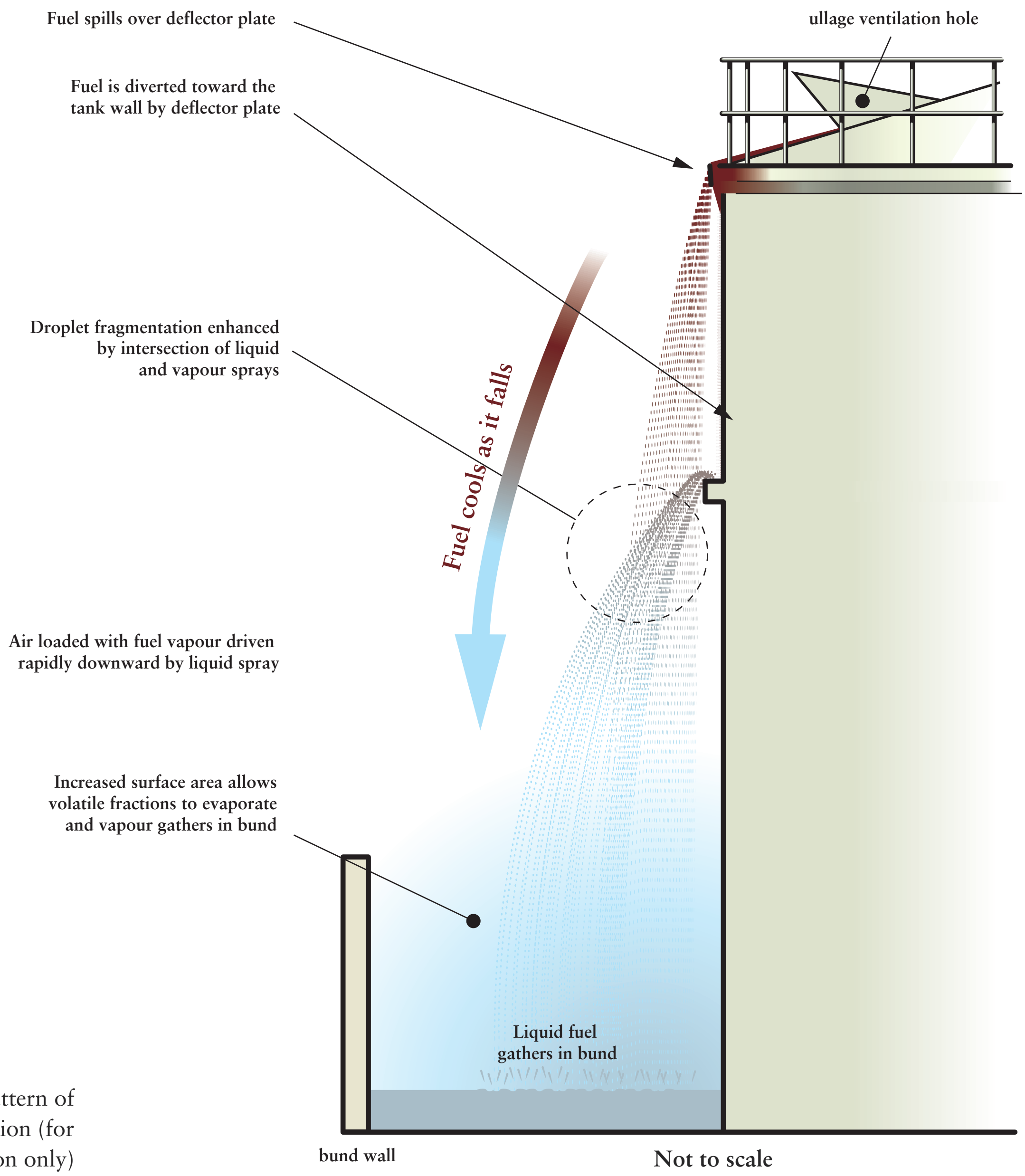

Figure 2 The pattern of fuel dispersion (for illustration only)

CCTV. The fuel/air mixture and its accompanying ice mist were heavier than air and so were initially contained within the bund. As the volume of the mixture grew from the continuing overfilling of the tank, it flowed out of the bund, dispersing and flowing off site. Further mixing with the air would have reduced the vapour concentration to the point where significant volumes of the mixture could support an explosion.[12]

27 Since publication of the Third Progress Report, further work to simulate the overflow of liquid from the full height of Tank 912 has confirmed the pattern of fuel dispersal and vaporisation shown in Figure 2.

The explosions

28 The Third Progress Report described a number of potential ignition sources of the main explosion that occurred at 06.01 on 11 December. The prime candidate appears to be an explosion within the emergency generator cabin on the south side of the Northgate building; this is consistent with the site of the main explosion event. However, further study of the CCTV evidence shows a sudden illumination of the east face of the Fuji building, consistent with an explosion or a flash fire at the location of the pumphouse to the east of the lagoon on the Hertfordshire Oil Storage Limited West site. This illumination was recorded by a camera before it was destroyed by the overpressure, suggesting that this explosion or flash fire occurred before the main explosion at 06.01. The pumphouse is the subject of continuing forensic investigation.

29 Much uncertainty remains about why the explosion was so violent, generating overpressures of a magnitude much greater than current understanding of vapour cloud explosions would predict. For example, a method in current use would predict overpressures of 20-50 millibar (mbar) in the open areas of the Northgate and Fuji car parks. The current best estimates of the overpressures that actually occurred in these areas are of 700-1000 mbar, leading to extensive damage to adjacent buildings. Annex 6 describes the mechanics of fire and explosion hazards from fuels such as petrol, as currently understood.

30 Continuing work relevant to gaining a better understanding of the explosion has included extensive sampling to identify the composition of the released fuels, as well as to verify the product distribution throughout the depot. It shows that the released fuel probably had a butane content of 10% and consequently would have had a high vapour pressure, ie it would be capable of evaporating rapidly to produce a flammable vapour. The total butane content is specified in the standard, and depends on whether the product is winter or summer grade. For winter grade petrol the vapour pressure limits are defined as 70-100 kiloPascals (kPa) and for summer they are reduced to 45-70 kPa. See Annex 7 for further information about standards and fuel composition.

31 Further research is needed to try to discover the actual mechanism for generating the unexpectedly high overpressures seen at Buncefield. The Board refers to this again in paragraph 76, and in relation to terms of reference 1 and 5 in Annex 1.

32 The number and severity of injuries at Buncefield was low compared to some other major incidents involving explosions, and there were no fatalities. Annex 6 provides more information about explosion overpressures, and includes tables which show the levels of damage or injury that would normally be expected to result from different overpressures.

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12 The explosive properties of petrol, including the significance of vapour concentrations, are explained in Annex 6.

Environmental monitoring

Air quality

33 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 the Environment, Food, and Rural Affairs (DEFRA) in May 2006.[13] 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.' It went on to say that 'overall it was concluded that the fire at Buncefield Oil Depot did not result in substantial pollution of soil and grasses' and 'that pollutant levels were, in general, unexceptional and typical of UK urban environments.'

34 The prevailing meteorological conditions at the time of the incident and the high buoyancy of the smoke plume from the fire resulted in most of the plume material reaching a high altitude in the atmosphere. It then dispersed over a wide area with minimal mixing down to ground level.

Land investigations

35 Trial pits were excavated starting in February on and surrounding the site to assess the impact on land. The initial findings indicate that the surface layer is contaminated with fuel and fire-fighting products.

36 The extent and degree of the contamination of the land within the Buncefield depot is continuing to be established. Many trial pits have been excavated to investigate the soil beneath the concrete hardstanding and under the bases of the bunds. All of this information will inform the continuing Investigation and allow the Environment Agency to assess the oil companies proposed remediation of the contamination when that is formally submitted to the Competent Authority.

Surface water and groundwater monitoring

37 Extensive surface water monitoring immediately following the incident was carried out at a number of locations, as detailed in the Second Progress Report. Monitoring will continue for the foreseeable future at these locations to determine any long-term effects on the aquatic environment.

38 The Environment Agency started to monitor the groundwater under and around the Buncefield site soon after the incident. This monitoring has shown that there is contamination of the groundwater by fire-fighting products, fuels, and fuel-related products. This has been reported in the previous Progress Reports and on the Environment Agency website.

39 Following the detection of contamination, the Environment Agency reviewed the sampling locations for the existing groundwater monitoring network (details of which were reported in the Second Progress Report) and concluded that further monitoring boreholes were required at specified locations. Some of the new boreholes are already installed.

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[13] This report presents and summarises the air quality measurements made during the Buncefield incident, and includes results obtained from targeted local monitoring, measurements from long-term monitoring networks, the modelling undertaken by the Meteorological Office, and emissions estimates of the pollutants from the fire. See Further information for further details.

40 The new monitoring boreholes will ensure that the extent of pollution is understood. Also, the increased groundwater monitoring network will improve the understanding of flow and contaminant transport within the chalk aquifer.

41 In addition to the extensive sampling that is currently underway, the Environment Agency is developing a groundwater conceptual model to assist in understanding the movement of pollutants within the groundwater and aquifer so that it may assess the likely extent of contamination. This model is a conceptual representation of the environment (in this case an aquifer) and the interactions within it.

42 All of the above will aid the assessment of the impact of the contamination on the environment and to human health. It will also assist in determining the best solutions for the clean up of the groundwater and the aquifer.

Perfluorooctane sulphonates (PFOS)

43 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 fire-fighting foam. PFOS does not appear to degrade in the natural environment. Due to this stability, it has now become widespread both in humans and in the environment. Annex 9 describes the environmental hazards presented by PFOS and the current approach to its regulation.

44 PFOS was not routinely monitored and analysed in any surface water or groundwater in the UK 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 groundwater or drinking water against which to assess any results.

45 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-water 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. The Board notes that it is the responsibility of the local water company to monitor the quality of drinking water (as opposed to groundwater and rivers), and that the Drinking Water Inspectorate (DWI) regulates the activities of water companies in relation to drinking water quality.

Results of monitoring

46 PFOS was detected in the Rivers Ver and Colne in the days immediately following the incident, however, these levels dropped below the lowest threshold detectable by the Environment Agency after a short period. Ongoing testing still shows sporadic detection of PFOS in the rivers. No direct impact has been detected either at the time or in the intervening months on fish or other aquatic species in these waters. Only long-term monitoring will identify if there has been a lasting environmental consequence of the presence of PFOS and its associated fluorinated compounds.

47 Results to date (six months since the incident) of groundwater monitoring have shown the presence of fuels, fuel-related products and residues from the fire-fighting foams in groundwater at a number of locations, but they are most prevalent under and close to the site.

48 Although PFOS above the level of three microgrammes per litre (which is the advisory level set by the DWI for PFOS in drinking water) has been detected in environmental monitoring samples, these levels have not been detected in samples of drinking water.

49 It could be many months before the full extent of the contamination of the groundwater is known. The Environment Agency is working with DWI and the local water supply companies to ensure that they are fully aware of sampling results, and are able to act appropriately to safeguard public water supplies.

Further monitoring

50 In view of the apparent widespread occurrence of trace quantities of PFOS around the Hemel Hempstead area, some apparently unconnected with Buncefield, the Environment Agency is conducting a targeted national groundwater sampling exercise to investigate the wider prevalence of PFOS and related compounds in groundwater.

51 The initial monitoring programme is being carried out in the period April to July 2006. Groundwater is being sampled at selected sites on the Environment Agency's national groundwater monitoring network. A range of sites have been selected in rural, urban and industrial areas. Some sites are where fire-fighting foams may have been used, eg fire stations, airbases etc, while others are where such use is not suspected. Approximately 150 sites will be sampled as a part of this programme.

52 If perfluorosurfactant compounds are detected in groundwater, repeat sampling will be carried out to verify the initial results and to investigate persistence. If widespread detection occurs, the programme will be extended beyond July and, if necessary, selected compounds added to the routine monitoring programme. A similar sampling exercise is planned for surface waters to take place over the period July to December 2006.

Notification to the European Commission

53 The Competent Authority (at Buncefield, jointly HSE and the Environment Agency) is required under regulation 21(1) and (2) of the COMAH Regulations to inform the European Commission of any major occurrence on a COMAH site. HSE, on behalf of the Competent Authority, issued a short report on 10 March 2006 for inclusion on the Major Accident Reporting System. As further information of international significance becomes known, the Competent Authority will also pass this on to the European Commission and hence the international community.

54 DEFRA has established threshold criteria defining a Major Accident To The Environment (MATTE), based on Schedule 7 (part 1) of the COMAH Regulations. The Environment Agency, using these criteria, has determined that the Buncefield incident is a MATTE, and the Competent Authority has recently reported this to the European Commission. This determination is based on the results of Environment Agency monitoring of groundwater beneath and in the vicinity of the Buncefield site, which has been shown to be contaminated with fuels and fire-fighting foam by-products. This area of contamination is deemed to extend over the one hectare threshold described in the Regulations. The reporting of this MATTE to the European Commission has no impact on the continued monitoring and remediation programme that is already taking place.

The continuing Investigation

55 Work continues on the Investigation to ensure that all reasonable lines of enquiry are followed. Evidence continues to be gathered from different sources. The emerging information contributes to a greater understanding of the underlying root causes, and will allow the Investigation team to refine its enquiries further and to bring into focus elements such as wider management systems and organisational factors.

56 Almost all the plant and equipment required for forensic examination has been recovered from the Buncefield site, which will allow the operators to demolish buildings, tanks and bunds. However, further investigation work will be carried out on the integrity of the floors of the bunds together with environmental monitoring of the ground underneath, in particular where tanks were located.

57 The Investigation has also considered previous incidents which may have similarities to the events at Buncefield. These are summarised in Annex 5. Work is in hand to identify other incidents that may be relevant.

Part 2 - Issues of concern arising from the Investigation to date

58 Knowledge of the Buncefield incident is still incomplete, but enough is known to draw some broad conclusions about actions which might be taken to improve health, safety and environmental protection at or near oil storage sites, including areas where further work is needed. The Board does not intend to make any comment at this stage on possible legal proceedings. The initial observations set out here concern broader issues. The Board will continue to ensure that information is made publicly available, either through its own reports or via the Competent Authority, where it is necessary to ensure continued safety, while also attempting to preserve the integrity of any future criminal proceedings that might be brought by the relevant enforcing authorities.

59 The Board's observations and conclusions at this stage fall into three areas, which are considered further below:

- Design and operation of storage sites.
- Emergency response to incidents.
- Advice to planning authorities.

60 We believe these, together with our examination of HSE's and the Environment Agency's roles in regulating the activities on the Buncefield site, will form the broad scope of our further work.

Design and operation of storage sites

61 The Buncefield incident involved failures of primary, secondary and tertiary means to contain fuel and associated fire-waters.

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

- **Secondary** means 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 fire-fighting.

- **Tertiary** means are things such as drains designed to limit the passage of chemicals off site, raised kerbs to prevent liquids that have breached the bunds from escaping into the general area around the site, etc.

62 The Board has already seen sufficient information from the Investigation to be able to express an obvious, but nonetheless important opinion that safety, health and environmental protection are of paramount importance at sites like Buncefield. We would expect this point to be uppermost in the mind of the industry-chaired task group recently convened by HSE to pursue improvements to safety and environmental protection at fuel depots.

63 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.

64 Safety and planning assumptions at fuel depots like Buncefield have until now been based upon fires in pools of escaped liquid, held in check by bunds while the emergency services establish control. The formation of a huge vapour cloud from tank storage was not considered a sufficiently credible scenario for land use planning purposes.[14] One particular lesson from the Buncefield incident is therefore that such a cloud can form while a highly flammable liquid such as unleaded petrol is escaping from primary containment in a storage tank, and where the path of escape involves cascading, fragmenting and dispersing the liquid from height (eg from the vents in the top of a tank that is being overfilled).

65 The Investigation has demonstrated that 'overtopping' a tank with highly flammable fuel is more likely to produce a potentially explosive mixture than pooling from a lower level escape, such as may result from a tank failure. The Investigation has also shown that the design of the tank itself may have contributed to the vapour formation at Buncefield. This suggests that design and construction of tanks and pipework that could be favourable to the formation of flammable vapours should be discouraged.

66 Secondary and tertiary means of containment are vital for environmental protection. However, the secondary containment provided by bunds around tanks is of lesser value where there is rapid formation of vapour that will fairly quickly overflow the bund wall. Tertiary containment also has little effect against a cloud of vapour, as it is intended to intercept and hold liquid flowing along the ground. It is the Board's view that the ineffectiveness of customary means of secondary and tertiary containment against migration of large volumes of vapour re-emphasises that the most urgent focus of attention should be on preventing loss of primary containment and, should that occur, inhibiting rapid large-scale vaporisation and any subsequent dangerous migration of a flammable vapour.

67 The Investigation also revealed that the fire pumphouse that provided the means to distribute cooling water for the whole Buncefield site was immediately adjacent to, and downhill from, Bund A. As described in paragraph 28, recent CCTV analysis has identified this pumphouse as a likely source of one of the early ignitions of the flammable vapour. The loss of the pumphouse, probably from an internal explosion of vapour that had entered from the surrounding cloud, immediately rendered inoperative the fire-fighting provisions for the site. It is foreseeable that flammable vapour in an enclosure could, if ignited, cause damage within that enclosure. The risk of flammable vapour reaching fire pumps increases the closer the pumps are to tanks containing volatile flammable liquids. The industry-chaired task group may want to review whether current guidance related to the siting and/or means of protection of emergency response facilities is suitable at sites such as Buncefield.

68 Following publication of the Investigation Manager's first Progress Report in February 2006, the Competent Authority (HSE with the Environment Agency in England and Wales, and with the Scottish Environment Protection Agency in Scotland) began a programme of site inspections to ensure operators reviewed key design and operational aspects of their sites, a process supported by the findings of subsequent Progress Reports.

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[14] At Buncefield, the formation of a flammable vapour cloud at the tanker loading gantry, as opposed to the tank storage areas, was considered by the Competent Authority and site operators, but the level of off-site hazard this would pose was judged to be lower than a large pool fire originating from the tank storage area.

