Dublin City Council
Comhairle Cathrach Bhaile Átha Cliath

South Dublin
County Council

Dún Laoghaire-Rathdown
County Council Comhairle Contae
Dhún Laoghaire-Ráth an Dúin

Fingal County Council
Comhairle Contae Fhine Gall

DUBLIN WASTE TO ENERGY PROJECT

www.DUBLINWASTETOENERGY.IE

Major Accident Hazard Assessment

February 2007

Elsam

NDP
NATIONAL DEVELOPMENT PLAN

Dublin Waste to Energy

Waste to Energy Facility

Major Accident Hazard Assessment

February 2007

CONTENTS

Figures

Appendices

1. INTRODUCTION

Dublin City Council (the Authority) acting on behalf of the four local authorities for the Dublin Region, i.e. Dublin City Council, Fingal County Council, South Dublin County Council and Dún Laoghaire Rathdown County Council, proposes to establish a waste to energy (WtE) facility (the Facility) to thermally treat household, commercial and non-hazardous industrial waste. The proposed Dublin WtE facility will have a design capacity to thermally treat up to 600,000 tonnes of waste annually and will be located on the Poolbeg Peninsula in Dublin.

The quantities of dangerous materials to be stored at the facility (refer to Appendix A) are such as bring it under the requirements of under the EC *Seveso II* Directive (Council Directive 96/82/EC of 9 December 1996 [1] as amended by Directive 2003/105/EC of the European Parliament and of the Council of 16 December 2003 [2]), as implemented in Ireland by the *European Communities (Control of Major Accident Hazards Involving Dangerous Substances) Regulations, 2006* (S.I. No. 74 of 2006) (herein referred to as 'the Regulations').

The site will be a "top tier" site under the Directive and the Regulations. As such the operator is obliged to submit a Safety Report to the Central Competent Authority for the Regulations (the Health and Safety Authority (HSA)) at least six months before commencement of construction. This report has been prepared to meet the requirements of the Directive and the Regulations.

2. STRUCTURE OF THE MAJOR ACCIDENT HAZARD ASSESSMENT REPORT

This Major Accident Hazard Assessment Report is set out in eight sections. Sections 1 and 2 are the report introduction and structure respectively.

Section 3 sets out basic information on the facility:

- an overview of the establishment and its activities
- information about the dangerous substance in use
- information about the surrounding environment

Section 4 describes the Safety Management System (SMS) of the operator and the major elements necessary to prevent and control major accidents:

- Overview of the SMS objectives
- Safety and training procedures
- Fire safety systems

Section 5 addresses the major accident potential of the site. The consequences of each possible accident are qualitatively and quantitatively assessed in this section.

Section 6 gives information about the measures to prevent or limit the consequences of the major accidents identified in section 5

Section 7 addresses the issue of protection of surface waters from potentially contaminated firewater run-off from the site.

Section 8 gives information about the emergency response measures to be implemented on site to limit the consequences of major accidents. This section describes the:

- objectives of the emergency plans
- information to be contained in the emergency plans
- procedures for the review of the emergency plans
- basis for implementation of the emergency plans

3. BASIC INFORMATION

3.1 Site and Operator

The proposed Dublin WtE Facility is being procured and developed as a public private partnership. Under the public private partnership arrangement it is proposed that the private company (the PPP Co) will be responsible for the design, construction and financing of the new WtE Facility as well as the ongoing operation of the Facility for a period of at least twenty-five years.

The tender competition for the design, build, finance and operation of the facility required certain minimum standards to be met. In this context, it might be noted that the current intended operator is from the DONG Energy (previously Elsam) in Denmark.

All statutory licenses/permissions will be in the name of Dublin City Council and DONG Energy will operate the proposed facility under the requirements/conditions of such licenses/permissions. The address of Dublin City Council is Engineering Department, Block 1, Floor 4, Civic Offices, Wood Quay, Dublin 8.

For the purposes of the Seveso II Directive, the contact will be the Executive Manager, Engineering Department, Dublin City Council.

The site is rectangular in shape with dimensions 160 m x 340 m. It covers an area of approximately 5.5 hectares. To the north it adjoins Pigeon House Road, to the west Shellybanks Road, to the east a Waste Water Treatment Works and to the south an undeveloped area (refer to Figure 1).

Currently the northern part of the site is used by the company Clearway Disposal, while the centre part is occupied by Hibernian Molasses. The southern part of the site is presently vacant. Clearance of the present structures on the site will be necessary prior to commencing terrain works for the construction of the Facility.

There will be three buildings on the overall site, the main process building, the cooling water pump house, and a security building. The cooling water pump house will be a two storey building and will contain a filter system, the main cooling water pumps and the biocide dosing system.

Main Process Building

The waste reception area, waste bunker, furnaces, boilers and flue gas treatment lines, turbine hall, and residue storage and handling areas will be accommodated in the main process building. The service areas including the control room, offices, staff facilities, administration area, workshop and stores will also be located in the main process building. The storages areas for residues and process materials will be located on the western side of the main building within the building shell.

The main building will be approximately 200 m long by 130 m wide by 52 m in height, at the highest point. The maximum height of the building is determined by the height of the process equipment, specifically the boiler. The ground floor level will be about 5.00mOD. The reception hall will have a floor level of about 12mOD. The bunker floor level will be about 0.00mOD and the hopper deck level will be about 30mOD. The process areas will generally be single storey.

The shape of the main building has been inspired by the shape of a snail shell. On all facades the walls will incline inwards with increasing height and the corners will be rounded. A lower outer zone will wrap around the high central core. Around the perimeter, at ground level will be a “heavy” base, consisting of pre-cast concrete panels. The upper parts of the external envelope will be formed in high quality architectural cladding panels and will incorporate large glazed panels. The flue gas treatment equipment will be visible through this glazed panel.

Two stacks will be located at the north-eastern corner of the main building. The stacks will be side by side and each will be about 3 m in diameter and 100 m in height.

Cooling Water Pump House

The cooling water pump house will be a two storey building and will contain a filter system, the main cooling water pumps and the biocide dosing system. It will be located north of Pigeon House Road.

Security Building

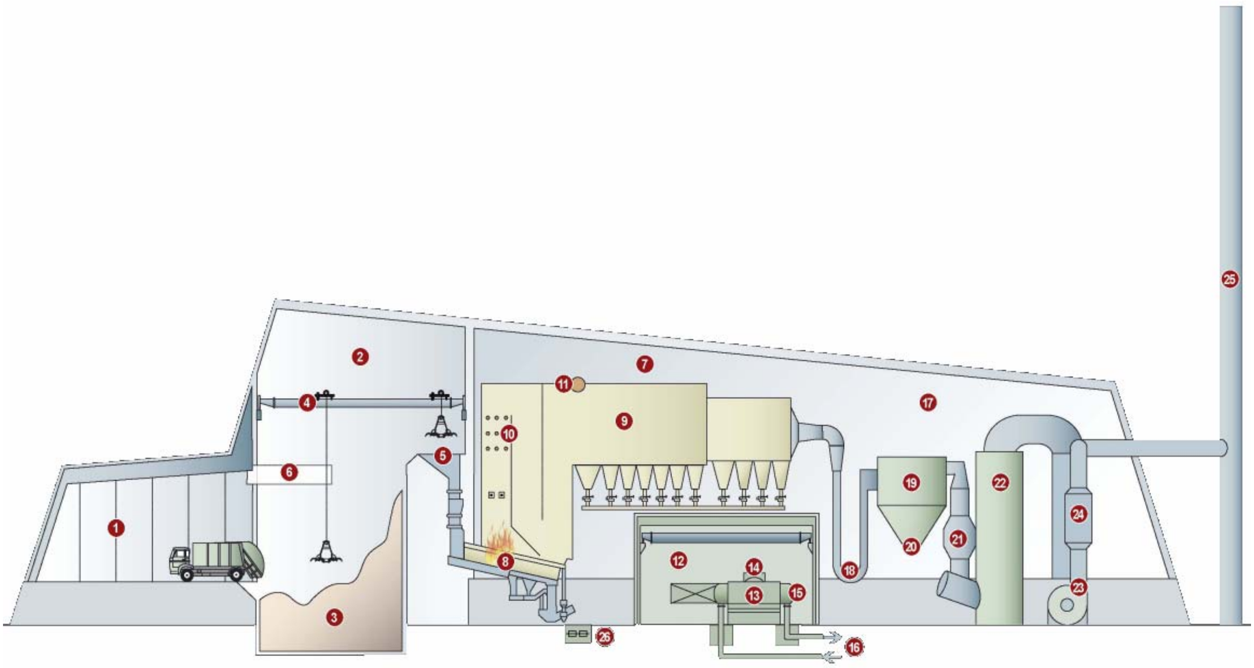
A security building will be located at the main access point. The ground floor levels of the building will also be about 5.00mOD.