69 The preliminary findings of the Competent Authority programme were published on 13 June 2006.[15] As a result of the programme, three Improvement Notices have been served. The Board welcomes this initiative and looks forward to the publication of the detailed findings of the Competent Authority programme of inspection this autumn. The Board notes the industry's efforts in working with the Competent Authority to review the findings from both the Investigation and the Safety Alert review, and to make recommendations to the joint industry/regulator task group regarding action needed to improve risk control. In particular, the Board notes that part of this work will be to review and revise published guidance on handling flammable liquids at storage sites by mid-2007, and expects this work to be pursued with vigour.

70 That guidance should be the culmination and record of a substantial effort by the industry, working with the regulators, and begun at once, to develop and implement better methods for handling flammable liquids at storage sites, particularly where volatile fuels are handled, with the principal aim of safely confining them in the vessels intended for that purpose. By 'methods' the Board means the plant, equipment, management systems, operational procedures and working practices provided to achieve safe operation and the ongoing verification by operators, supported by the Competent Authority, that all these control measures are effective.

71 In summary, the Investigation has revealed a number of matters concerning the design and operation of sites such as Buncefield where improvements to maintaining primary containment must be considered by the industry, working closely with the Competent Authority. These matters include:

- the electronic monitoring of tanks and pipework, and associated alarms that warn of abnormal conditions;
- the detection of flammable vapours in the immediate vicinity of tanks and pipework;
- the response to the detection of abnormal conditions, such as automatic closure of tank inlet valves and incoming pipeline valves;
- the extent to which the exterior construction of tanks (eg tank top design) inhibits, or contributes to, flammable vapour formation;
- the siting and/or means of protection of emergency response facilities; and
- the recording of monitoring, detection and alarm systems and their availability (eg off site) for periodic review of the effectiveness of the control measures by the operator and the Competent Authority, as well as in root cause analysis should there be an incident.

72 Where a need for additional systems is identified, HSC and the Competent Authority should satisfy themselves that current legal requirements are robust enough, and supported with sufficient resources, to ensure that these systems are provided and maintained at every fuel storage site where the risks require them, without relying upon voluntary compliance. It has not been established whether changes in the law or in the resources available to the Competent Authority are required to achieve this end. The Board is, however, clear that the severity of the Buncefield incident makes a compelling case for any such changes to be made as a matter of very high legislative priority, should the need be identified.

15 The full report is available on HSE's website at www.hse.gov.uk/comah.

73 As well as ensuring the effectiveness of primary containment, the industry, working with the Competent Authority, should embark on a review of the purpose, specifications, capacity, construction and maintenance of secondary and tertiary containment, and in particular the bunds around tanks. This work should lead to revised guidance, either as part of that referred to in paragraphs 69 and 70, or produced separately – but on at least as rapid a timescale. Again, the necessary standards should be capable of being insisted upon by law.

74 The Board is clear that it will wish to offer further advice when the Investigation is further advanced. This might deal with, for instance, the human and organisational factors that contribute to the safe operation of a major hazard site such as a fuel storage depot. Such factors include, for example, job organisation, management of organisational change, monitoring and supervision, training and control room layout.

75 In the longer term, it may prove necessary to consider additional standards for the overall layout of storage sites.

76 The system for delivering fuel safely around the country depends on good communications between those responsible for delivery and those responsible for receiving the delivered batches, to ensure sites receiving fuel are able to accept deliveries safely. The adequacy of existing safety arrangements, including communications, may also need to be reviewed. The Board expects to return to these and other matters in due course.

77 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.

Emergency response to incidents

78 Improving the arrangements to prevent fires and explosions in no way lessens the need to have effective emergency arrangements in the event of an incident. This covers both planning for emergencies and the effectiveness of the response. 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. The adequacy of these plans depends, among other things, on a full appreciation of the potential for major accidents. In the light of the emerging findings:

- Operators of oil storage depots should review their on-site emergency plans and the adequacy of information they supply to local authorities to ensure they take full account of the potential for a vapour cloud explosion, as well as fires. From the 'forthwith actions' taken by depot operators and the Competent Authority in response to the Competent Authority's Safety Alert of 21 February 2006, responsible operators should have already undertaken such reviews. The Competent Authority must ensure that this is the case and work with the industry to ensure that all learning is fully shared.

- The public health implications of potential vapour cloud explosions must be considered in both on-site and off-site emergency plans. Though the public health impact of Buncefield appears to have been minimal, this may not necessarily have been the case under different conditions.[16]

- As with on-site protective systems, HSC and the Competent Authority bodies should satisfy themselves that legal requirements are robust enough to ensure any necessary changes to emergency plans are duly made.

79 Several separate reviews are looking at the effectiveness of the emergency response to Buncefield. The emergency services, particularly the fire and police services, responded impressively and on a massive scale that was almost certainly unprecedented in modern times. Inevitably there are lessons to be learned from such an exceptional event. This is particularly important given the newness of the local, regional and national resilience arrangements tested at Buncefield. The Board intends to return to this topic when more information is available from those reviews. Meanwhile the Board has the following observations:

- Given the huge cost of the Buncefield incident, it is essential not to miss any of the lessons it has provided for emergency response. Like the response itself, this is a multi-agency task that requires a clear lead. It will be part of the Board's ongoing work to establish a clear picture of the lead provided by central Government for first responders.

- The public health impacts of Buncefield appear to have been minimal. Nevertheless, the incident has revealed the importance of prompt, useful advice to early responders such as the Fire and Rescue Services, and to the public. There may also be scope to improve the co-ordination of sampling and monitoring activities, particularly in the early stages of major incidents. The Board welcomes the establishment of a Health Protection Agency-led working group aiming to establish frameworks and agreed working practices for any future post-incident environmental sampling, and awaits with interest the results of this work. The Board also welcomes the steps being taken by the Health Protection Agency to draw to the attention of regional resilience fora in Britain the immediate lessons of Buncefield for the provision of health protection advice during a major incident.

- The local residential and business communities have interests to be considered, eg the maintenance of employment and support in effecting a rapid return to social normality. This appears to be both a regional and, on the scale of Buncefield, a national issue. It is not clear to the Board how far emergency planning arrangements have taken account of this aspect in the past. The Secretary of State for Communities and Local Government, through the Government Office for the East of England, recently established a task force to investigate options for Government support to businesses and local economies in the period following an exceptional disaster. This initiative is very welcome and the Board hopes swift progress will be made in this work.

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16 The low impact on public health of the Buncefield incident is an initial conclusion of the Health Protection Agency. Their review of the health effects of the Buncefield fire is available at www.hpa.org.uk/explosions/hemel.htm.

Advice to planning authorities

80 One of the starkest issues raised by the Buncefield explosion is the location of sites with such major hazard potential alongside neighbouring commercial and residential development. The situation poses the fundamental planning question that all parties have to address – quite simply, what to do about such development.

81 The Board is acutely aware of the problems that planning uncertainties cause for local communities, particularly those directly affected by the Buncefield incident. Decisions about rebuilding businesses near the Buncefield depot – crucial to the livelihood of those who work in those businesses and to the local economy in general – hinge on decisions about rebuilding the whole of the area, including the depot itself.

82 A key element of the land use planning process for developments around Buncefield and many similar sites is the advice HSE provides to planning authorities. The Board, in its statement of 9 May on publishing the Third Progress Report, indicated its view that enough information had emerged at that stage to enable HSE to review as a matter of urgency the basis and standard of the advice it provides. The Board notes that HSE has acted on that challenge and expects to produce some preliminary conclusions in the autumn of this year.

83 The Board recognises that this is a complex issue for which there are no simple solutions. There is a need to balance the risks and benefits of development – a judgement made no easier by technical and scientific uncertainties. This is illustrated by the fact that HSE's advice on this site was based on a representative 'worst credible scenario' of a major liquid fuel pool fire. A vapour cloud explosion was initially considered, but arising from tanker loading operations and not tank storage. A pool fire was assessed as presenting the greater off-site hazard. The Buncefield incident brings into question the assessment policy for many oil/fuel depot sites, and the zone setting method which it informs.

84 The Board intends to address these issues in more detail, but not before seeing the preliminary conclusions of HSE's review. A measured approach is justified since the likelihood of a similar explosion remains low, and should be made lower still by a programme of actions designed to increase the reliability of primary containment. In our view, the importance of reaching conclusions that are considered, costed, and sustainable greatly outweighs any benefit that might be derived from coming to summary judgements.

85 We will be interested to know HSE's views on the desirability and feasibility of an approach to advise on developments around sites like Buncefield based more on consideration of risk. Under such an approach, the likelihood of major incidents, taking into account all the measures in place against them, would play a more explicit part than hitherto in determining planning advice.

86 The Board has also noted the incremental development around Buncefield (and presumably other sites).[17] Given that most planning advice currently focuses on specific developments subject to planning approval, this could mean that in the future, more attention should be paid to the total population at risk from a major hazard site. The Board welcomes the Ministerial Statement laid in the House of Commons on 15 May, which referred to cross-Government work on this issue currently being co-ordinated by the Cabinet Office, and to which HSE is making an important contribution, and looks forward to the consultation with stakeholders expected later this year.

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[17] The history of development within a 3 km radius of the Buncefield depot site between 1966 and 2005 is shown in Figure 5, Annex 3.

Annex 1

Terms of reference and progress

This annex sets out the eight terms of reference for the Investigation and explains the progress that is being made towards accomplishment of each of them.

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

The Board has published three Progress Reports from the Investigation Manager. These have revealed the main facts of the incident, but have not speculated on why control of the fuel was lost. The explosion mechanism, ie the means by which unexpectedly high overpressures were generated, is subject to significant further investigation. This may require wider expert consultation and research.

The criminal investigation is pursuing all reasonable lines of inquiry into the facts and causes of the incident to enable the Competent Authority (HSE and the Environment Agency) to take a view on legal proceedings.

2 To identify and transmit without delay to duty holders 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

The Competent Authority issued a Safety Alert to around 1100 COMAH duty holders on 21 February 2006. Special attention was paid to 108 fuel depot owners storing COMAH quantities of fuel in Great Britain, seeking a review of arrangements for detecting and dealing with conditions affecting containment of fuel. Most duty holders responded to the alert by the Easter deadline. Meanwhile, the Competent Authority visited all 108 depots to follow up the alert. An interim report was published on 13 June and is available at www.hse.gov.uk/comah/alert.htm.

The Environment Agency issued further advice to its inspectors to investigate secondary (bunding) and tertiary (drains and barriers) containment at depots in England and Wales in response to the Second Progress Report. The Environment Agency is expected to publish a report in the summer. The Environment Agency also continues to monitor the effects of Buncefield on the surrounding environment and to issue updates on its website, www.environment-agency.gov.uk. The initiative is being handled separately for Scotland by the Scottish Environment Protection Agency, with joint inspections undertaken with HSE covering primary, secondary and tertiary containment, and management systems. However, it is intended that an overall view of the situation in Britain will be available this summer.

On 16 June investigators served two Improvement Notices on the manufacturers of the high-level alarm switch installed on Tank 912, having identified a potential problem at other sites related to the setting of the switch for normal operations following testing. This was followed up by a Safety Alert from HSE on 4 July alerting operators relying on such switches of the potential problem.

The Chairman of the Buncefield Board wrote to the Chief Executive of the Health Protection Agency on 3 July enquiring into progress with informing regional resilience groups of early lessons learned from Buncefield, focusing on public health issues in the immediate aftermath of a major airborne incident.

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

Work is progressing steadily on both parts of the review, concerning respectively HSE's and the Environment Agency's prior regulatory activities at Buncefield. The full findings of the review will be incorporated into the Board's final report (see term of reference 8). Any immediate important lessons from the examination of the Competent Authority's prior role will be incorporated into the lessons learned programme under term of reference 5.

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

The ongoing impact on residents and businesses of the Buncefield incident has been reported in all three Progress Reports. The Board has maintained an active interest in releasing as much new information as possible to the community and its representatives, such as the local MP Mike Penning, to assist in understanding the events of 11 December 2005, and to maintain public confidence that progress is being made with the Investigation. Residents and businesses have shown remarkable resilience in great adversity. Dacorum Borough Council in particular, but also St Albans and Hertfordshire Councils, have performed extremely effectively in very difficult circumstances, and have supported the Board in its engagement with residents and businesses, as has Mike Penning MP.

The Board has also kept key Government stakeholders informed of the Investigation's progress, and has maintained its interest in developments that have taken place since Buncefield to help manage the aftermath and support a return to normality for residents and businesses.

The Board has engaged with all the public sector agencies involved in the emergency response to Buncefield and has met with a number of the key agencies, particularly the Category 1 (Gold) responders. This is not an issue in which the Board has primary responsibility but, as reported in this Initial Report, the Board is giving further consideration to emergency response and emergency preparedness issues, and will say more on this later.

The Buncefield Major Incident Investigation made presentations to two multi-agency debriefing sessions on 21 and 28 June to inform regional resilience groups around Britain of the response to the Buncefield incident.

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 offsite as well as onsite risks and consider prevention of incidents, preparations for response to incidents, and mitigation of their effects

HSE, the Environment Agency and the Health Protection Agency are contributing to this work to assist the Board to make sensible, practical and affordable recommendations for improvements in the light of the Buncefield incident. Key workstreams are in environmental protection; land use planning; fire and explosion mechanisms; control and instrumentation; human and organisational factors; health; emergency response and preparedness; and regulatory impact.

HSE has convened an industry-chaired task group that includes the Environment Agency and the Scottish Environment Protection Agency, to consider design and operation issues. The Board is considering how to make suitable arrangements for further research and modelling of explosion mechanisms in flammable vapour clouds. HSE has begun work on changes to land use planning advice and is working closely with a Cabinet Office-led team on applying new knowledge of risks to society in the planning system. The Health Protection Agency is consulting key agencies to improve public health advice and support during significant pollution events.

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

This element is discharged by the publication of this report.

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

A report from the Environment Agency and HSE was made to the European Commission on 10 March. Subsequently, the Environment Agency declared Buncefield a Major Accident To The Environment (MATTE), and the Competent Authority has recently reported this to the European Commission.

8 To make the final report public

The timing for the publication of the final report remains uncertain and is of course linked to progress on the main terms of reference and to any decision on any criminal proceedings that might be considered. The possibilities include a further interim report or reports; decisions must necessarily depend on the timing of developments and consideration of the public interest.

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 DTI. 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. Prior to 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. Paul has worked for 30 years in the health and safety and environmental field.

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

Planning history of Buncefield site and neighbouring developments

1 Planning permission was granted in 1966 to Shell Mex and BP Limited, Regent Oil Co Limited, Mobil Oil Co Limited, and Petrofina (GB) Limited to develop 91 acres of land at Buncefield for the construction of a storage and distribution depot for petroleum products. St Albans Rural District Council initially refused the application on the grounds that it was an inappropriate development in the Green Belt and would have a detrimental effect on the amenity of the locality. On appeal, the Minister of Housing and Local Government granted permission subject to a number of conditions relating to design of the site, tree planting and restrictions on the size of office premises.

2 At the time that the terminal was built in 1968, the site was well screened by hedges and trees, but there were about nine dwellings on the periphery of the site to the north whose amenities were affected by the site, and a farm to the south. One of the nine dwellings to the north was converted in 2000 to create five separate properties. Since 1968 there has been general encroachment and development of adjacent land. This can be seen on the map in Figure 5. The majority of this building development took place during the period from the mid 1960s to the early 1980s, comprising the construction or redevelopment of residential properties and a number of schools and industrial premises to the west of the site, all of which fell within a 3 km radius as shown on the map. Between 1990 and 2006, a few additional industrial premises were built around the site.

3 Dacorum Borough Council is the principal planning authority for the site, but a small section to the north of Cherry Tree Lane falls to St Albans District Council.

4 The local planning authority decides whether developments can go ahead. But arrangements have existed since 1972 for local planning authorities to obtain consultee advice from HSE and its predecessors about the safety implications for developments from risks associated with major hazards. Between 1991 and 2005, 28 applications were passed to HSE for advice relating to a variety of commercial or residential developments around the Buncefield site. HSE advised against four of these proposals and advised that seven others could be allowed subject to certain conditions. As far as is known, the local authority followed HSE's advice in these cases.

5 In addition to these specific developments on which HSE was a statutory consultee, HSE is from time to time consulted on other matters. For example, HSE was consulted on four local structure plan revisions.

6 The complex began operations in 1968 after a pipeline was constructed to link two Shell refineries at Stanlow at Ellesmere Port in Cheshire and Shell Haven on the Thames Estuary at Stanford-le-Hope in Thurrock. The depot operated originally under licence given under the Petroleum (Consolidation) Acts 1928 and 1936. The Planning (Hazardous Substances) Act 1990 and subsequent statutory provisions, the Planning (Hazardous Substances) Regulations 1992 (PHS Regulations) and later the Planning (Control of Major Accident Hazards) Regulations 1999 introduced new procedures for consent to be sought from the hazardous substances authority to store hazardous substances.

7 The consent identifies the hazardous substances and their location on site and defines certain conditions of use such as maximum size, temperature and pressure of storage vessels. Figure 6 contains some details of consents obtained for the Buncefield depot. The consents for Shell UK Oil Limited have been included in this table as they have not been revoked, although Shell no longer operates from this site.

HSE's role in land use planning

8 HSE's specific role in land use planning is twofold:

- Under the PHS Regulations, the presence of hazardous chemicals above specified threshold quantities requires consent from the local hazardous substances authority, which is usually also the local planning authority. HSE is a statutory consultee on all hazardous substances consent applications. Its role is to consider the hazards and risks which would be presented by the hazardous substance(s) to people in the vicinity, and on the basis of this to advise the hazardous substances authority whether or not consent should be granted. In advising on consent, HSE may specify conditions that should be imposed by the hazardous substances authority, over and above compliance with statutory health and safety requirements, to limit risks to the public (eg limiting which substances can be stored on site, or requiring tanker delivery rather than on-site storage). Hazardous substances authorities should notify HSE of the outcome of all applications for consent, and where consent has been granted should supply copies of the site plans and conditions.

- HSE uses the information contained in consent applications to establish a consultation distance around the installation. This usually comprises three zones or risk contour areas. The consultation distance is based on the maximum quantity of hazardous substance(s) that the site is entitled to have under its consent. HSE notifies the local planning authorities of all consultation distances in their areas. The General Development Procedure Order 1995 requires the local planning authority to consult HSE about certain proposed developments (essentially those that would result in an increase in population) within any consultation distance. HSE advises the local planning authority on the nature and severity of the risks presented by the installation to people in the surrounding area so that those risks are given due weight by the local planning authority when making its decision. Taking account of the risks, HSE will advise against the proposed development or simply note that it does not advise against it.