3.2 Overview of the Establishment, its Activities and Products

The waste to energy process will consist of the following main elements:

- Waste acceptance
- Waste intake and storage
- Combustion process
- Energy recovery process
- Flue gas cleaning.

Schematic diagram of the WtE process



1. Waste reception hall
2. Waste bunker compartment
3. Waste bunker
4. Waste crane for feeding the boiler grate
5. Waste hopper
6. Control room
7. Boiler area
8. Grate
9. Boiler, where the heat energy is transferred from the flue gas to the boiler water
10. NO_x reduction by spraying ammonia water into the flue gas
11. Boiler drum, where water and steam are separated
12. Turbine room
13. Steam turbine
14. Generator, producing electricity
15. Condenser, where the remaining heat energy in the steam is cooled
16. Cooling system
17. Flue gas treatment area
18. Activated carbon and lime are added to the flue gas to bind dioxins and other components
19. Fabric filter, where the flue gas treatment residue is removed from the flue gas
20. Extraction point for flue gas treatment residues
21. Flue gas cooler
22. Two-stage wet scrubber for reduction of HCI, SO2, HF and Hg emissions

23. ID fan

24. Silencer

25. Stack

26. Bottom ash for recycling

3.3 Surrounding Industrial Sites and Residential Areas

The Synergen Dublin Bay Power Plant is adjacent to the west of the site across Shellybanks Road. It is a 400 MW Combined Cycle Gas Turbine (CCGT), and is located on Pigeon House Road within the south port area. The principal fuel is natural gas, but distillate oil is stored on site as a back-up or reserve fuel. Further industrial activities and Dublin Port quays are located to the north.

The Seveso sites in the south port area are:

- Poolbeg ESB Generating Station
- Synergen Dublin Bay Power Plant

The Poolbeg ESB Generating Station is situated at the eastern end of the Poolbeg peninsula. Both the Poolbeg and Synergen Dublin Bay Power stations are establishments covered by the Seveso Directive i.e. they are potential major accident hazard sites subject to the requirements of SI No 74 of 2006.

The Poolbeg ESB Generating Station stands on ninety acres of land, a large part of which was reclaimed from the sea. The basic generating system (500 MW) is a steam turbine system. A 470 MW CCGT was added in 1999. As in the case of the Synergen Dublin Bay Power Plant, the principal fuel is natural gas, but distillate oil (gas oil) is stored on site as a back-up or reserve fuel.

The Seveso sites in the north port area are:

- CalorGas - LPG storage and filling depot
- Minchem – waste handling and blending facility
- Albion Chemical Distribution (Irl) Ltd – chlorine gas cylinder and drum storage
- Irish Shell, Statoil, Esso and Tedcastle – bulk oil storage

Irishtown Nature Park is located to the southeast of the site. The established residential areas of Irishtown and Ringsend lie approximately 1 km to the west of the site. The established residential area of Sandymount lies approximately 1 km to the south of the site. The main facilities of Dublin port are located across Dublin harbour, to the north of the site. The site of the former Irish Glass Bottle Company (IGB) factory lies approximately 0.5 km to the west. Operations on this former Seveso site ceased some years ago, and it is now vacant. Planning permission has been sought for a site beside the former IGB site by Fabrizia for residential development. At the time of writing, the decision to grant planning permission is under appeal to An Bord Pleanála.

3.4 Dangerous Substances and Seveso Threshold Quantities

The dangerous substances to be stored at the facility are compared to their threshold quantities in the Regulations in Appendix A. The dangerous substances making the main contribution to the facilities upper tier status are as follows:

- Ammonium hydroxide (used for abatement of emissions to atmosphere of nitrogen oxide)
- Diesel oil (gas oil) (used as a standby fuel)

- Flue Gas Treatment (FGT) residues (the high content of heavy metals results in classification as toxic to aquatic organisms)

The rationale for classification of FGT residues as risk phrase R51/53, toxic to aquatic organisms/may cause long-term adverse effects in the aquatic environment, is described below.

A report by the European Environment Agency (EEA) (Technical report No 38 Dangerous substances in waste, February 2000), gives information on the composition of solid wastes from Municipal Waste Incineration:

Table 1 Composition of Solid Wastes from Municipal Waste Incineration

Substances	**Contents (mg/kg)**		
	Slags*	**Fly Ash**	**Residues from Gas Cleaning**
Cd	<0,5 — 10	50 — 1000	300 —500
Tl	< 2	0 — 50	0 — 2
Hg	<0,05 — 5	2 — 30	10 — 30
As	0,5 — 50	10 — 100	40 — 100
Co	15 — 35	30 — 100	5 — 20
Cr	50 — 1000	50 — 2000	50 — 200
Cu	500 — 1500	300 — 5000	500 — 1500
Ni	25 — 100	100 — 400	30 — 100
Pb	100 — 3500	1000 — 12000	4000 — 10000
Sb	20 — 200	300 — 1000	300 — 1000
Sn	100 — 250	500 — 3000	—
Zn	500 — 2500	5000 — 40000	20000 — 30000
	Contents ngTE/kg		
PCDD/F	4-25 ngTE/kg	100-10000 ngTE/kg	100-10000 ngTE/kg

* Bottom Ash

Source: T. Leclaire: Behandlung und Verwertung von HMV-Rückständen, Gerhard Mercator-Universitat-GH Duisburg; 1998

The above figures are similar to those reported by T. Astrup in 2005 for incinerators in Denmark.

Classification of Heavy Metals

The EEA report referred to above states that a high percentage of metals are gasified by the incineration process. These metals are transferred to the gas phase and partly condense before entering the gas cleaning unit. The condensed metals are mostly adsorbed on the surface of small fly ash particles. The fly ash tends to concentrate metals. The remaining vaporised metals are transported to the gas cleaning unit and are washed out.

Hence some of the metals are present as pure metals, and some as inorganic compounds. The following is the classification of each metal assumed for this assessment.

Cadmium (Cd)

Cadmium and cadmium oxide are both classified as very toxic (T+) and dangerous to the aquatic environment (N) by the International Labour Organization (ILO) and cadmium compounds as a group are classified as harmful (Xn) and N-R50/53 by the EC. Therefore the Cd portion of the FGT Residues are classified as N-R50/53.

Thallium (Tl)

Thallium is classified by the EC as T+ and R53. Thallium compounds are classified as T+ and R51/53. Therefore, the Tl portion of the FGT Residues is classified as N-R51/53.

Mercury (Hg)

The ILO classifies mercury metal as toxic (T) and N-R50/53 and mercury oxide (HgO) as T+ and N-R50/53. The EC classifies inorganic mercury compounds as T+ and N-R50/53. Therefore the Hg portion of the FGT Residues is classified as N-R50/53.

Arsenic (As)

The ILO classifies arsenic metal as T and N-R50/53, and the EC classifies arsenic compounds as T and N-R50/53 also. The ILO classifies arsenic trioxide as T and N-R50-53, and arsenic pentoxide as T+ and N-R50/53. Therefore the As portion of the FGT Residues is classified as N-R50/53.