9 HSE's approach to land use planning is set out in more detail in Annex 2 of the first Progress Report. Some of this process is now being devolved to certain local planning authorities.

10 The consultation distance represents the furthest distance at which HSE wishes to be consulted about developments near hazardous installations/major accident hazard pipelines. This does not mean that there is no risk beyond the consultation distance, just that the predicted risks are sufficiently low that they need not be part of a planning decision.

11 Within the consultation distance, HSE undertakes an assessment of the hazards and risks from the installation and produces a map with three contours representing defined levels of harm or risk which any individual at that contour would be subject to, based on information relating to the hazardous substances consent. The harm or risk to an individual is greater the closer to the installation.

The contours form three zones, with the outer contour defining the consultation distance around major hazard sites. The local authority consults HSE on relevant proposed developments within this consultation distance.

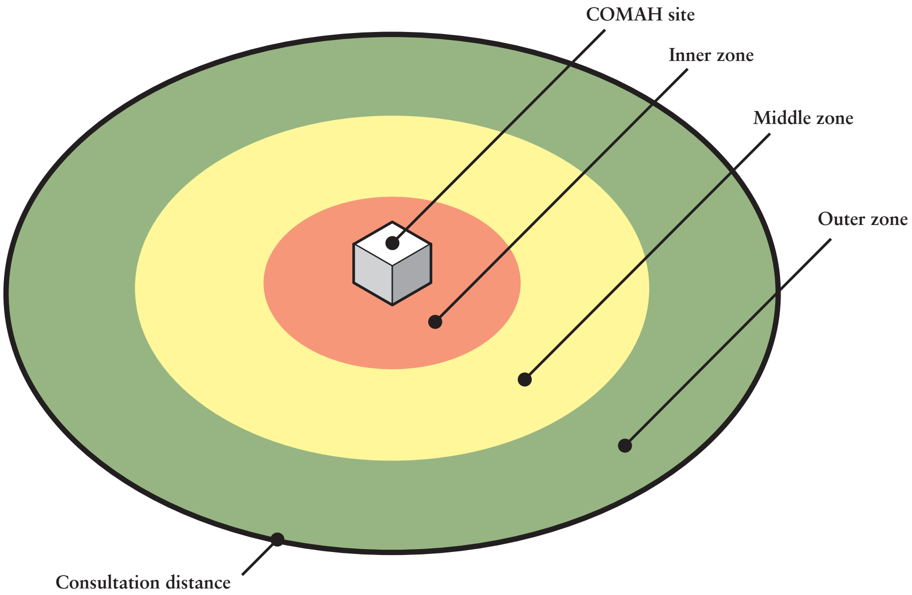

Figure 3 Consultation distance and zones

12 When a planning application is received, HSE or the local planning authority first identifies in which of the three zones the proposed development is located. Secondly, the proposed development is classified into one of four 'sensitivity levels'. The main factors that determine these levels are the number of people at the development, their sensitivity (vulnerable populations such as children, old people) and the intensity of the development. With these two factors known, a simple decision matrix is used to give a clear 'Advise Against' or 'Do not Advise Against' response to the local planning authority, as shown below:

Level of sensitivity	Development in inner zone	Development in middle zone	Development in outer zone
1	DAA	DAA	DAA
2	AA	DAA	DAA
3	AA	AA	DAA
4	AA	AA	AA

Sensitivity level 1	*Example*	Factories
Sensitivity level 2	*Example*	Houses
Sensitivity level 3	*Example*	Vulnerable members of society eg primary schools, old people's homes
Sensitivity level 4	*Example*	Football ground/large hospital

DAA means Do not Advise Against the development
AA means Advise Against the development

Figure 4 Land use planning 'sensitivity levels' and decision matrix

13 More comprehensive guidance on the allocation of sensitivity levels is given on the Planning Advice for Developments near Hazardous Installations website (www.hse.gov.uk/landuseplanning/padhi.pdf).

History of the consultation distance around the Buncefield site

14 HSE has had arrangements with local planning authorities for consultation around developments in the vicinity of major hazards since the early 1970s, although it was not until the implementation of the Notification of Installations Handling Hazardous Substances Regulations 1982 (NIHHS Regulations) in 1983 that HSE first received notification from Shell Mex and BP of the terminal as a major hazard. A generic non-site specific consultation distance of 250 m from the boundary of the site was set for consultation purposes and the relevant local planning authority was notified. At that time it was customary to issue a generic consultation distance without performing a site-specific assessment. This consultation distance was based upon the assumption that the main hazard was from thermal radiation following a major fire within the bund.

15 In 1992 the site expanded and Mobil and Shell sent another notification and application for consent to store certain amounts of flammable material. The existing consultation distance was maintained at a generic 250 m from the site boundary. There are no records of the technical assessments that were performed when the local planning authority sought advice on developments within the vicinity of the site, but early assessments were based then, as now, upon a pool fire following loss of containment of a substantial quantity of flammable liquid. However, for tanks that were bunded there was a continuing assumption that any subsequent fire would be within the confines of the bund.

16 In 1996 a site-specific reassessment was performed based upon consented amounts of flammable material, and the consultation distance was reduced from 250 m to 190 m. The original 250 m was set in the early days of HSE giving land use planning advice, to ensure that all developments that might be advised against would be subject to consultation. By 1996, technical policy and methodology had been reviewed. In addition, three-zone maps were now being produced so that development control advice could be given more quickly and efficiently. The new policy assumed that the bund would not be able to contain the full contents of a tank following a sudden, catastrophic failure. It was assumed that the bund would be overtopped and the resulting pool fire would extend beyond the confines of the bund.

17 In July 2001 another consultation distance was calculated due to an extensive reassessment of the hazards from the site following the submission of a batch of new consent applications from the oil companies. The regulations requiring consent to store flammable substances were changed in 1999 to include additional flammable materials. The consultation distance was reduced from 190 m to 185 m. This was unchanged following a further consent application on 8 July 2005 from BP. The presence of the additional material did not alter the main basis of the calculation which assumed the worst-case event was the catastrophic failure of the largest tank containing gasoline. The consultation distance was reduced slightly owing to a slight change to the inputs in the model used to perform the calculations. See Figure 7 for a representative plan of the site showing the consultation distance since July 2001.

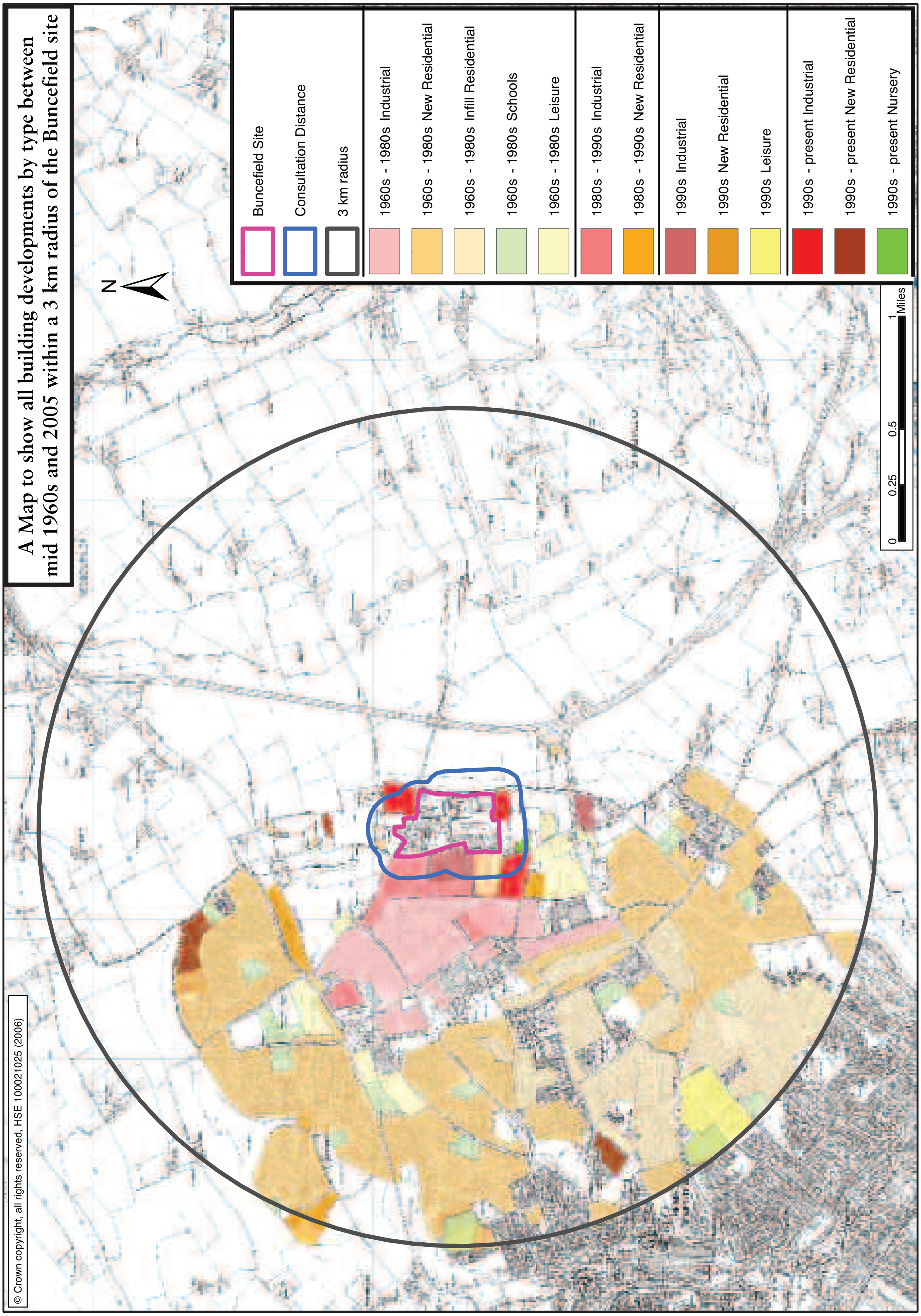

Figure 5 Developments within 3 km of the Buncefield site between 1966 and 2005

Some details of hazardous substances consents issued for the Buncefield oil storage and transfer depot

Operator	Hazardous Substances Consent applications
Texaco Limited	19 September 1983*: 10 571 tonnes motor spirit
Mobil Oil Co Limited	8 November 1983*: 17 650 tonnes petrol
Hertfordshire Oil Storage Limited	30 November 1992: 34 020 tonnes motor spirit 18 October 1999: 15 314 tonnes kerosene
BP Oil UK Limited	18 November 1992: 17 650 tonnes gasoline in name of Mobil Oil Co Limited 26 October 1999: 15 080 tonnes automotive petrol and other petroleum spirits 21 October 2003: 15 200 tonnes automotive petrol and 10 522 tonnes petroleum products classified as dangerous for the environment (most likely to be gasoline or diesel) 3 May 2005: 26 900 tonnes automotive petrol and 10 522 tonnes petroleum products classified as dangerous for the environment (most likely to be gasoline or diesel)
British Pipeline Agency Limited	26 October 1999: 70 000 tonnes automotive petrol and other petroleum spirits
Shell UK Oil Limited	19 September 1983*: 37 397 tonnes HFLs Class 4 and 42 561 tonnes kerosene and white oils 30 November 1992: 34 013 tonnes petroleum spirit and 39 000 tonnes diesel, gas oil and kerosene 1999: 33 000 tonnes motor spirit and 17 000 tonnes kerosene

Figure 6 Hazardous substances consents issued

* ***Note:*** *The first applications for 'consent' were in 1992, before then different arrangements were in place, ie these were notifications under NIHHS and consent was not required.*

Figure 7 Plan representing the hazardous substances consents and consultation area around the Buncefield depot since July 2001 (for illustration only)

Annex 4

UK petroleum refinery, pipeline and storage system

Refineries

1 Petroleum products in the UK are predominantly supplied from nine refineries where crude oil is refined into liquefied petroleum gas (LPG), petrol, diesel, aviation fuel, gas oil, heating oil and residual bitumen. From a typical barrel of North Sea crude oil, approximately 3% becomes LPG, 37% petrol, 25% diesel, 20% kerosene (aviation fuel/heating oil) and 12% fuel oil (for power generation). Figure 8 shows the location of the refineries. They are sited on the coast or on estuaries so that they can receive crude oil by ship.

Figure 8 UK oil refinery and pipeline network

2 Storing, moving and delivering these fuels to the end user are important elements of the UK economy. Each year approximately 75 million tonnes of petroleum products are moved around the UK.

3 All nine main refineries in the UK have substantial storage for finished products coming out of the refinery. However, given the location of refineries, there are also large storage terminals around the country, generally near major conurbations. These terminals are mainly supplied from the refineries by pipeline, rail and sea. Often they are run as joint ventures between a number of oil companies. Commercial arrangements are commonly negotiated between companies to draw products on exchange from another company's terminal. This avoids the need to transport products over long distances from one terminal to another. Figure 9 shows the place of oil storage and transfer depots in the UK oil distribution system.

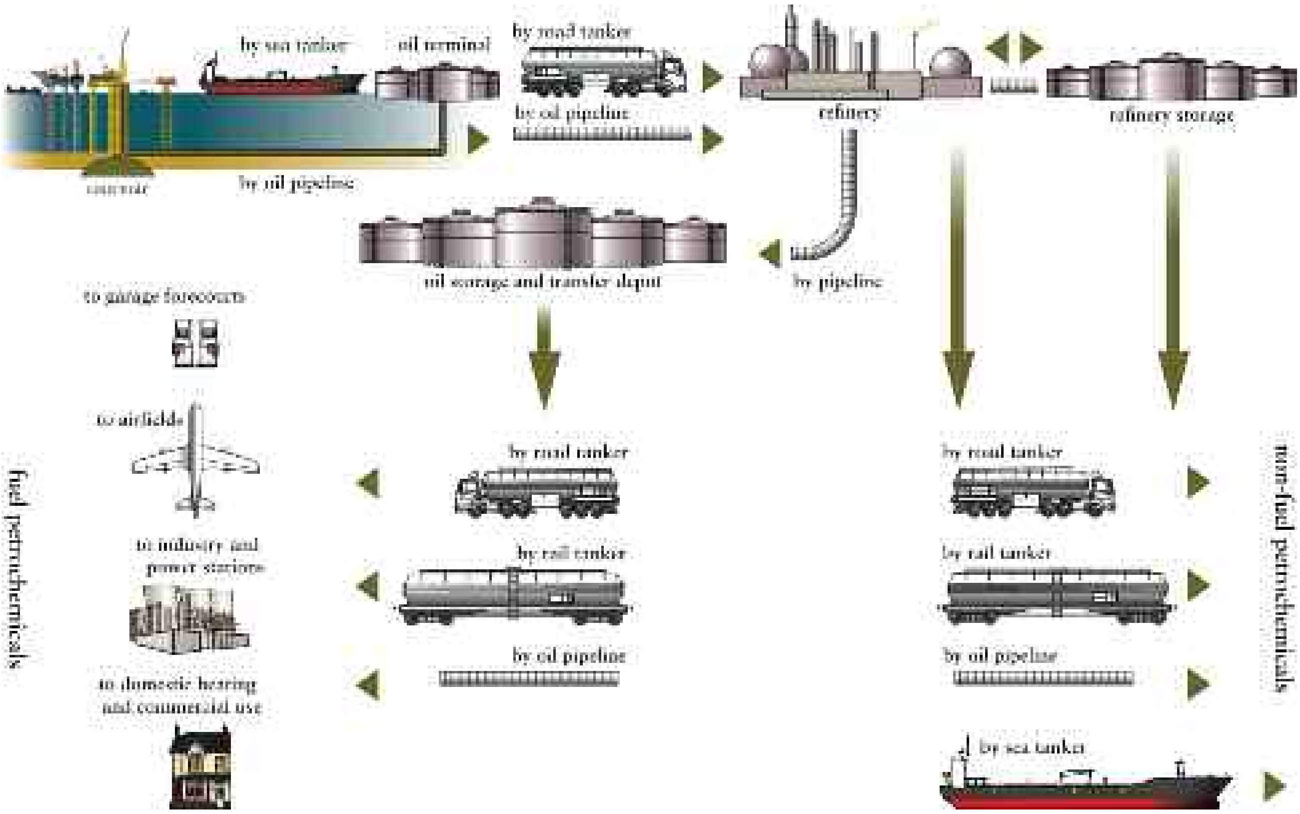

Figure 9 The UK oil distribution system

Petroleum pipelines

4 The UK mainland has a network of approximately 1500 miles of petroleum pipelines. Some of them are owned by individual oil companies dedicated to supplying their own terminals, and some are owned by joint ventures such as United Kingdom Oil Pipelines Limited (UKOP). Others belong to the Government. Once installed, underground pipelines offer substantial environmental and safety benefits, not least from the elimination of road tanker journeys or transportation by rail or sea.

5 These pipelines are used to transport a variety of fuels, including petrol, diesel, heating oil and aviation fuel. After a batch of predetermined volume of one fuel has been delivered through the pipeline, a different fuel may be transported. As the fuels travel along the pipeline, a relatively small degree of mixing will occur at the interface. As this volume of mixed fuels has to be reprocessed, the pipeline operator manages the flow rates continually to minimise these interfaces to reduce wastage. Around 30 million tonnes of fuel are moved around the UK in this way in a year.

Annex 5

Incidents that have similarities with the Buncefield incident

Location	Date and time	Comments – background	Comments – explosion	Ref *see over*
1 Houston, Texas, USA	April 1962	'Severe leak' from a gasoline tank. Almost windless conditions. Ignition near adjacent highway.	Described as a 'blast', but no details are available.	1
2 Baytown, Texas, USA	27 January 1977	Overfilling of a ship with gasoline.	Few details are available, but it is likely that there would have been congestion.	1
3 Texaco, Newark, New Jersey, USA	7 January 1983 After 00.00 hrs	Overfilling of a tank containing unleaded gasoline. 114-379 m^3 (80-265 tonnes) of gasoline released. Slight wind, ignition source 300 m away.	Relatively uncongested area. High overpressures reported, but not quantified. Three minor explosions preceded the main blast.	2
4 Naples Harbour, Italy	21 December 1985	Overfilling of a tank containing unleaded gasoline. 700 tonnes escaped. Low wind speed (2 m/s).	Relatively congested area. The tank overtopped 1.5 hours before ignition. Various overpressures estimated from damage analysis, but they are minimum values (eg >48 kPa).	3
5 St Herblain, France	7 October 1991 04:00 hours	Leak of gasoline from a transfer line into a bund. Wind <1 m/s. 20 minutes delay, ignition in car park c. 50 m away. Volume of flammable cloud est. 23 000 m^3.	Presence of parked petrol tankers may have been sufficient to generate turbulence. High overpressures produced, but not quantified.	4
6 Jacksonville, Florida, USA	2 January 1993 03:15 hours	Overfilling of a tank containing unleaded gasoline. 50 000 gallons (190 m^3, 132 tonnes) released.	High overpressure produced, but not quantified.	5
7 Laem Chabang, Thailand	2 December 1999 23:25 hours	Overfilling of a gasoline tank. Few details.	High overpressure produced, but not quantified. Relatively low congestion in the area.	6

Note: *The root cause of each of the above incidents was the spillage (loss of containment) of a large quantity of gasoline (eg >100 tonnes) due to overfilling of a tank, or failure of pipework inside a bund. In each case, the windspeed was very low, or zero, and a significant vapour cloud was able to form. The feature of the Buncefield explosion that appeared unique was the apparent lack of obstacles which could induce turbulence and thereby lead to rapid flame propagation, sufficient to produce the high overpressures recorded. Accordingly, incidents 2, 4 and 5 may not be relevant. As the 'lack of confinement' cannot be quantified, the relevance of the other incidents might be superficial. More information is required. Work is in hand to identify other incidents that may be relevant.*

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2 Bouchard JK *Gasoline Storage Tank Explosion and Fire: Newark NJ January 7, 1983* National Fire Protection Association (NFPA) Summary Investigation Report (in co-operation with Federal Emergency Management Agency/United States Fire Administration and National Bureau of Standards/Center for Fire Research)

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5 Edited from a report prepared by Lt Lorin L Mock, Training Division, Jacksonville Fire and Rescue Department 'Covered Floater in Jacksonville: Steuart Petroleum Bulk Storage Tank Fire' *Industrial Fire Safety* May/June 1993 17-32

6 *THAIOIL Fire: A whiff of oil, then a thundering explosion* Witness Accounts, Bangkok Post (FBKP) 5 December 1999 Page 1

Annex 6

Fire and explosion hazards from petrol

Introduction

1 This annex sets out a general explanation of the fire and explosion hazards from fuels such as petrol, as currently understood. It is not limited to the circumstances of the Buncefield incident.

Flashpoint

2 The physical properties of highly flammable liquids, such as petrol, are such that if they are mishandled or released they present a significant risk of fire or explosion. In this context, perhaps the most important property of petrol is its high volatility. At normal ambient temperatures, the vapour released by simple evaporation from the fuel surface can readily be ignited as it mixes with air. It is classified legally as a Highly Flammable Liquid, ie it has a flashpoint (measured in a 'closed cup' apparatus) below 32 ^{o}C.

3 'Flashpoint' is used to define the hazard associated with liquid fuels and to help determine safe working conditions. The flashpoint is defined as the minimum temperature at which a liquid fuel produces sufficient vapour to form a flammable or ignitable mixture with air. Petrol has a flashpoint of around minus 40 ^{o}C, well below normal (ambient) temperatures, and can be ignited very easily. It is the vapour that 'burns', releasing heat, some of which is transferred to the surface of the fuel, thus increasing the rate of evaporation that supplies the flame with fuel vapour. Paragraph 7 of this annex provides more information about fuel fires.

4 Not all concentrations of fuel vapour in air are flammable, ie capable of being ignited by a small ignition source such as a spark or a flame. Ignition can only occur if the mixture of flammable vapour in air falls within certain concentrations, known as the lower and upper explosion (or flammability) limits. For petrol vapour, concentrations below 1.4% in air are too lean to burn, while those above 7.6% are too rich.[18] At all concentrations between these two limits, known as the flammable range, the mixtures will burn, in that a flame will propagate away from the ignition source.

5 The flash point and the flammable range are determined by standard test methods.

6 Whether an ignition can give rise to a fire, an explosion or a combination of both depends on a number of factors, including the conditions prevailing at the time and the immediate surroundings of the release, but particularly on the amount of vapour present and how it is able to mix or diffuse with air.

Fires

7 In a fire, the vapour evolved from spilt or released material is ignited and continues to burn above the fuel surface where the vapour mixes with the surrounding air. This type of flame is known as a diffusion flame as the fuel vapour

[18] The concentration of petrol vapour in a partially full petrol tank is above the upper explosive limit and therefore too rich too burn.

and air mix by diffusion, and it is the type of flame associated with fires involving liquid and solid fuels. Heat transferred from the flame to the fuel provides the energy required to maintain the flow of fuel vapours that support the flame. The flames associated with a liquid pool fire will completely cover the surface and will continue to burn as long as there is fuel remaining. The flames of a petrol pool fire will extinguish when all the petrol is consumed, or if air can be excluded from the flames, or if the vapour release can be prevented or inhibited (as happens when the liquid surface is completely covered with a layer of fire-fighting foam).

8 With large hydrocarbon pool fires such as those at Buncefield, the flames are so large that mixing of fuel vapour and air is not efficient. This leads to the formation of species within the flame that cause the release of copious amounts of black smoke. The immediate precursors of the smoke are minute soot particles which radiate, producing the characteristic yellow colour associated with almost all diffusion flames. The hazards arising from such fires are due to heat transfer by radiation to neighbouring surfaces and to the hot fire products (rich in smoke and toxic gases) carried aloft by buoyancy. Pressure effects are negligible and could not cause structural damage, but heat transfer to structures immersed in the flames will cause weakening and eventual collapse.

Explosions

9 For an explosion involving petrol vapour to occur, the vapour/air mixture must be within its flammable range when it encounters a potential source of ignition. A flame will propagate rapidly, spreading spherically from the ignition source throughout the entire flammable mixture. The heat released as the fuel is consumed causes the gases to expand as a result of the associated temperature rise. If confined, eg if the mixture is contained within a building, the gases cannot expand freely and the pressure will rise until parts of the confining structure (such as the windows of a building) fail and relieve the pressure. This is normally a violent event and may produce a shock wave that can cause remote damage.

10 High temperature effects from the explosion are transient, but they will ignite highly flammable liquids and can ignite lightweight combustible solids (eg tissue paper). Some can be left burning after the explosion has passed. The flame created by an explosion of petrol vapour in air is blue or very pale yellow, depending on the fuel/air mixture. It is known as a premixed flame as the fuel vapour and air are mixed before ignition occurs. The amount of smoke produced is negligible compared to that produced in a fire.

11 In general terms, overpressures are not developed if an unconfined petrol vapour/air mixture is ignited because the gases can expand freely. However, the speed at which the flame travels through the flammable mixture can vary considerably, depending on a number of different factors. If the flame speed is very high, some overpressure will be created as the expansion cannot occur rapidly enough, despite the (apparent) lack of confinement. Factors that affect the speed with which a flame will travel through a flammable mixture include:

- composition of the mixture;
- amount of vapour and size of the flammable cloud;
- strength of the ignition source;
- degree of confinement within the flammable cloud (‘partial confinement’);
- turbulence created within the mixture as the flame front forces the unburnt mixture through a partially confined space.

12 The term 'partial confinement' is used to describe a situation in which obstacles lie in the path of the advancing flame. As the (as yet) unburnt mixture is forced past these obstacles, turbulence is produced. The flame will travel much more rapidly through a turbulent mixture than through a quiescent one.

13 The flame speed may vary from a few metres per second (m/s) to sonic velocities (340 m/s). Under certain conditions, supersonic velocities may be reached. If the velocity is subsonic the propagating flame is termed a deflagration. If the flame speed is greater than the speed of sound the explosion is termed a detonation. The faster a flame travels, the greater the overpressure produced. A cloud of petrol vapour in the open without any turbulence creating obstructions, such as complex pipe racks or congested plant, would on ignition produce a deflagration with a relatively slow flame speed (eg 10 m/s). Such an event would give rise to overpressures of about 0.2 psi (14 mbar). For a flame to accelerate beyond this and create higher overpressures, some or all of the factors mentioned above would have to play a part. A flame would not accelerate to detonation unless it was confined in a long narrow structure such as a pipeline.

14 As indicated above, if a flammable mixture is ignited within an item of enclosed plant or equipment, the pressure will build up until the plant either fails or a purpose-built vent or explosion relief panel opens. Storage tanks, for example, are normally designed with a weak roof joint so that in the event of an internal explosion, the explosive forces are vented upwards without the rest of the tank failing. Without any venting, and provided that the item of plant does not fail, an internal deflagration from hydrocarbon vapours could theoretically give a maximum pressure rise of approximately 130 psi (8.9 bar).

Flash fires

15 A flash fire can occur if a vapour rich cloud spreads from its release point, undergoing some dilution at the interface between the cloud and the surrounding air so that a flammable mixture exists only at the interface. The cloud still has a fuel-rich core. Upon ignition the flame front will rapidly propagate through the flammable regions of the cloud and the fuel-rich region will burn more slowly as it mixes with air. The flames will eventually become established as an ordinary diffusion flame at the point of origin. Flash fires do not usually generate any appreciable overpressure effects.

Overpressure

16 The pressure wave created by an explosion can have an effect on people, plant or property, in addition to the harmful effects from the burning vapour. The greatest effects from the pressure wave will be at the closest point to the explosion. Previous work to categorise the damage from blast overpressure has mainly considered the effects from conventional explosives and nuclear bomb tests, rather than the type of incident that occurred at Buncefield. Explosions are often classified according to their TNT equivalent, with an 'efficiency factor' used to compensate for the lower efficiency of an igniting vapour cloud in converting chemical energy into blast energy.

17 Another difference is that the blast from a conventional explosive has a high peak pressure over a short period of time, when compared to a hydrocarbon cloud which generates a lower peak pressure but of longer duration. The longer duration creates a higher impulse and therefore a different damaging effect than the same energy release from a high explosive. A further problem with using this information to analyse vapour cloud explosion events is the fact that conventional explosives have a point source, whereas a vapour cloud occupies a large volume.

18 The following table lists commonly accepted damage figures from blast overpressure and can be used for comparative purposes. However, care has to be taken in using this data as it does not take into account the duration of the pressure wave.

Commonly accepted damage figures from blast overpressure

Pressure (psi)	Pressure (millibar)	Damage
0.02	1.4	Annoying noise, if of low frequency
0.10	7	Breakage of small windows under strain
0.15	10	Typical pressure for glass failure
0.30	21	Damage to some ceilings
0.40	28	Minor structural damage
0.5-1.0	34-70	Large and small windows shattered, damage to window frames
0.75	52	Minor damage to houses, 20-50% of tiles displaced
0.9	63	Roof damage to oil storage tanks
1.0	70	Houses made uninhabitable
1.0-2.0	70-140	Asbestos cladding shattered, fastenings of corrugated steel panels fail, tiled roof lifted and displaced
2.0	140	Partial collapse of walls and roofs of houses, 30% of trees blown down
3.0	210	90% of trees blown down, steel framed buildings distorted and pulled away from foundations
3.0-4.0	210-280	Rupture of oil tanks
4.0-5.0	280-350	Severe displacement of motor vehicles
5.0	350	Wooden utility poles snapped
7.0-9.0	490-630	Collapse of steel girder framed buildings
8.0-10	560-700	Brick walls completely demolished
>10	>700	Complete destruction of all unreinforced buildings
70	4900	Collapse of heavy masonry or concrete bridges

Source: HSE Specialist Inspector Report Number 37 – Simplified calculations of blast induced injuries and damage

Commonly accepted figures for direct harm to people from blast overpressure

Pressure (psi)	**Pressure (millibar)**	**Direct harm to people**
2	138	Threshold for eardrum rupture
1.5-2.9	103-200	People knocked down or thrown to the ground
10-15	690-1035	90% probability of eardrum rupture
12-15	830-1035	Threshold of lung haemorrhage
30-34	2068-2400	Near 100% fatality from lung haemorrhage

19 HSE uses the following levels of overpressure for providing land use planning advice around hazardous installations. These are based on estimates of fatalities within occupied buildings.

Pressure (psi)	**Pressure (millibar)**	**Direct harm to people**
8.6	600	50% fatalities for a normal population
2	140	Threshold of fatality (1-5%) for a normal population
1	70	Threshold of fatality (1-5%) for a vulnerable population

Annex 7

Product composition at Buncefield

1 Extensive sampling of the various petroleum products at the Buncefield depot has been carried out to verify the product distribution through the site from the different supply pipelines, and also to identify the composition of the released materials. The majority of the samples were taken from the Hertfordshire Oil Storage Limited site but samples were also taken from the two pipelines feeding unleaded petrol to the site, the United Kingdom Oil Pipelines Limited T/K pipeline and the FinaLine pipeline from the Lindsey refinery.

2 As a release of unleaded petrol is considered to be the initiating event for the explosion and subsequent fire, all petrol samples have been tested against the standard BS EN 228 for automotive fuels, together with a full chemical analysis by an independent accredited test house.[19] Samples of other products handled on site including diesel, aviation fuel and gas oil have been subject to simple laboratory tests to confirm their identity.

Product identification

3 The test results from the samples taken on site are consistent with the product type identified from the site plans or by the company as being contained or held within any particular plant or section of pipework. Many of the samples showed degradation or contamination caused by heat-damaged plant or open pipework as a result of the incident. This degradation is particularly noticeable by the loss of the more volatile components, including butane, from many of the samples.

4 The loss of volatile components from the samples has made a direct comparison of their analytical results and subsequent tracking of the different product sources through the site extremely difficult. In addition representative samples from Tank 912 after the incident are not available as this tank completely burnt out, and only fire-damaged residues consisting mainly of water could be extracted from the tank bottom. The samples of the material feeding Tank 912, taken by the operator prior to the incident and retained on site, were destroyed during the incident.

Product composition

5 The evidence to date is consistent with the release of petrol from Tank 912 while it was being fed from the British Pipeline Agency Limited manifold. Petrol is a blend of many different hydrocarbons, each of which will have an impact on the vapour pressure. The British Pipeline Agency Limited manifold feeding Tank 912 was being supplied by a parcel of unleaded petrol from the British Petroleum PLC oil refinery at Coryton, Essex. That in turn was made up from the feed from four separate tanks. No sample of the parcel is available as the part-batches from the feeder tanks are not blended and tested as a composite batch before being pumped from site. British Petroleum PLC has provided the Conformity Certificates for the individual feeder tanks showing their analysis against the British Standard. The British Standard is a performance specification and only details specific limits for

[19] BS EN 228: 2004 *Automotive fuels. Unleaded petrol. Requirements and test methods*. Available online at www.bsonline.bsi-global.com.

the chemicals lead and benzene. By way of example, the standard does not specifically limit the content of butane, which comprises a mixture of butanes and butenes, and therefore the presence and levels of these individual components are not routinely determined. The total butane content, however, will affect the vapour pressure and this is specified in the standard depending on whether the product is marketed as winter or summer grade. For winter grade petrol the vapour pressure limits are defined as 70-100 kPa and for summer they are reduced to 45-70 kPa.

6 The Conformity Certificates show that the vapour pressure for the four part-batches were all at or very close to 100 kPa. This was corroborated by evidence obtained from the British Pipeline Agency Limited site after the incident. This corresponded to a total butane content of 10.0%. By contrast, other samples of petrol taken from the site after the incident and which had been degraded by exposure to the fire were found to have lower vapour pressures and correspondingly lower butane levels. Therefore the product released on site was at the top end of the winter grade limit for vapour pressure. A reasonable estimate of the butane content of the released material is 10% by weight.

Annex 8

Regulatory framework for high hazard sites

1 The regulatory framework for sites such as Buncefield, which present potential major accident hazards, comprises requirements imposed on the site operators under both health and safety and environmental legislation, complemented by the requirements of planning law. In particular, the Control of Major Accident Hazards Regulations 1999 (COMAH) apply.

Health and safety law

2 Operators in the process industries are subject to the requirements of the Health and Safety at Work etc Act 1974 (the HSW Act) and the Management of Health and Safety at Work Regulations 1999 which require, respectively, safety policies and risk assessments covering the whole range of health and safety risks.

Control of Major Accident Hazards Regulations 1999 (COMAH)

3 COMAH's main aim 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 COMAH 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. There are two thresholds, known as 'lower-tier' and 'top-tier'. The requirements of COMAH are fully explained in The requirements of COMAH are fully explained in *A guide to the Control of Major Accident Hazards Regulations 1999 (COMAH). Guidance on Regulations* L111 HSE Books 1999 ISBN 0 7176 1604 5.

4 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. Operators will generally receive a single response from the Competent Authority on all matters to do with COMAH. The Competent Authority operates to a Memorandum of Understanding, which sets out arrangements for joint working.

5 The COMAH Regulations require operators of top-tier sites to submit written safety reports to the Competent Authority with the purpose, among others, of demonstrating that major accident hazards have been identified and that the necessary measures have been taken both to prevent such accidents and to limit any consequences. Operators of top-tier sites must also prepare adequate emergency plans to deal with the on-site consequences of possible major accidents, and to assist with off-site mitigation. Local authorities for areas containing top-tier sites must prepare adequate emergency plans to deal with the off-site consequences of possible major accidents, based on information supplied by site operators.

6 The COMAH Regulations place duties on the Competent Authority to have in place a system of inspections for establishments subject to the Regulations, and to prohibit the operation of an establishment if there is evidence that measures taken for prevention and mitigation of major accidents are seriously deficient. The Competent Authority also has to examine safety reports and inform operators about the conclusions of its examinations within a reasonable time period.

7 The inspection plan for a particular establishment is drawn up by inspectors from the Competent Authority based on previous interventions at the site and on information gained from the assessment of the safety report. The inspection programme requires input from a range of inspectors with specialist knowledge and identifies and prioritises issues. The focus of the programme is to ensure that the key risk control measures for preventing and mitigating major hazards are maintained.

8 The adequacy of this process and its application at Buncefield by HSE and Environment Agency inspectors is subject to a review under term of reference 3.