Cobalt (Co)

The EC classifies cobalt oxides as harmful N-R50/53, but the ILO classifies cobalt metal as harmful (Xn). It is considered prudent to classify the Co portion of the FGT residues as N-R50-53.

Chromium (Cr)

The EC and the ILO classify Cr(VI) compounds as T and N-R50/53, but Cr(III) compounds are not classified as hazardous. The ILO classifies chromium metal as N, but does not assign risk phrases. It is considered prudent to classify the Cr portion of the FGT Residues as N-R50/53.

Copper (Cu)

The ILO classifies cuprous oxide (Cu) as N-R50/53, but does not classify copper metal as hazardous. The EC classifies copper oxides as harmful, but not as N. Therefore the Cu portion of the FGT Residues is not classified as hazardous.

Nickel (Ni)

The ILO and the EC classify nickel monoxide (NiO) as toxic (T) but not N. The ILO classifies nickel metal as harmful. Therefore the Ni portion of the FGT Residues is not classified as hazardous.

Lead (Pb)

The EC classifies lead compounds as T and N-R50/53. The ILO does not classify lead metal as hazardous, the EC has not classified lead metal. Fischer Laboratories classifies lead metal as T and N-R50/53. Therefore the Pb portion of the FGT Residues is classified as N-R50/53.

Antimony (Sb)

The EC classifies antimony compounds as T and N-R50/53. The ILO has not classified antimony metal as hazardous. It is considered prudent to classify the Sb portion of the FGT Residues as N-R50/53.

Tin (Sn)

Neither the EC or the ILO has classified tin or its compounds as hazardous, and the Sn portion of the FGT Residues is therefore not classified as N.

Zinc (Zn)

The EC and the ILO have classified zinc oxide (ZnO) as N-R50/53. Zinc metal is not classified as N. It is considered prudent to classify the Zn portion of the FGT Residue as N-R50/53.

3.4.1 Basis for Classification

The EC Dangerous Preparations Directive 1999/45/EC gives the basis for classification of mixtures or preparations containing dangerous substances.

Table 2 Annex II Part B Concentration Limits to be used in the Evaluation of Health Hazards, Non-Gaseous Preparations, Acute Lethal Effects

Classification of the Substance	Classification of the Preparation		
	T^+	T	X_n
T^+ with R26, R27, R28	$C \geq 7\%$	$1\% \leq C < 7\%$	$0.1\% \leq C < 1\%$
T with R23, T24, T25		$C \geq 25\%$	$3\% \leq C < 25\%$
X_n with R20, R21, R22			$C \geq 25\%$

Table 3 Annex III Part B Concentration Limits to be used for the Evaluation of Environmental Hazards, Acute Aquatic Toxicity and Long-term Adverse

Classification of the Substance	Classification of the Preparation		
	N, R50-53	N, R51-53	R52-53
N, R50-53	$C_n \geq 25\%$	$2.5\% \leq C_n < 25\%$	$0.25\% \leq C_n < 2.5\%$
N, R51-53		$C_n \geq 25\%$	$2.5\% \leq C_n < 25\%$
N, R52-53			$C_n \geq 25\%$

3.4.1.1 Application to FGT Residues

On the basis of the above, the concentrations of metals classified as N with risk phrase R50/53 are as follows:

Table 4 Concentrations of Metals Classified as N with Risk Phrase R50/53

Substances	Classification	Concentration (mg/kg)
Cd	N-R50/53	300 - 500
Hg	N-R50/53	10 - 30
As	N-R50/53	40 - 100
Co	N-R50/53	5 - 20
Cr	N-R50/53	50 - 200
Pb	N-R50/53	4,000 - 10,000
Sb	N-R50/53	300 - 1,000
Zn	N-R50/53	20,000 - 30,000
Total		**24,705 - 41,850**

The total is equivalent to a concentration of 2.4705% to 4.1850%. Taking the minimum as 2.5% approximately, this results in classification of the mixture as N-R51/53.

3.5 Environment

3.5.1 Water

There will be no direct discharge to surface water of rainwater, sewage or process wastewater from the facility. Rainwater from roof areas and paved areas will be collected in an underground Stormwater Storage Tank and will be used for recycling in the process water system. The Stormwater Storage Tank will be designed with an overflow to the main combined sewer pipeline. The reservoir will be equipped with a monitoring station to continuously monitor pH-values.

Ammonium hydroxide and diesel will be isolated from surface waters by primary containment (storage tanks), secondary containment (bunds) and tertiary containment (the facility's closed drainage system). In the event of a fire/emergency an automatic shutoff valve will prevent any discharge of firewater from the Storm water Storage Tank to the combined sewer, and the Tank will overflow through a higher level overflow to the Waste Bunker.

The area of interest comprises the Liffey estuary and Dublin Bay.

Dublin Bay is a shallow bay with water depths not greater than 20 m at low tide at its outer limit between Sorrento Point and Baily at Howth. The water depth decreases towards the harbour with depths of less than 5m occurring in the inner half of the Bay. North of the harbour at Bull Island and south around Sandymount extensive areas dry out at low tide.

The Liffey enters Dublin Bay between Clontarf and Ringsend in the channel formed by the North Bull Wall and the Great South Wall. The North Bull Wall is a natural bank reinforced by a stone embankment that is only inundated at half tide. It therefore holds back the water flowing out of the harbour at and after half ebb. The navigation channel runs close to the South Wall and extends from the Port area through the mouth of the harbour. This navigation channel is maintained at a depth of 7 to 8 metres below chart datum by dredging and natural scouring. To the north of this channel are extensive areas which dry out at low water. These mudflats extend from the mouth of the River Tolka almost to the end of the Bull Wall and north-eastwards to the Bull Island Causeway at St. Annes.

3.5.2 The Natural Environment – Land Based Flora and Fauna

Biosphere Environmental Services completed the terrestrial ecology assessment.

3.5.2.1 Habitats, Vegetation and Flora Around Site

The site is surrounded by developed land to the north, east and west. These areas include buildings, hard surfaces and some ground with a weedy vegetation (Recolonising bare ground). Some bare ground and spoil heaps also occurs to the south of the site, along with further recolonising bare ground. The Shellybanks Road skirts the western boundary of the site and associated with this is a line of planted sycamore trees and a strip of shrubbery.

The sycamore trees can be classified as a low **Treeline**. There is approximately 26 trees, all sycamore, which were planted along the eastern side of the Shellybanks Road. These are in the region of 7-8 m in height. A strip of shrubbery (**Ornamental/non-native shrub**) has been planted along the western side of the road. This is dense and predominantly of Escallonia (*Escallonia* spp.), with brambles and such species as butterfly bush. Some trees also occur, including cypress (*Cypressus* spp.), white poplar (*Populus alba*) and sycamore.

3.5.2.2 Fauna

Mammals, Amphibians and Reptiles

Brown rat *Rattus norvegicus* was the only mammal species recorded within the site.

House mouse *Mus domesticus* would also be expected, and probably the ubiquitous pygmy shrew *Sorex minutus*. The low number of species reflects the low diversity of habitats present.

Signs of fox *Vulpes vulpes* were found near the boundary fence of the Irishtown Nature

Park and this species, which has a permanent presence in the port area, could pass through the site at times. Long-tailed field mouse *Apodemus sylvaticus* may also occur, and possibly rabbits *Oryctolagus cuniculus*. The site does not have suitable roost sites for bats.

The habitats on site or in the immediate vicinity are not suitable for amphibians such as the common frog *Rana temporaria* or for the common lizard *Lacerta vivepara*.

Birds

Few bird species occur within the site owing to the low diversity of habitats present. Only two species, wren *Troglodytes troglodytes* and dunnock *Prunella modularis*, were considered to nest within the site, and these were confined to the strip of vegetation along the southern and south-west boundary lines. Starlings *Sturnus vulgaris* and pied wagtail *Motacilla alba* were noted in the vicinity of the buildings on site and could breed in suitable holes or gaps within the buildings.