Environmental legislation

9 Some of the establishments regulated under the COMAH Regulations are also regulated by the Environment Agency and SEPA (the Agencies) under the Pollution Prevention and Control Act 1999 (PPC) or Part I of the Environmental Protection Act 1990 (EPA 90). The regime under EPA 90 is gradually being replaced by the PPC regime and will be fully replaced by 2007.

10 While the purpose of the COMAH Regulations (the prevention of major accidents) differs from that of PPC, the means to achieve them are almost identical. They require industry to have good management systems to control risk. PPC includes a specific duty to prevent and mitigate accidents to the environment which is complementary to the main COMAH duty. The Agencies manage this overlap between their different regimes following the principle that accident prevention work on COMAH sites is generally more significant because of the greater risks.

Supporting guidance and standards

11 The legal requirements are supported by a large body of guidance and standards that set out recognised good practice in the control of major accident hazards. This includes national and international standards, industry guidance and guidance published by the Competent Authority. Examples of the latter are *Reducing error and influencing behaviour* HSG48 (Second edition) HSE Books 1999 ISBN 0 7176 2452 8 and *Successful health and safety management* HSG65 (Second edition) HSE Books 1997 ISBN 0 7176 1276 7.

Land use planning

12 The land use planning aspects of the Seveso II Directive are given effect in the UK by the Planning (Hazardous Substances) Regulations 1992, as amended in 1999. Under these Regulations the presence of hazardous chemicals above specified thresholds requires consent from the hazardous substances authority, usually the local planning authority. HSE is a statutory consultee on such occasions. The role of HSE is to consider the hazards and risks which would be presented by the hazardous substances to people in the vicinity, and on the basis of this advise the hazardous substances authority whether or not consent should be granted. HSE will also supply a consultation distance around the site. Any future developments in these zones require HSE to be consulted.

13 The aim of health and safety advice relating to land use planning is to mitigate the effects of a major accident on the population in the vicinity of hazardous installations, by following a consistent and systematic approach in providing advice on applications for planning permission around such sites.

14 Historically, HSE has based its land use planning advice on the presumption that site operators are in full compliance with the HSW Act. Section 2 of the Act places a duty on an employer to ensure, so far as is reasonably practicable, the

health and safety of his employees. There is a corresponding duty in section 3 to ensure, so far as is reasonably practicable, that others (including the public) are not exposed to risks to their health and safety. These duties are goal-setting and operators are expected to determine the most appropriate means to comply with them, without the need for detailed approval from HSE.

15 Under the General Development Procedure Order 1995, both HSE and the Environment Agency are statutory consultees for:

- the development of a new major accident hazard site; or
- developments on an existing site which could have significant repercussions on major accident hazards; or
- other developments in the vicinity of existing establishments, where the siting or development is such as to increase the risk or consequences of a major accident.

Annex 9

Regulation of perfluorooctane sulphonates (PFOS)

1 Perfluorochemicals are a family of chemicals used in products designed to repel dirt, grease and water, including kitchenware, carpet treatments, food wrappers, sprays for leather and other clothing, paints and cleaning products.

2 A group of these substances, perfluorooctane sulphonates (collectively identified as PFOS), has been shown to be hazardous (persistent, bioaccumulative and toxic). PFOS has been used in a diverse range of applications, from fire-fighting foam additives to use as a mist suppressant in chromium plating. PFOS was also used in common household anti-soil treatments often referred to by the trade name 'Scotchgard' (a trademark of 3M PLC).

3 The UK Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT), an independent scientific committee that provides advice to the Food Standards Agency, the Department of Health and other Government Departments and Agencies on matters concerning the toxicity of chemicals - is currently evaluating PFOS, most recently in May 2006.[20]

4 On the basis of the preliminary COT discussions, the Health Protection Agency advised the Drinking Water Inspectorate in March 2006 that, 'It appears unlikely that a lifetime's consumption of drinking water containing concentrations up to three microgrammes (of PFOS) per litre would harm human health' and that 'drinking-water concentrations of PFOS should not exceed three microgrammes per litre.' The Health Protection Agency will review its advice when COT has finalised its assessment of PFOS.

5 In the light of current Health Protection Agency advice, the Drinking Water Inspectorate's view (29 March 2006) is that to safeguard human health, PFOS should not be present in drinking water supplies above three microgrammes/litre (µg/l).

6 PFOS does not appear to undergo any degradation in the natural environment. Due to this extreme stability it has now become widespread both in man and the environment. The biological persistence of PFOS in living organisms is high, with an estimated elimination half-life for humans of the order of four to eight years.

7 These concerns resulted in the principal manufacturer of PFOS (3M) announcing a voluntary phase-out of PFOS manufacture from 2001 onwards. PFOS, however, continues to be produced by some companies and is used in some industrial processes, for example semiconductor production and chromium plating. PFOS was used as an ingredient in some AFFF Class B fire-fighting foam concentrates until a few years ago. These concentrates have a shelf life of at least ten years and remaining stocks will therefore continue to be available for use on oil fires.

8 DEFRA consulted on a national action to restrict the use of PFOS and substances that may degrade to PFOS in October 2004. This included proposals to phase out the use of PFOS in fire-fighting foams. In December 2005, the European Commission issued a proposal for a Directive restricting the marketing and use of PFOS. In this draft Directive PFOS used in fire-fighting foams as well as

[20] The COT minutes and background working paper are available from www.food.gov.uk/science/ouradvisors/toxicity/cotmeets/cot2006/334454.

photolithography, photographic coats, chromium plating and hydraulic fluids for aviation would be allowed to continue.

9 The Environment Agency has conducted a national environmental risk assessment of PFOS.[21] This concluded that there was an environmental risk for all PFOS uses. For now, the drive to minimise PFOS in the environment and drinking water has to be reconciled with its continued use in some industrial sectors.

10 The risk reduction strategy proposed by DEFRA would have phased out PFOS use in chrome plating two years after the legislation came into force, and in fire-fighting foam and most other applications five years after the legislation came into force. The draft EU Directive (December 2005) on PFOS does not phase out the use of PFOS in these applications. The EU has now prohibited the UK from imposing unilateral restrictions on the use of PFOS and any action to restrict the use of PFOS will now proceed at an EU level.

The Environment Agency's approach

11 The Environment Agency's policy aim is to progressively reduce and ultimately phase out the discharge of PFOS to controlled waters. However, the Environment Agency does not regulate all users and, due to its widespread presence, it is not feasible to prevent all discharges of PFOS into controlled waters. When calculating acceptable concentrations of PFOS in consented effluent discharges to surface water the Environment Agency will aim to prevent detectable emissions where possible. As PFOS is a List I substance under the Groundwater Directive, the Environment Agency cannot authorise its disposal to groundwater.

21 Brooke D, Footitt A and Nwaogu TA *Environmental risk evaluation report: perfluorooctane sulphonate (PFOS)* Research Contractor: Building Research Establishment Ltd. Risk and Policy Analysts Ltd.

Annex 10

Legal considerations

Prosecution decision making

1 The Board is aware that the process of making enforcement decisions is complex. Every duty holder and situation is unique. The prosecution decision can only be considered once the criminal investigation is fully complete, ie all reasonable lines of enquiry have been followed (in line with the Code of Practice issued pursuant to the Criminal Procedure and Investigations Act 1996). In the case of HSE, the HSC Enforcement Policy Statement sets out the approach to be followed, in accordance with the aims of the Government's 'Principles of Good Enforcement' and requires HSE to apply the Code for Crown Prosecutors (The Code).

2 The Environment Agency has its own Enforcement and Prosecution Policy, which also relies on those principles and commits the Agency to take account of the Code. Each case is unique and will be considered on its own merits. Any prosecution decision requires a careful balancing of individual factors present in that particular case and will be taken by a lawyer who is independent of the Investigation.

3 The Code states that the decision-maker (prosecutor) must be fair, independent and objective. It is their duty to review cases and to ensure that the law is properly applied, that all relevant evidence is put before the court and that obligations of disclosure are complied with. The prosecutor will also ensure that the investigators have identified any material that might undermine the prosecution case or assist the defence, and that they have acted in compliance with the Human Rights Act 1998. The more complex the circumstances of a case and/or the technical evidence, the longer this process may take.

Evidential stage

4 There is a strict order in which the prosecutor must apply the two stages which form the Full Code Test under the Code. The prosecutor must first consider the evidential stage. If there is not the required level of evidence then no prosecution can go ahead, no matter how important the case or how strong the public interest is in favour of prosecution. The prosecutor must be satisfied that the evidence is admissible to meet the evidential test.

5 To pass the evidential stage the Approval Officer must be satisfied that there is enough evidence to form 'a realistic prospect of conviction' against each defendant on each charge. This is a different test to the one that magistrates or juries have to apply. This is not simply a case of percentages. The evidential stage is met if there is 'sufficient evidence to ensure that a jury or bench of magistrates, with a correct understanding of the law, is more likely than not to convict the defendant of the alleged charge.'

6 The prosecutor's considerations will include:

- Is there any evidence which might support or detract from the reliability of an admission?
- What explanation has the suspect given?
- Is the character of any of the witnesses likely to weaken their evidence?
- Does the witness have a motive that might influence his or her evidence?
- Is there any concern over the accuracy or credibility of a witness? If so, what is the basis for that concern?

Public interest stage

7 If the case meets the standard required by the evidential stage, only then can the prosecutor consider whether a prosecution is required in the public interest. The prosecutor has to balance the factors for and against prosecution very carefully. The decision must not be affected by improper or undue pressure from any source.

8 For HSE, the HSC Enforcement Policy Statement sets out the common health and safety public interest factors, which, if one or more is present, HSC expects should lead to a prosecution, eg where:

- death was a result of the breach of legislation;
- the gravity of an alleged offence, taken together with the seriousness of any actual or potential harm, or the general record and approach of the offender, warrants it;
- there has been a reckless disregard for health and safety requirements, repeated breaches which give rise to significant risk, or persistent and significant poor compliance;
- work has been carried out in serious non-compliance with an appropriate licence or safety case;
- a duty holder's standard of managing health and safety is found to be far below what is required by health and safety law and to be giving rise to significant risk;
- there has been a failure to comply with an improvement or prohibition notice, or there has been a repetition of a breach that was subject to a formal caution;
- false information has been supplied wilfully, or there has been an intent to deceive, in relation to a matter which gives rise to significant risk;
- inspectors have been intentionally obstructed in the lawful course of their duties.

9 The list is not exhaustive. The Enforcement Policy Statement acknowledges that there may be occasions where these factors may be present but that the public interest does not require a prosecution.

10 The Environment Agency will consider the environmental effect of the alleged offence, the foreseeability of the offence or the circumstances leading to it, the intent of the offender, any history of offending, the attitude of the offender, whether a prosecution is required in order to ensure deterrence, and the personal circumstances of the offender. Again the list is not exhaustive.

11 There is a presumption that the Environment Agency will prosecute where one or more of the following are present:

- Incidents or breaches that have significant consequences for the environment, or which have the potential for such consequences.
- Operations have been carried out without a licence.
- There have been excessive or persistent breaches of regulatory requirements.
- There has been a failure to comply or to comply adequately with formal remedial requirements.
- There has been reckless disregard for management or quality standards.
- There has been a failure to supply information without reasonable excuse, or knowingly or recklessly supplying false or misleading information.
- Agency staff have been obstructed.
- There has been an attempt to impersonate Agency staff.

12 The Code for Crown Prosecutors also lists other relevant factors for and against prosecution, which again are not exhaustive. The prosecutor balances the factors for and against prosecution.

Views of the victim(s) (part of the public interest stage)

13 The prosecutor will also take into account the consequences for the victim of the decision to prosecute or not to prosecute, and any views expressed by the victim or the bereaved. While the prosecutor will 'take into account' their views, neither enforcement authority is bound to follow those views when reaching the final decision on enforcement.

Glossary

ambient temperature The temperature of the surrounding air

aquifer A water-bearing stratum of porous rock, gravel or sand

bar and millibar Although a bar is not a measure in the International System of Units (SI), it is one of the units used in meteorology when describing atmospheric pressure. The SI unit for measuring pressure is the pascal (Pa). A millibar is equal to 1/1000 of a bar, or 100 pascals (a hectopascal)

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

Bronze command The working name for the operational command level during a Major Incident

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 fire-fighting water and foam, etc

COMAH See Control of Major Accident Hazards Regulations 1999

COMAH sites A site to which the Control of Major Accident Hazards Regulations 1999 apply

Competent Authority The Control of Major Accident Hazards Regulations (COMAH) are enforced by a joint Competent Authority comprising the Health and Safety Executive (HSE) and the Environment Agency in England and Wales, and HSE and the Scottish Environment Protection Agency in Scotland

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. See also Seveso II

duty holder In the context of this report, any person or organisation holding a legal duty – in particular those placed by the HSW Act, the Management Regulations, and the COMAH Regulations

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, fire-fighting operations

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

forthwith action The Investigation terms of reference require the Investigation team and Board to 'identify and transmit without delay to duty holders 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.' This is referred to as 'forthwith' action for both the Investigation, the Competent Authority, and duty holders

Gold command The working name for the strategic command centre during a Major Incident - also known as the Strategic Co-ordinating Group

groundwater All water below the water-table, as opposed to 'ground waters', which include groundwater but also sub-surface water above the water-table. The term 'ground water', where used in the previous progress reports, should normally have read 'groundwater'

hazard Anything with the potential to cause harm

Health and Safety Commission The Health and Safety Commission is a statutory body, established under the Health and Safety at Work etc Act 1974, responsible for health and safety regulation in Great Britain

Health and Safety Executive The Health and Safety Executive is a statutory body, established under the Health and Safety at Work etc Act 1974. It is an enforcing authority working in support of HSC. Local authorities are also enforcing authorities under the Health and Safety at Work etc Act 1974

HSC See Health and Safety Commission

HSE See Health and Safety Executive

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

kiloPascal Pascals (Pa) are the unit of pressure in the International System of Units (SI). A kiloPascal (kPa) is equal to 1000 Pa. Although bar are not units within SI, they are sometimes used as units to measure atmospheric pressure. 1 kPa = 10 bar. See also bar and millibar

kPa See kiloPascal

lower-tier See tier

Major Accident To The Environment DEFRA has established threshold criteria defining a 'Major Accident To The Environment' (MATTE), based on Schedule 7 (part 1) of the Control of Major Accident Hazards Regulations 1999. The Environment Agency, using these criteria, has determined that the Buncefield incident is a MATTE, and the Competent Authority has recently reported this to the European Commission

MATTE See Major Accident To The Environment

millibar See bar and millibar

overpressure For a pressure pulse (or blast wave), the pressure developed above atmospheric pressure

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 fire-fighting foam

perfluorosurfactant In the context of the Buncefield incident, a surfactant is a chemical added to fire-fighting foam which allows the foam to form a thin sealing film over the burning fuel. Perfluorosurfactants are a type of surfactant

PFOS See perfluorooctane sulphonates

pool fire A fire over a pool of fuel and/or water or other liquids

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

pumphouse In the context of this report, the structure enclosing the pumping equipment used to move water around the Buncefield site prior to the incident. It principally stored water intended for fire-fighting operations

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

run off Uncontained liquid, either deposited on site as rain, or in the context of the Buncefield incident, fuel and/or fire-water not contained as part of the operation to control the incident

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

SCG See Strategic Co-ordinating Group

Scottish Environment Protection Agency The public body which 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 fire-fighting

SEPA See Scottish Environment Protection Agency

Seveso II In 1976, a major accident occurred in Seveso, Italy, where the accidental production and release of a dioxin as an unwanted by-product from a runaway chemical reaction led to widespread contamination. A number of such incidents, and the recognition of the differing standards of controls over industrial activities within the European Community, led the European Commission to propose a Directive on the control of major industrial accident hazards. The Directive on the Major Accident Hazards of Certain Industrial Activities (82/501/EEC) was adopted on 24 June 1982, and is generally known as the Seveso Directive. Following a complete review of the Directive by the European Commission a new one, now known as Seveso II, came into force on 3 February 1997 and was implemented in Great Britain on 1 April 1999 by the Control of Major Accident Hazards Regulations 1999, except for land use planning requirements, which were implemented by changes to planning legislation

Silver command The working name for the tactical command centre during a Major Incident

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

tier The Control of Major Accident Hazards Regulations 1999 apply where threshold quantities of dangerous substances identified in the Regulations are kept or used. There are two thresholds, known as 'lower-tier' and 'top-tier', and COMAH sites fall into one or other of these

topography The physical configuration of the surface of the land, including its elevation, slope, and orientation

top-tier See tier

ultimate high-level switch Part of the system to prevent overfilling of the tank, the ultimate high-level switch is an independent mechanism which should be triggered when the 'ultimate high level' (ie the specified maximum capacity) is reached in a tank to which it is fitted, both causing an alarm to sound and shutting down the supply of fuel to the tank

vapour pressure A measure of the tendency of a material to form a vapour. The higher the vapour pressure, the higher the potential vapour concentration

volatility The readiness of a substance to evaporate

wind girder Structural stiffening ring attached to the tank side wall

Further information

Useful links

Buncefield Major Incident Investigation
Marlowe Room, Rose Court
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Community/Business support
Dacorum Business Contact Centre
Tel: 01442 867 805

Business Link Helpline
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Hertfordshire Chamber of Commerce
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Dacorum Community Trust Mayor's Fund
To apply, call the freephone helpline on 0800 131 3351.
Lines are open 9.30 am-4.30 pm, Monday to Friday

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

Hemel Hempstead Citizens Advice Bureau
19 Hillfield Road, Hemel Hempstead HP2 4AA
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Local authorities and emergency services
Dacorum Borough Council
Tel: 01442 228 000
Web: www.dacorum.gov.uk
(Dacorum Borough Council Digest newsletter, available monthly
Dacorum Borough Council Buncefield Update Newsletter)

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

Government Office for the East of England
Web: www.go-east.gov.uk

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

Department of Trade and Industry
Oil and Gas Directorate
Web: www.og.dti.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

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

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

Available from www.buncefieldinvestigation.gov.uk

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

Hertfordshire Fire and Rescue Service's Report into the 'Fire Response' – to be published in November 2006

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 on: *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*

Contract research reports for HSE

- W.S. 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/

07/06 C10

Recommendations on the design and operation of fuel storage sites

Buncefield Major Incident Investigation Board

Recommendations on the design and operation of fuel storage sites

Buncefield Major Incident Investigation Board

Contents

Figure 1 An overview of an oil storage depot on the east coast of England.

Introduction

1 This report sets out recommendations to improve safety in the design and operation of fuel storage sites. We make these recommendations as the independent Investigation Board, chaired by Lord Newton of Braintree, set up to supervise the investigation into the explosions and fires at the Buncefield oil storage and transfer depot, Hemel Hempstead, Hertfordshire on 11 December 2005. The investigation was directed by the Health and Safety Commission (HSC) using its powers under section 14(2)(a) of the Health and Safety at Work etc Act 1974.

2 Item 5 of the investigation's terms of reference requires us to 'make recommendations for future action to ensure the effective management and regulation of major accident risk at COMAH[1] 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.'

3 Our initial report, published on 13 July 2006, identified four principal workstreams that would form the basis for our continuing work and developing recommendations. Those workstreams are:

- design and operation of storage sites;
- emergency preparedness for, and response to, incidents;
- advice to planning authorities; and
- examination of the Health and Safety Executive's (HSE's) and the Environment Agency's roles in regulating the activities on the Buncefield site.

4 This report concentrates on the first of these – design and operations. Future reports will make recommendations on other areas, though we anticipate some overlap as the workstreams are closely related. Improving control measures goes hand in hand with improving emergency arrangements and with considering the potential impacts of major incidents on local communities. This report builds on the broad conclusions set out in paragraphs 61-77 of our initial report, which in turn reflect the findings of the investigation, as summarised in the initial report and in the three progress reports preceding it. That material is referenced, but not repeated, in this report. In preparing this report we have also considered information from other sources, such as the Buncefield Standards Task Group,[2] the Competent Authority[3] and the Baker report (see paragraph 15). Our broad aim in making these recommendations is to catalyse improvement in the fuel storage sector so that it is continually alert to the major hazard potential of its operations.

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1 The Control of Major Accident Hazards Regulations 1999. These 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 in Scotland.

2 The joint Competent Authority/Industry Standards Task 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.

3 See footnote 1. The Competent Authority issued Safety Alerts in February and July 2006.

The Board's approach

5 Our starting point in developing these recommendations is the importance of primary containment,[4] 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.*

6 Recommendations 1-16 therefore emphasise the need to increase the protection provided by primary containment systems. The Buncefield incident highlighted the need for high integrity systems for this purpose. Notwithstanding the importance of primary containment, there remains a need for effective means of preventing environmental pollution in the event of a failure of primary containment. While implementing our recommendations should significantly reduce the likelihood of such a failure, the potential for failure remains. Recommendations 17-18 therefore deal with improvements to secondary and tertiary containment.[5]

7 Recommendations 1-18 essentially deal with technological matters and their management. However, paragraph 74 of our initial report noted that human and organisational factors are also important and these are covered in Recommendations 19-22. Finally, Recommendations 23-25 deal with broader strategic objectives relating to sector leadership and culture, essential to ensure that the benefits of the more detailed recommendations are fully realised.

8 In several areas work is already underway that has the potential to meet these recommendations, in response both to the Buncefield Standards Task Group report[ref 1] and to Safety Alerts issued by the Competent Authority. We understand that the Task Group is also working on other aspects of design and operation, including aspects recommended in our initial report. We welcome the initiative of the sector and the Competent Authority in taking this forward. However, the Task Group is a temporary body set up to deliver a specific project of improvements (a so-called 'task-and-finish' group). Without implying any criticism of the Task Group, this is not a suitable arrangement for leadership of the sector. As we indicate in paragraphs 34-36 of this report, the Board believes that the sector, in consultation with the Competent Authority, needs to build on its work to put in place continuing arrangements for comparable leadership in relation to operating and safety standards on a long-term basis. In our view action to improve sector leadership will be the key to facilitate implementation of our recommendations and to provide a focus for continuous improvement.

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4 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.

5 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.

Scope of the recommendations

9 As a minimum the recommendations in this report address Buncefield-type sites as defined in the Buncefield Standards Task Group report,[6] ie depots that store and transfer petroleum products on a large scale. We use the term 'the sector' to denote these sites collectively, except where the context clearly indicates otherwise. Some recommendations will also apply to a wider range of fuel storage facilities. In some cases, although we have not studied the wider chemical industry, we consider that relevant lessons for fire and explosion risks can be applied beyond fuel storage and distribution. We indicate in the text some obvious areas where our recommendations may apply beyond the sector, as defined above. More generally, we encourage the chemical industry, working with the Competent Authority, to consider the broader relevance of our findings so far.

10 The recommendations are addressed to those in the sector who have the legal duties to prevent and control major accidents.[7] Primarily this means operators of Buncefield-type sites as described in paragraph 9, but also includes designers, suppliers and contractors, as well as professional institutions or trade associations where appropriate. In practice this will require close working with the regulators (the Competent Authority), who will also need to ensure the recommendations are implemented.

Status of the recommendations

11 In making these recommendations we recognise that work continues, including the work to investigate explosion mechanisms mentioned in paragraphs 16-19 and work in the Buncefield Standards Task Group. Further recommendations will follow in relation to other areas of interest mentioned in paragraph 3.

12 We expect our recommendations to be put into practice throughout the sector. Unless the context indicates otherwise, we envisage the Competent Authority will adopt the recommendations as the minimum necessary to comply with legal requirements. For example, where the recommendations call for higher standards to be incorporated in revised guidance, those standards should be capable of being insisted upon by law. The recommendations do not specifically call for changes to the law on the assumption that the existing legal framework is sufficient to ensure that necessary improvements are put in place. However, if this proves not to be the case in any respect, HSC and the Department for Environment, Food and Rural Affairs (DEFRA) should draw up proposals for the necessary legal changes.

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[6] The Task Group initial recommendations apply to petrol stored at COMAH top and lower tier sites in vertical, cylindrical, non-refrigerated, above ground storage tanks with side walls greater than 5 metres in height and where the filling rate is greater than 100 cubic metres/hour.

[7] COMAH requires operators of major hazard sites subject to the Regulations to take all measures necessary to prevent major accidents and limit their consequences to persons and the environment. Operators of top tier COMAH sites (like Buncefield) are also required to submit written safety reports to the Competent Authority; and to prepare emergency plans to deal with the consequences of a major accident. Operators and others (including contractors, designers, suppliers) also have relevant duties under the Health and Safety at Work etc Act 1974 and related regulations and under environmental legislation.

Figure 2 Aerial view of the Buncefield depot

13 Where the recommended improvements are self evidently necessary or where the sector is already intent on their implementation we expect the recommendations to be implemented without undue delay. Some recommendations, particularly those involving large-scale engineering improvements, will be easier to implement in new sites than in existing sites. Other recommendations, such as those needing cultural and leadership changes, should be addressed immediately, though their effects may not be apparent in the short term. It is essential to have clear timescales, understood both by the industry and the Competent Authority, against which progress can be measured and reported. We therefore ask the Competent Authority to start without delay a programme of reviews with operators of Buncefield-type sites of their response to these recommendations, leading to site-specific timed action plans.

14 Where commitments have already been made (eg through the Buncefield Standards Task Group) or the need for action is self-evident, we have not made detailed cost-benefit assessments. In most cases we consider the costs will be reasonable and the benefits, in preventing another Buncefield incident, beyond argument. We are exploring further the costs and other implications of some recommendations relative to their perceived benefits, though we expect this to confirm our belief that the improvements we recommend are affordable. In agreeing priorities for the action plans we call for in paragraph 13, the Competent Authority will need to take account of cost, as described in paragraph 31.

The Baker report

15 We have noted with interest the recent report of the BP US Refineries Independent Safety Review Panel by James Baker's panel in the United States.[ref 2] Some of the recommendations and findings in that report align with our thinking arising from the Buncefield investigation. In particular the Baker report's recommendations relating to process safety leadership, process safety culture, performance indicators, independent monitoring and industry leadership are relevant. The Baker panel's findings regarding the implementation of good engineering practices, safety knowledge and competence also align with our views.

Figure 3 Damage to property on the Maylands estate adjacent to Buncefield

Further work to investigate explosion mechanism

16 Current explosion models do not predict the blast damage that occurred at Buncefield. Paragraph 77 of our initial report 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.*

17 Towards the end of 2006 we appointed an advisory panel to assist us in formulating proposals for a programme of work. The panel is chaired by Professor Dougal Drysdale who is a member of the Board. The panel is considering the evidence currently available in respect of potential explosion mechanisms of a flammable vapour cloud that could cause the type and extent of damage seen at Buncefield.

18 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.

19 The advisory panel experts are:

Professor Dougal Drysdale, University of Edinburgh (Chair)
Professor Derek Bradley, University of Leeds
Professor Geoffrey Chamberlain, Shell Global Solutions
Dr Laurence Cusco, Health and Safety Laboratories
Mike Johnson, Advantica
Professor Hans Michels, Imperial College London
Professor Vincent Tam, BP Exploration

The recommendations

20 Our recommendations are grouped under the following six headings:

- Systematic assessment of safety integrity level requirements (Recommendation 1)
- Protecting against loss of primary containment using high integrity systems (Recommendations 2-10)
- Engineering against escalation of loss of primary containment (Recommendations 11-16)
- Engineering against loss of secondary and tertiary containment (Recommendations 17-18)
- Operating with high reliability organisations (Recommendations 19-22)
- Delivering high performance through culture and leadership (Recommendations 23-25)

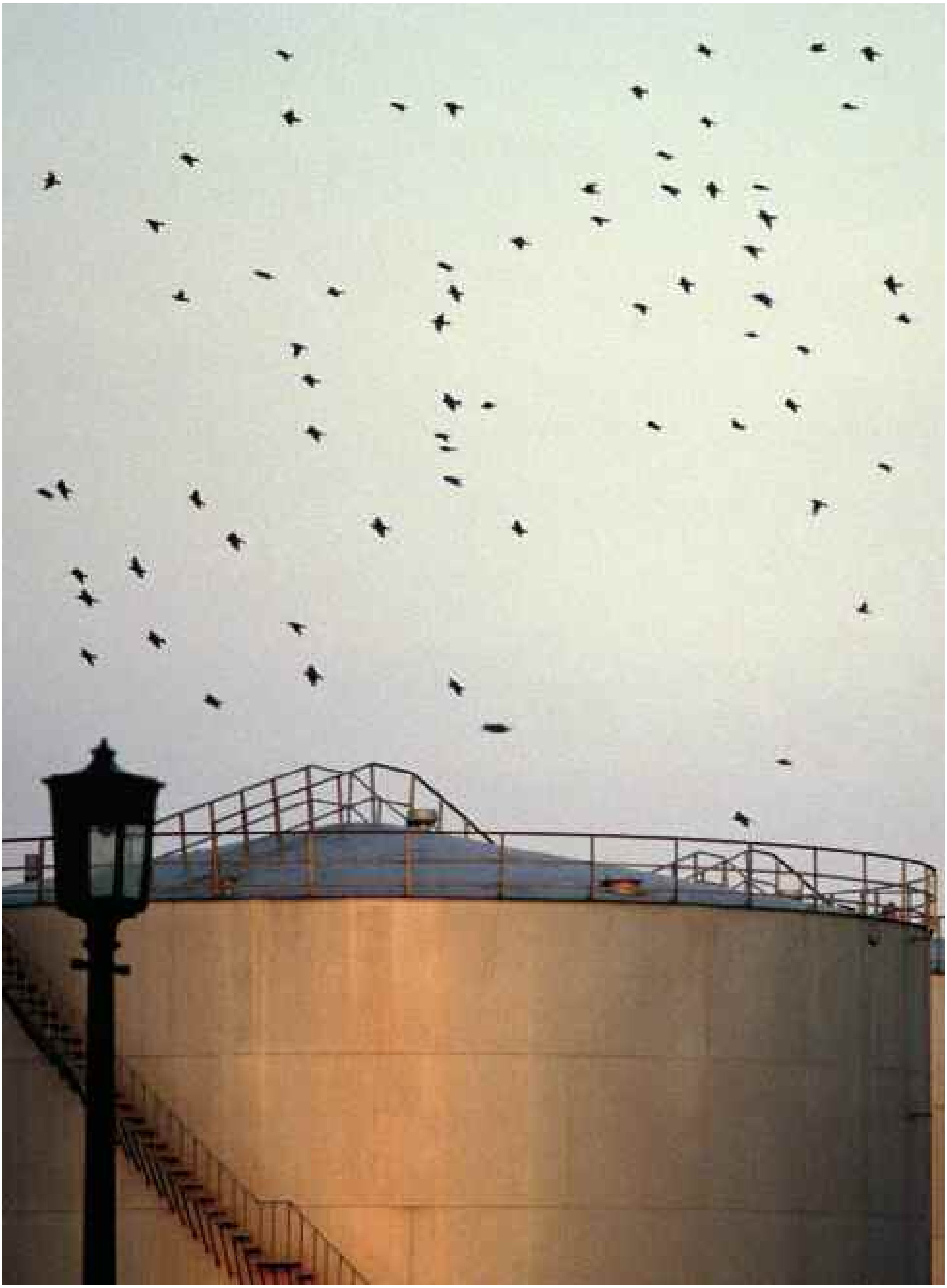

Figure 4 Tops of a tank farm in South London

Systematic assessment of safety integrity level requirements

21 The recommendations under this and the next two headings are based on the conclusions set out in paragraphs 61-77 of our initial report and on the findings of the first and third progress reports. The Buncefield incident highlighted the need for high integrity systems, which we discuss further in the next section. However, our firm belief is that before protective systems are installed there is a need to determine the appropriate level of integrity that such systems are expected to achieve. The sector currently lacks a common methodology to ensure a systematic approach to this determination process. Several methodologies exist, but there is no consistency. A common methodology would provide greater assurance.

22 Recommendation 1 is in line with work now underway following the Buncefield Standards Task Group's initial recommendations relating to tank overfill protection, particularly paragraph 9, which states *'The overall systems for tank-filling control must be of high integrity – with sufficient independence to ensure timely and safe shutdown to prevent tank overflow. Site operators should meet the latest international standards.'*

Recommendation 1 The Competent Authority and operators of Buncefield-type sites should develop and agree a common methodology to determine safety integrity level (SIL)[8] requirements for overfill prevention systems in line with the principles set out in Part 3 of BS EN 61511.(ref 3) This methodology should take account of:

- the existence of nearby sensitive resources or populations;
- 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.

8 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.

Figure 5 General view of fuel storage tanks with associated pipework and instrumentation

Protecting against loss of primary containment using high integrity systems

23 Paragraph 21 notes that the Buncefield incident highlighted the need for high integrity systems to prevent breaches of primary containment. The background is summarised in paragraphs 61-77 of our initial report, based on the findings of the third progress report. In particular, paragraph 63 of our initial report emphasised the overriding need to ensure the integrity of the primary means of containment. The following recommendations, particularly Recommendations 2-8, are closely related and need to be considered as a whole. Our recommendations for automatic systems, that do not depend on the need for human intervention, are not intended to override the risk-based approach of Recommendation 1 but to act as a starting point.

24 Recommendations 3-5 reflect our firm view that to ensure integrity the sector must move towards installing independent overfill prevention systems at sites handling large quantities of highly flammable liquids[9] such as petrol. We welcome indications that API Code 2350[ref 4] is also moving in this direction. In many respects Recommendations 3-5 align with work underway to implement paragraphs 8-11 of the Buncefield Standards Task Group's initial report, except that the Task Group stopped short of recommending automatic overfill prevention systems. Annex 1 to this report sets out our arguments for installing automatic overfill prevention systems (Recommendation 3). This would be a significantly higher standard than that generally installed in this sector. These changes will need to be carefully planned to consider up-stream implications and phased in to avoid undue disruption to the UK fuel supply.

25 Recommendations 6 and 7 follow up paragraph 76 of our initial report, which referred to the need for good communication between the parties responsible for transferring fuel safely around the country. We indicated that the adequacy of existing safety arrangements for transferring fuel between sites, eg between refineries and Buncefield-type sites, may need to be reviewed. In returning to this, we firmly believe that such a review is necessary given the number of responsible parties in a typical system – refinery operator, pipeline operator, and depot operator.

26 The safety report for any given depot or refinery (gasoline pipelines are not currently subject to COMAH, though we may return to this in our next report) does not deal specifically with the relationship between the transmitter and the receiver of hazardous products. Therefore we welcome the recommendation at paragraph 7 in the Buncefield Standards Task Group's first report relating to improving the communications between site operators and operators of pipeline transfers. This does not, however, go so far as to require site operators to have ultimate control to stop receiving fuel into tanks to prevent an overfill. We believe it is essential for such a hierarchy of control to be established, at the same time dealing with any upstream consequences.

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[9] A liquid fuel is classified under the Planning (Control of Major Accident Hazards) Regulations 1999 according to its flashpoint, defined as *'The minimum temperature at which a liquid, under specific test conditions, gives off sufficient flammable vapour to ignite momentarily on the application of an ignition source'*. A highly flammable liquid is defined as one with the flashpoint below 21°C. As petrol has a flashpoint in the region of c -40°C, it is therefore classified as a highly flammable liquid.