A small number of other species were recorded in the shrubbery along the Shellybanks Road, with robin *Erithacus rubecula*, blackbird *Turdus merula*, great tit *Parus major*, blue tit *Parus caerulea,* greenfinch *Carduelis chloris* and chaffinch *Fringilla coelebs* all nesting. A single reed bunting *Emberiza schoeniclus* was recorded in August in the rough vegetation to the south of the site and could nest locally. At least one pair of skylarks was present in the recently cleared ground south of the site. Other birds which nest in the general vicinity include woodpigeon *Columba palumbus*), jackdaws *Corvus monedula*, hooded crow *Corvus corone cornix* and magpie *Pica pica*.

A flock of c.30 linnets *Carduelis cannabina* was present on the rough ground to the south of the site in August, along with a small number of goldfinches *Carduelis carduelis*.

Recently planted grassland within the adjacent Ringsend Waste Water Treatment Works, and also to the south of it, supports brent geese *Branta bernicla horta* during winter. Gulls, mostly black-headed *Larus ridibundus*, are common in the vicinity of the Ringsend Waste Water Treatment Works during winter.

Irishtown Nature Park

The Irishtown Nature Park physically consists of an elevated central plateau of land, which slopes down to the sea on its southern side and is bounded on its northern edge by amenity grassland adjacent to the Ringsend Waste Water Treatment Works. Its eastern boundary contains a small area of sand dune in front of the main road whilst its western edge culminates in a path linking the Park with the road at Sandymount.

The vegetation and plant species present reflect the past use of the site together with its current management as a park and amenity area. Most of the southern side is under the influence of the sea and especially salt spray and this has allowed coastal vegetation to develop in places. As might be expected from the past use of the area and from the planting that has been carried out, there is little in the way of natural or semi-natural habitats to be found within the Park. The only piece, which has not been directly influenced in its development by humans, lies on the eastern side in the corner between the Park proper and the main road. Here a small area of sand dune occurs.

Over most of the Park a habitat of coarse grassland is found, which mostly corresponds to the category **Amenity Grassland**. Species such as perennial rye grass *Lolium perenne*, red fescue *Festuca rubra*, creeping bent *Agrostis stolonifera* and creeping thistle *Cirsium arvense* are present. Blackberry *Rubus fruticosus* is invading this in parts. Also invading this grassland are stretches of scrub consisting mostly of native species such as blackthorn *Prunus spinosa*, elder *Sambucus nigra* and ash *Fraxinus excelsior*. However, two exotic species, sycamore *Acer pseudoplatanus* and Japanese knotweed *Reynoutria japonica,* are acting invasively here. This habitat can be broadly accommodated within the category of **Scrub**.

Non-native, planted shrubs have formed a scrub of sorts, and includes escallonia

Escallonia macrantha, butterfly bush *Buddleja davidii*, field maple *Acer campestre* and 2 species of Cotoneaster. Trees are present in the form of evergreen oak *Quercus ilex,* sessile oak *Quercus petraea* and Italian alder *Alnus cordata*. This habitat is that of **Ornamental, non-native shrubs**.

The stony, rock and boulder-dominated areas adjacent to the sea, reflect the infilled nature of the area and the species cover is sparse and very scattered. Weedy species such as teasel, *Dipsacus fullonum,* mugwort *Artemisia vulgaris*, red valerian *Centranthus ruber* and common mallow *Malva sylvestris* are found here. This habitat can be included within **Buildings and artificial surfaces** and nearer the sea, the influence of salt spray has allowed the growth of a number of coastal species notably sea beet *Beta maritima* and sea mayweed *Matricaria maritima*.

The habitat **Re-colonizing bare ground** is common throughout and the principal species here is coltsfoot *Tussilago farfara* and hoary mustard *Hirschfeldia incana*.

In summary, the Park, whilst not of significant conservation importance, is rich in plant species as they have come from a number of sources.