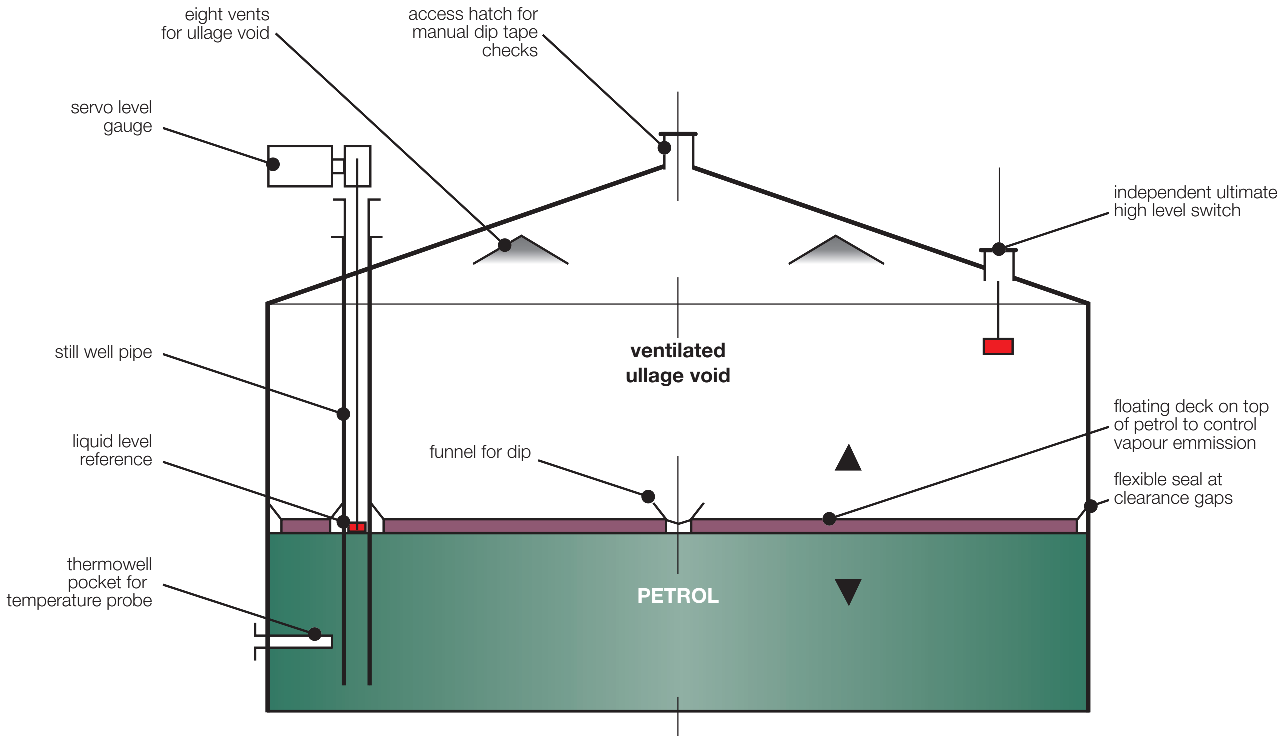

Figure 6 General schematic of a typical internal floating roof tank

27 Annex 2 to this report sets out our arguments for developing improved components and systems (Recommendation 8). Recommendations 9 and 10 are needed to help monitor and review the effectiveness of improved control measures.

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:

- 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[10] (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).

[10] 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 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 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 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.

Figure 7 General view of fuel terminal in Aberdeen's harbour area

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 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[11] 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 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 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 5]

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11 Also commonly known as 'high high' level alarms.

Engineering against escalation of loss of primary containment

28 The recommendations under this heading follow on from our earlier arguments about the importance of primary containment – see paragraph 23 above. The Buncefield incident demonstrated the potential for a vapour cloud to form from a loss of primary containment of a highly flammable liquid such as petrol. We have adopted a precautionary approach in drawing up these recommendations as we believe they are appropriate in the light of the Buncefield incident, notwithstanding that the investigation into the severity of the explosion continues. Recommendation 12, in particular, anticipates our coming recommendations on emergency response arrangements.

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[ref 6]). 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 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 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 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 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 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.

Figure 8 View of fuel tank set in earth bund

Engineering against loss of secondary and tertiary containment

29 While we emphasise the priority that should be given to preventing a loss of primary containment, adequate secondary and tertiary containment remains necessary for environmental protection in the event of a loss of primary containment of hazardous substances. Paragraphs 66 and 73 of our initial report and, in particular, the second progress report, described the failure of secondary and tertiary containment at Buncefield to prevent a major accident to the environment (MATTE).

30 Significant improvements to primary containment[12] will have implications for environmental protection systems. A fundamental review of the whole system of containment, taking account of site-specific conditions, will provide the greatest assurance for the safety and environmental protection of the site and its neighbourhood. As well as Buncefield-type incidents, other causes of primary containment failure such as sudden or undetected creeping loss of tank or pipework integrity can give rise to serious environmental consequences. This underlines the importance of maintaining high bunding standards.

31 Though there is a need for an integrated approach to containment, the recommendations below are segmented for convenience. Operators should adopt a risk-based approach and draw up plans for phased investment and improvement. They should be able to demonstrate to the Competent Authority why it is not practicable to meet fully improved standards, if that is so. We stress that the overflow of highly flammable liquid which led to the Buncefield explosions is only one foreseeable cause of a MATTE. Industry should therefore include improvements against those other foreseeable events in its remedial programme to secondary and tertiary containment, taking the same risk-based and phased approach.

[12] For example, in preventing tank overfilling, structural failure and loss of integrity (eg gasket failure) of pipework and valve joints.

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 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.

Figure 9 A modern process control room

Operating with high reliability organisations

32 The need for high reliability organisations[13] was not addressed directly in our initial report or in the Buncefield Standards Task Group's interim recommendations, though many of the issues below are being considered in the Task Group's continuing work. The need follows from the preceding recommendations relating to technological improvements in hardware. Such improvements are vital in improving process safety and environmental protection, but achieving their full benefit depends on human and organisational factors such as the roles of operators, supervisors and managers. Paragraph 74 of our initial report indicated our interest in this area.

33 The recommendations are more broadly applicable than Buncefield-type sites, but are intended to apply to those sites as a minimum.

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.

[13] That is, robust organisations with a strong safety culture that have a high probability of achieving safe and reliable performance. More detail is given in Annex 5.

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 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 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.

Figure 10 Maintenance worker inspecting a tank top

Delivering high performance through culture and leadership

34 Culture and leadership were not addressed directly in our initial report or in the Buncefield Standards Task Group's first report, but are necessary prerequisites to achieving full compliance with the preceding recommendations. We have set the sector several tasks which we acknowledge to be very challenging:

- to substantially strengthen safety standards at Buncefield-type sites;
- to identify analogous sites where the same high level of engineered safety is necessary and to install it;
- to continue with and extend a programme of revision of guidance and standards to ensure more consistent responses to broadly similar risks than are the case today; and
- to bring about a wide range of cultural and behavioural changes.

35 Implementing our recommendations will require the sector to show clear leadership in setting high standards of process safety and environmental protection and in pursuing excellence in operations. At paragraph 8 we indicated our support for the work done thus far by the Buncefield Standards Task Group. We see the Task Group as continuing to play a key role. However, the scale of the improvements that we believe the sector needs to make can only come about through sector leadership at the highest level. We welcome the sector's acknowledgement of the need for more consistent responses to broadly similar risks. However, some fifteen months have passed since Buncefield, and we believe that the sector will face deserved criticism if clear and energetic progress is not now made on our recommendations.

36 The recommendations below require collaboration across the sector, as will several of our earlier recommendations in practice (eg Recommendation 19). Collaboration in turn requires leadership and vision. We make no specific recommendations about the form of leadership structures or the precise arrangements for taking forward implementation. These are matters for the sector to determine if it is to embrace the arrangements fully. They could build on existing arrangements, but need to engage and motivate all parts of the sector, including the workforce. Leadership should also embrace the important relationship between site operators and the surrounding communities, businesses and the local authorities.[14] This needs to be characterised by openness and transparency. The recommendations can also be applied to other sectors. The Competent Authority should actively encourage and support the development of robust arrangements for continuing leadership in the sector, and other sectors as necessary.

[14] We intend to return to this point in our recommendations for emergency preparedness and response.

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

- 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[15] 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.

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

Annex 1

Terms of reference and progress

This annex sets out the eight terms of reference for the Investigation and explains the progress that is being made towards accomplishment of each of them.

> ***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***

The Board has published three progress reports from the Investigation Manager. This was followed by the Board's initial report on 13 July 2006, which summarised the three preceding reports and set out the Board's four main areas of concern. These have revealed the main facts of the incident, but have not speculated on why control of the fuel was lost. The explosion mechanism, ie the means by which unexpectedly high overpressures were generated, is subject to significant further investigation. Wider expert consultation has been undertaken on whether and what further research may be required and this is explained in this report.

The criminal investigation is pursuing all reasonable lines of inquiry into the facts and causes of the incident to enable the Competent Authority (HSE and the Environment Agency) to take a view on legal proceedings.

> ***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***

The Competent Authority issued a Safety Alert to around 1100 COMAH dutyholders on 21 February 2006. Special attention was paid to 108 fuel depot owners storing COMAH quantities of fuel in Great Britain, seeking a review of arrangements for detecting and dealing with conditions affecting containment of fuel. Most dutyholders responded to the alert by the Easter deadline. Meanwhile, the Competent Authority visited all 108 depots to follow up the alert. An interim report was published on 13 June 2006 and is available at www.hse.gov.uk/comah/alert.htm.

The Environment Agency issued further advice to its inspectors to investigate secondary (bunding) and tertiary (drains and barriers) containment at depots in England and Wales in response to the Second progress report. The Environment Agency continues to monitor the effects of Buncefield on the surrounding environment and to issue updates on its website, www.environmentagency.gov.uk. The initiative is being handled separately for Scotland by the Scottish Environment Protection Agency, with joint inspections undertaken with HSE covering primary, secondary and tertiary containment, and management systems. However, it is understood that an overall view of the situation in Britain will be available following the publication of this report by the Buncefield Board.

On 16 June 2006 investigators served two Improvement Notices on the manufacturers of the high level alarm switch installed on Tank 912, having identified a potential problem at other sites related to the setting of the switch for normal operations following testing. This was followed up by a Safety Alert from HSE on 4 July 2006 alerting operators relying on such switches of the potential problem.

The Chairman of the Buncefield Board wrote to the Chief Executive of the Health Protection Agency on 3 July 2006 enquiring into progress with informing regional resilience groups of early lessons learned from Buncefield, focusing on public health issues in the immediate aftermath of a major airborne incident, following up with a meeting December 2006. HPA is assisting the Board with its recommendations for improving emergency preparedness and response to major incidents which is likely to be the subject of the next report from the Board.

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

Work is progressing steadily on both parts of the review, concerning respectively HSE's and the Environment Agency's prior regulatory activities at Buncefield. The full findings of the review will be incorporated into the Board's final report (see term of reference 8). Immediate important lessons from the examination of the Competent Authority's prior role will be incorporated as appropriate into the lessons learned programme under term of reference 5.

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

The ongoing impact on residents and businesses of the Buncefield incident has been reported in the three progress reports and in the initial report in which, in Part 2, the Board set out its main areas of concern. The Board has maintained an active interest in releasing as much new information as possible to the community and its representatives, such as the local MP Mike Penning, to assist in understanding the events of 11 December 2005, and to maintain public confidence that progress is being made with the Investigation. As has been reported previously, residents and businesses continue to show remarkable resilience in the difficult aftermath to the Buncefield incident. Dacorum Borough Council in particular, but also St Albans and Hertfordshire Councils, have performed extremely effectively in very difficult circumstances, and have supported the Board in its engagement with residents and businesses, as has Mike Penning MP.

The Board has also kept key Government stakeholders informed of the Investigation's progress, and has maintained its interest in developments that have taken place since Buncefield to help manage the aftermath and support a return to normality for residents and businesses.

The Board has engaged with all the public sector agencies involved in the emergency response to Buncefield and has met with a number of the key agencies, particularly the Category 1 (Gold) responders. This is not an issue in which the Board has primary responsibility but, as reported in this Initial Report, the Board is giving further consideration to emergency response and emergency preparedness issues, and will say more on this in its report on emergency preparedness and response.

The Buncefield Major Incident Investigation made presentations to two multiagency debriefing sessions on 21 and 28 June 2006 to inform regional resilience groups around Britain of the response to the Buncefield incident.

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

Staff seconded from HSE, the Environment Agency and the Health Protection Agency are assisting the Investigation Manager and the Board to make sensible, practical and affordable recommendations for improvements in the light of the Buncefield incident. Key workstreams are in environmental protection; land use planning; fire and explosion mechanisms; control and instrumentation; human and organisational factors; health; emergency response and preparedness; and regulatory impact.

This report, making recommendations for the design and operation of Buncefield-type sites, is the first report under this term of reference. HSE has convened an industry chaired task group (the Buncefield Standards Task Group) that includes the Environment Agency and the Scottish Environment Protection Agency, to also consider design and operation issues in parallel with the Board's work. This initiative has been welcomed by the Board in this report.

Work is advanced in producing recommendations on emergency preparation for, and response to, extreme events such as Buncefield. This work is supported by an immense amount of work undertaken by other agencies such as Hertfordshire Resilience, Hertfordshire Fire and Rescue Service, and the Health Protection Agency. The Board intends to join together the many strands of this subject, including issues concerning support to communities and businesses in the aftermath of an extreme incident.

The Board is close to recommending suitable arrangements for further research and modelling of explosion mechanisms in flammable vapour clouds.

HSE has completed its initial work on changes to land use planning advice and has issued a public consultation document seeking views by 22 May 2007 (see http://hse.gov.uk/consult/condocs/cd211.htm). The Board will be setting out its own views to the consultation document in due course. HSE is also working closely with a Cabinet Office led team on applying new knowledge of risks to society in the planning system. The Health Protection Agency is consulting key agencies to improve public health advice and support during significant pollution events.

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

This element is discharged by the publication of the Board's initial report on 13 July 2006.

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

A report from the Environment Agency and HSE was made to the European Commission on 10 March 2006. Subsequently, the Environment Agency declared Buncefield a major accident to the environment (MATTE), and the Competent Authority has recently reported this to the European Commission.

8 To make the final report public

The timing for the publication of the final report remains uncertain and is of course linked to progress on the main terms of reference and to any decision on any criminal proceedings that might be considered. The possibilities include a further interim report or reports; decisions must necessarily depend on the timing of developments and consideration of the public interest.

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 DTI. 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. Prior to 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. Paul has worked for 30 years in the health and safety and environmental field.

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

Rationale for Recommendation 3 – Independent and automatic storage tank overflow prevention

1 It is common practice to employ an ultimate high level detection system to detect when the liquid in a storage tank has reached a level beyond which any further filling is likely to result in an overspill of liquid unless suitable averting action is taken. The benefit of such a system being independent of the tank gauging system is recognised in the current standards and guidance for storage tank operations.[refs 4,7,8] However, the current standards and guidance (other than in the case of reference 2 for unattended facilities only) do not require the overfill prevention system to be automatic.

2 Nevertheless, the benefit of an automatic overfill prevention system is recognised by the Energy Institute[ref 7] which says that 'where tank filling operations are complex, such as with tanks fed by cross-country pipelines, consideration should be given to the fitting of high level alarms and devices for automatically cutting off the supply. Ideally automatic cut-off devices should be high integrity and independent of any normal measuring alarm or system.' We also note that a draft revision to API Code 2350 considers requiring automatic independent shutdown systems to control filling of tanks at Buncefield type sites.

3 The benefit of an automatic overfill prevention system stems from the diversity that such a system provides in combination with the tank gauging system. Without such diversity the combination of the systems is vulnerable to common cause failures as they would both rely on human operators. For example, abnormal events may distract or disable the operators such that they fail to properly control the tank gauging system and then also fail to respond to the ultimate high liquid level alarm in time to prevent overfilling. Such common cause failures can significantly degrade the overall integrity of the gauging and overfill prevention systems such that the likelihood of an overspill is much higher than would be evaluated by considering the systems as being independent.

4 It is our considered view, having consulted with experts in the industry, that the assurance for the overall integrity of containment provided by the diversity of manual and automatic systems justifies overfill prevention systems being automatic in Buncefield like sites. This is particularly so given the potentially high consequences for both safety and the environment, together with the associated societal concern, that may result from a substantial overspill of petrol or similar substance in such sites.

5 We consider that a further benefit of an automated overfill prevention system stems from the greater confidence in testing, inspection, verification and auditing that competently engineered arrangements allow for, compared with that afforded by manually operated systems.

6 However, even with such an approach it remains vital that both the gauging system and the overfill prevention systems are maintained in effective working order. It also remains important to properly evaluate the required safety integrity level (SIL) for the automated overfill prevention system, taking into account the associated risks in line with Recommendation 1 of this report. This will ensure a low enough level of residual risk taking into account a realistic view of the reliability of the systems.

7 We consider that the preferred way of achieving automated overfill prevention will include the use of positively isolating valves such as remotely operated shut-off valves (ROSOVs) or emergency shutdown valves (ESDVs).(ref 9) Such valves are designed to achieve and maintain rapid isolation of plant items and thereby prevent further movement of liquid that could result in overfilling of a tank. However, we recognise that the use of ROSOVs or ESDVs may not be appropriate in some applications, such as filling from a ship or train, or from a refinery process. In such applications it may be more appropriate to employ other or additional control arrangements such as automatic diversion of flow and/or shutdown of a pump. Whatever system is selected, the safety integrity level required for that site must not be compromised.

8 In all applications, the desired outcome must be the same. Namely, if petrol (or similar flammable substance) filling at a Buncefield-type site continues after the system has warned operators to take action, but action has not been taken or is not effective, then means that require no further human intervention (ie automatic) should safely stop the tank filling before overflow occurs.

9 We further recognise that certain applications may require the industry, working with the joint Competent Authority, to resolve some practical and technical considerations to achieve what we have stipulated.

Annex 4

Background and supporting material for 'improved components and systems' (Recommendation 8)

Alternative means of ultimate high level detection

1 The detection of ultimate high liquid level in storage tanks often relies on a switch mounted on the roof of the tank (or on the uppermost level of the tank wall). This is commonplace within the industry. For example it is illustrated in API RP 2350.[ref 4] However, the arrangement suffers from a number of disadvantages with regard to safety, namely:

- the operation of the switch cannot be tested fully in situ other than by raising the liquid level in the tank to the ultimate high level. Any other means of testing will leave a number of potential failure modes uncovered and so leave the switch in a faulty state unbeknown to the operator or maintenance staff. However, such testing itself introduces the possibility of overfilling so must be undertaken under strict supervision. There is often a reluctance to undertake such testing;

- simple switches do not benefit from 'on line' diagnostics. More advanced sensors (such as those based on tuning fork or thermocouple technology) incorporate diagnostics so that all foreseeable failure modes are detected as they occur.

2 The recommendation is intended to encourage the industry to move away from the use of simple level switches for ultimate high level indication and towards the use of more advanced sensors that incorporate 'on line' diagnostics and can therefore be considered to be 'fail safe'. Such sensors are in widespread use and a number are available that have been certified for use in SIL2/3 applications in accordance with BS EN 61511.

3 The second part of this recommendation is that the means of ultimate high level detection should not rely on components 'internal to the storage tank'. Reliance on such internal components will always be problematic from a safety viewpoint as access to the inside of the tank for inspection and maintenance will be very limited. It also means that a 'wet test' of the switch can only be carried out by filling the tank to the ultimate high level. While such a test could possibly be carried out safely under controlled conditions, there would be significant difficulties in ensuring safety at all times with such an approach.

4 A reasonably practicable alternative solution may be the use of a small external tank tapped into the main tank through a small bore pipe at the ultimate high level. The ultimate high level sensor would be fitted to this external tank such that the 'overspill' from the main tank is sensed. Initial considerations suggest that such an approach is feasible. It appears to offer a number of significant benefits. The setting of the ultimate high level would be determined by the physical position of the tapping. This would not be vulnerable to unintended changes. Access to the tank, especially if fitted adjacent to the existing stairway, would be relatively easy and wet testing of the level sensor would be possible without the need to overfill the main tank. These are significant benefits and worthy of further consideration. The practicalities of fitting such an external tank and the associated instrumentation and cabling will also need to be considered. It may be that the

tapping could be made without the need to empty the main tank, although this would need to be confirmed. This would significantly reduce the installation costs. The potential benefits on the face of it justify a recommendation to encourage the industry to explore this approach further.

Increased dependability of tank level gauging systems

5 Tank gauging systems often employ mechanical servo gauges to sense the liquid level. However, such gauges appear to be vulnerable to a number of potential failure modes.

6 This recommendation is intended to encourage the industry to make effective use of the facilities provided in state-of-the-art tank gauging systems to reconcile the indications of product level in tanks with all available information such as product movement requests, pipeline flow measurements, temperature, etc. In this way it may be arranged that the failure of a single element of the system, such as a servo gauge, is detected and the operators alerted before a hazardous situation develops or before a demand is placed on the overfill prevention system.

7 A further contribution to enhanced dependability may result from the use of modern electronic gauge sensors, for example based on radar technology. Electro-mechanical servo gauges are intricate devices vulnerable to many failure modes. Electronic sensors eliminate the failure modes associated with mechanical components and may offer a higher reliability alternative. Such devices are readily available.

Annex 5

High reliability organisations (Recommendations 19-22)

1 A 'high reliability organisation' (HRO) is a robust organisation with a strong safety culture that has a high probability of achieving safe, reliable and quality performance over a long period of time.

Background

2 Since the early 1980s studies have been made of organisations that operate 'high-hazard, low-risk' technologies at very high levels of reliability;[refs 10-13] examples are in the air traffic control sector, and on aircraft carriers. The manufacturing and banking sectors also contain examples of companies that have elected to build HROs that are significantly in advance of their peer groups. The studies show that safe operation is not just a matter of compliance with various regulations, codes and standards, but also crucially depends on organisational design and culture. HROs have developed a culture of reliability to drive the business (including high productivity), without sacrificing the drive for improvement or the capability to change.

Culture

3 The ethos of a HRO is based on the prevention of unplanned events (including accidents) through good organisational design and management. The culture of a HRO is one that expects its organisation and sub-systems to fail and works very hard to avoid failure and to minimise its impact. This preoccupation with the possibility of failure leads to a continual state of 'mindfulness' combined with a strong desire to be a 'learning organisation'. High reliability organisations actively seek to know what they do not know, design systems to make all knowledge relating to a problem available to everyone in the organisation, learn quickly and efficiently, train staff to recognise and respond to system abnormalities, empower staff to act, and design redundant systems to catch problems early. Maintenance and proof testing are optimised to increase knowledge and to raise productivity to very high levels through avoidance of unplanned interruptions of which major accidents are the extreme examples.

Characteristics

4 Frequently cited characteristics of high reliability organisations include:

- **Extensive process auditing.** The organisation will have an established system for monitoring compliance with procedures, and also the efficacy of the procedures themselves. Audits will be designed to identify both expected and unexpected safety problems. There will be robust follow up on actions and problems identified in earlier audits. Regular safety drills and equipment testing will be part of the process auditing system.

- **Reward and recognition.** Organisational reward systems have powerful influences on the behaviour of individuals in them. HROs will have reward systems that drive the desired behaviours and value the contribution of all in the organisation. For instance full and accurate reporting of incidents, and exemplary care of work equipment will be valued more than 'zero reported lost time incidents' (which can encourage competitive under-reporting). They will also be aware that punitive measures may reward behaviour that hides results or redirects blame.

- **Higher quality standards.** HROs will maintain high quality standards and avoid quality degradation as core values. This will involve regular evaluation of the organisation's performance, capabilities and goals.

- **Perception of risk.** The HRO will be aware of all risks and, importantly, the significance of each key risk and suitable (but not excessive) control measures will be in place.

- Command and control systems that will include:

  - *Delegated decision-making*. Relevant competent staff will be integrated into the decision-making process.
  - *Redundancy.* Critical protection systems, process technology and personnel responsibilities are protected against predicted failure that can cause process interruptions and hazardous outcomes.
  - *Senior management involvement*. Top managers will be expected to understand and communicate the 'big picture' rather than being involved too much in the detail and 'micromanaging'.
  - *Formal rules and procedures*. Standard operating procedures (SOPs) will be set out and their implementation will be monitored. The SOPs will deal with all main processes, including response to hazards to personnel, the environment and capital assets. SOPs are updated as lessons are learned from abnormal events and systems failures.
  - *Competency*. Particular emphasis will be given to training in safety critical tasks and in continuous improvement in process efficacy.
  - *Needs of front line staff*. Operator training will incorporate hands-on simulation. Communications will be geared to awareness of adverse situations that can arise, and how to deal with them. Positive behaviours are encouraged. Unwanted behaviours are challenged.

Annex 6

BS EN 61511 Functional safety – Safety instrumented systems for the process industry sector

Background

1 BS EN 61511[refs 14,15,16] is the process industry standard for 'safety instrumented systems'. Such systems are widely used in the chemical and petrochemical process industries to measure and control process variables (such as liquid levels and temperatures or gas pressures) so as to ensure that the safe working limits of plant items are not exceeded and thereby avoid hazardous events such as loss of containment of flammable or toxic materials. Other common terms for safety instrumented systems (SIS) are 'emergency shutdown (ESD) systems', 'trip systems', 'safety interlock systems' or 'safety shutdown systems (SSD)'.

2 The standard (comprising three parts) was first published by the International Electrotechnical Commission (IEC) as IEC 61511 in 2003. It was developed by an international working group comprising experts from the chemical and petrochemical industries. As such it represents the worldwide consensus view on how such systems should be engineered to ensure safety. It covers all aspects of the lifecycle of a system from initial specification and design through to installation, operation, maintenance and eventual decommissioning.

3 Member countries of the IEC agree to adopt IEC standards as national standards. IEC 61511 as adopted as the national standard for the UK when it was published by the British Standards Institution (BSI) as BS IEC 61511 in 2003. Subsequently, the standard was adopted by the European standardisation body for Electrotechnical matters, CENELEC, and is now published by BSI as BS EN 61511. The standard has similarly been adopted by all member countries of the IEC. For example, in the USA it is published as ANSI/ISA-84.00.01-2004.

Principles of BS EN 61511

4 The principles of BS EN 61511 were established by the generic standard for functional safety, BS EN 61508.[ref 17] The overall aim is to ensure that the performance of a safety instrumented system, in terms of both the functions it provides and their integrity, is adequate to ensure safety. It defines four levels of safety integrity, SIL1, SIL2, SIL3 and SIL4. The higher the SIL level the higher the associated safety level and the lower the probability that the system will fail to perform properly. The required SIL is determined by a hazard and risk assessment taking into account any measures that reduce the risks associated with the hazard under consideration and the tolerable risk target for the specific application. Generally it is preferred to avoid sole reliance on SIS, particularly in high hazard applications. Consequently, most SIS in the chemical and petrochemical process industries in the UK are specified as SIL1 or SIL2.

Application of BS EN 61511 to overfill protection systems

5 BS EN 61511 has no specific requirements for storage tank overfill prevention systems. However, the principles of the standard are directly relevant and can be readily applied to such systems. Application of the standard will provide a risk-based design target for the SIL of an overfill protection system. It will ensure that the design and installation is adequate to achieve the required SIL and that sufficiently frequent periodic testing of the system is carried out to reduce, so far as is reasonably practicable, the risks of tank overfilling.

6 While the application of BS EN 61511 provides a risk-based target for the integrity of an overfill protection system (recommendation 1), and hence for the reliability of the constituent components, it does not require such systems to be automatic in operation. However, if the overfill protection system relies on human operation, the possibility of human failure remains resulting in common cause failure of both a tank gauging system and its overfill protection system. This possibility is very difficult to quantify but is likely to be a critical factor in determining the likelihood of overfilling. For this reason it is felt necessary to make the additional recommendation (recommendation 3) that overfill protection systems should be automated.

Annex 7

Examples of incidents that have involved loss of primary containment from storage tanks

Records of incidents of this type are held by the companies involved for purposes of monitoring the effectiveness of their health and safety policy. The following table gives some examples of such incidents to illustrate the fact that they should not be considered as 'rare events'. Data have been compiled by a reputable operator in the USA that indicate that overfilling occurs once in every 3300 filling operations.

Location	Date	Fuel released	Consequence
Jacksonville, Florida, UK	1993	Unleaded petrol/ gasoline	190 m^3 released. The spill ignited, leading to a major explosion and fire.
Coryton, UK	1997	Unleaded petrol/ gasoline	81 m^3 released. Spill contained within bund – no ignition.
Belgium	2001	Hexene	Approx 90 m^3 released. Spill contained within bund – no ignition.
Sour Lake, Texas, USA	2003	Crude oil	80 m^3 released. Spill contained within bund – no ignition.
Torrance, California, USA	2004	Jet fuel	Approx 10 m^3 released. Contained in bund – no fire or explosion.
Bayonne, New Jersey, USA	2004	Fuel oil	825 m^3 released. Oil 'contained on tank farm' – no fire or explosion.
Casper, Wyoming, USA	2004	Unleaded petrol/ gasoline	Up to 1270 m^3 released. Spill contained within bund – no ignition.
Rensselaer, NY, USA	2005	Unleaded petrol/ gasoline	0.4–4 m^3 released. Spill contained within bund – no ignition.

Table 1 Examples of loss of primary containment from fuel storage tanks

Table 2 contains examples of situations in which the loss of primary containment created circumstances (actual or potential) for environmental damage.

Location	Date	Fuel released	Cause	Consequence
Fawley	1999	Crude oil (400 tonnes)	Corrosion of tank base.	No injuries or off-site effects. All of the oil was recovered from primary containment. ECRA* (major loss of inventory).
Milford Haven	2005	Kerosene (653 tonnes)	Leak from damaged sump escaped through permeable floor of bund.	No injuries, but nearby gardens, farmland, and stream contaminated. All wildlife killed in stream. ECRA (contamination of groundwater).
Antwerp, Belgium	2005	Crude oil (26 000 tonnes)	Catastrophic failure of storage tank as a result of corrosion.	Overtopping of bund wall occurred due to sudden release. No injuries. ECRA (major loss of inventory).
Plymouth Harbour	2005	Kerosene (tonnage uncertain)	Corrosion of the tank base and a permeable bund base.	No injuries. Kerosene entered into the ground.
Coryton	2006	Gas oil (121 tonnes)	Tank overfilled, oil escaped from bund by defective drain valve.	No injuries or harm to the environment.
Poole Harbour	2006	Diesel oil (19 tonnes)	Diesel escaped through damaged base plate and through cracks in concrete bund floor.	No injuries. Pollution of ground but not of the harbour.

* ECRA – European Commission Reportable Accident

Table 2 Loss of primary containment from fuel storage tanks, some with environmental consequences

References

1 Buncefield Standards Task Group – Initial Report 2006 (www.hse.gov.uk/comah/buncefield/bstg1.htm)

2 *Safety Review Panel ('The Baker Report')* BP US Refineries Independent Safety Review Panel 2007

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

4 API RP 2350 *Overfill protection for storage tanks in petroleum facilities* (Third edition) January 2005

5 *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

6 *Dangerous Substances and Explosive Atmospheres Regulations 2002* SI 2002/2776 The Stationery Office 2002 ISBN 978 0 11 042957 1

7 *Model Code of Safe Practice in the Petroleum Industry, Part 2, Design, Construction and Operation of Petroleum Distribution Installations* (Third edition) Energy Institute September 2005

8 *The storage of flammable liquids in tanks* HSG176 HSE Books 1998 ISBN 978 0 7176 1470 7

9 *Remotely operated shutoff valves (ROSOVs) for emergency isolation of hazardous substances: Guidance on good practice* HSG244 HSE Books 2004 ISBN 978 0 7176 2803 2

10 Hofmann D, Jacobs R and Landy F 'High reliability process industries: Individual, micro, and macro organisational influences on safety performance' *Journal of Safety Research* 1995 **26** (3) 131-149

11 Reason J *Managing the Risks of organisational accidents* Aldershot, Ashgate 1997 ISBN 978 1 84014 105 4

12 Roberts K *New challenges to understanding organisations* Macmillan, New York 1993 ISBN 978 0 02 402052 9

13 Weick K and Sutcliffe K *Managing the unexpected: Assuring high performance in an age of complexity* Jossey-Bass, San Francisco 2001

14 BS EN 61511-1: 2004 *Functional safety – Safety instrumented systems for the process industry sector – Part 1: Framework, definitions, system, hardware and software requirements* British Standards Institution

15 BS EN 61511-2: 2004 *Functional safety – Safety instrumented systems for the process industry sector – Part 2: Guidelines for the application of BS EN 61511-1* British Standards Institution

16 BS EN 61511-3: 2004 *Functional safety – Safety instrumented systems for the process industry sector – Part 3: guidance for the determination of the required safety integrity levels* British Standards Institution

17 BS EN 61508-1: 2002 *Functional safety of electrical/electronic/programmable electronic safety-related systems* British Standards Institution

Glossary

API American Petroleum Institute. It is the American national trade association for the petroleum industry, but it has an increasingly collaborative stance with other bodies such as BSI. API produces a number of guides to standards and recommended practices. Of interest is API Recommended Practice 2350 *Overfill protection for storage tanks in petroleum facilities* which is currently being reviewed

BSI Formerly British Standards Institution, now the BSI Group, it was founded in 1901 as the Engineering Standards Committee, it is now diversified into making standards, certifying management systems, product testing and other engineering services related to quality

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

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

CENELEC European Committee for Electrotechnical Standardisation

COMAH See Control of Major Accident Hazards Regulations 1999

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

Competent Authority The Control of Major Accident Hazards Regulations (COMAH) are enforced by a joint Competent Authority comprising the Health and Safety Executive (HSE and the Environment Agency in England and Wales, and HSE and the Scottish Environment Protection Agency in Scotland

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

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, the Management of Health and Safety at Work Regulations, and the COMAH Regulations

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

firefighting pumps The pumping equipment, normally permanently installed in a pumphouse to move water around the site during fire fighting operations

firewater Water stored for use during, and used during, firefighting operations

firewater lagoon An artificial pond that principally stores water intended for firefighting operations

flashpoint The lowest temperature at which a liquid gives off sufficient vapour to form a flammable mixture

hazard Anything with the potential to cause harm

Health and Safety Commission The Health and Safety Commission is a statutory body, established under the Health and Safety at Work etc Act 1974, responsible for health and safety regulation in Great Britain

Health and Safety Executive The Health and Safety Executive is a statutory body, established under the Health and Safety at Work etc Act 1974. It is an enforcing authority working in support of HSC. Local authorities are also enforcing authorities under the Health and Safety at Work etc Act 1974

high reliability organisations Robust organisations with a strong safety culture that have a high probability of achieving safe and reliable performance. More detail is given in Annex 5

high integrity systems Systems that are designed and maintained so that they have a high probability of carrying out their intended function. Safety instrumented systems having safety integrity levels in the range SIL1 to SIL4 are regarded as high integrity systems

HSC See Health and Safety Commission

HSE See Health and Safety Executive

IEC International Electrotechnical Commission

independent overfill protection system A system that detects when the liquid in a storage tank has reached a level where continued further filling will result in loss of containment and acts to prevent further filling in time to prevent such loss of containment. Where such systems are automatic they do not rely on any human operator action

kiloPascal Pascals (Pa) are the unit of pressure in the International System of Units (SI). A kiloPascal (kPa) is equal to 1000 Pa. Although bar are not units within SI, they are sometimes used as units to measure atmospheric pressure.
1 kPa = 10 bar

major accident to the environment DEFRA has established threshold criteria defining a 'major accident to the environment' (MATTE), based on Schedule 7 (part 1) of the Control of Major Accident Hazards Regulations 1999. The Environment Agency, using these criteria, has determined that the Buncefield incident is a MATTE, and the Competent Authority has recently reported this to the European Commission

manual emergency switches Simple and robust push switches that will initiate emergency action such as shutting down pumps or interrupting process operations, and which are located at strategic and accessible locations around the site

MATTE See major accident to the environment

overpressure For a pressure pulse (or blast wave), the pressure developed above atmospheric pressure

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

pumphouse In the context of this report, the structure enclosing the pumping equipment used to move water around the Buncefield site prior to the incident. It principally stored water intended for firefighting operations

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

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

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

ultimate high level switch Part of the system to prevent overfilling of the tank, the ultimate high level switch is an independent mechanism which should be triggered when the 'ultimate high level' (ie the specified maximum capacity) is reached in a tank to which it is fitted, both causing an alarm to sound and shutting down the supply of fuel to the tank

Further information

Useful links

Buncefield Major Incident Investigation
Marlowe Room, 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 Community Trust Mayor's Fund
To apply, call the freephone helpline on 0800 131 3351. Lines are open 9.30 am to 4.30 pm, Monday to Friday

Dacorum Borough Council Tel: 01442 228 000
Web: www.dacorum.gov.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 Borough Council Digest newsletter, available monthly Dacorum Borough Council Buncefield Update Newsletter)

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

Department for 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.environmentagency.gov.uk

Department of Trade and Industry
Oil and Gas Directorate
Web: www.og.dti.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.ork.uk

Buncefields Standards Task Group (BSTG)
Chair: Ken Rivers Tel: 0151 951 4078

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

Available from www.buncefieldinvestigation.gov.uk
DEFRA: Initial review of Air Quality aspects of the Buncefield Oil Depot Explosion
www.defra.gov.uk/environment/airquality/buncefield/buncefieldreport.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 on: *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 Decorum Borough Council January 2007
www.decorum.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/