3.5.3 The Natural Environment – Aquatic Flora and Fauna

Ecological Consultancy Services Ltd (EcoServe) were commissioned by M.C. O'Sullivan Ltd in 2003 to conduct a baseline marine and estuarine ecological study of the area.

3.5.3.1 Littoral Survey

Irishtown

The biotopes[1] along the shore were mapped in accordance with the procedures detailed by Davies *et al*. (2001) and Emblow *et al*. (1998) (refer to Figures 2-4). The survey, a total of 11

[1] A biotope is defined by the EU as a "small area with uniform biological conditions (climate, soil, altitude, etc.)." (http://ec.europa.eu/research/biosociety/library/glossarylist_en.cfm?Init=B)

biotopes were recorded in the study area of Irishtown. These included five sediment and six hard or mixed substrata biotopes. Four core samples were taken in total.

Core 1 (C1) was taken in muddy sand towards the west of the study area. The presence of the cockle *Cerastoderma edule* and polychaetes allowed for a biotope code of LMS.PCer to be assigned indicating *Cerastoderma edul*e and polychaetes in fine sand or muddy sand shores. However, the polychaeta species recorded were not typical of this biotope.

Core 2 (C2) was taken in the sandier areas to the east of Core 1. Polychaetes and amphipods were recorded although species diversity and abundance was low, it was considered high enough to assign a biotope code of LGS.AP indicating burrowing amphipods and polychaetes to this site. However, it should be noted that this is not a good example of the biotope, primarily as the sand has a significant anoxic element just below the surface.

Core 3 (C3) was taken towards the eastern end of the study area near the start of the Bull Wall. Significant numbers of the bivalve *Angulus tenuis* were recorded. However, an absence of other significant fauna did not allow for the assignation of a lower biotope. A higher biotope of LGS was assigned indicating littoral gravels and sands.

Core 4 (C4) was taken from the sediments approximately half way along the Poolbeg peninsula where species abundance and diversity was again relatively low. A biotope code of LMU.HedMac was assigned using the principle of best fit. This indicates *Hediste diversicolor* and *Macoma balthica* in sandy mud shores.

A number of other sediment biotopes were observed during the study. On sandy areas above the high tide mark, the sand had no obvious infauna. Below areas of barren sand areas of decomposing drift algae occurred, supporting talitrid amphipods. The extreme north western corner of the site consisted of a black anoxic mud covered with a grey pink coloured sewage fungus. There were also smaller patches of sewage fungus along the stream running beside the rock armour.

Overall the sediment biotopes of the Irishtown area varied from mud to sandy mud in places through muddy sand to fine sand. Boundaries between the sediment types were frequent and indistinct and as such not possible to map clearly for this report.

An almost continuous band of "rock armour" stretched from the western end of the study area to the start of the Bull Wall to the east of the study area. The highest points of this were generally not intertidal and thus barren of marine life. They are shown on the map as "rock armour". The lower sections of this armour were colonised by various organisms and have been assigned biotopes. It should be noted that the hard substrata biotopes have become established on the rock armour itself and are such, in part, man-made habitats.

Two areas supported a biotope dominated by the channelled wrack *Pelvetia canaliculata*, and were assigned the biotope code SLR.Pel, indicating *P. canaliculata* on sheltered fringe rock. The areas supporting this biotope were an area at the western extreme of the study area and a significant length above the biotope SLR.Fves towards the centre of the study area. Other species present in this biotope included *Fucus spiralis* and *Enteromorpha* sp. SLR.Pel is found above the biotope SLR.Fspi.

An almost unbroken line of the biotope SLR.Fpi indicating Fucus spiralis on moderately exposed to very sheltered upper eulittoral rock, was recorded along the rock armour. The biotope was dominated by growths of *Fucus spiralis*, recorded as common, and also by the ephemeral green algae *Enteromorpha* sp. The barnacles *Semibalanus balanoides* were recorded frequently as was the periwinkle *Littorina saxatilis*. The small gastropod *Hydrobia* sp. was also present in high numbers. While much of the length of this biotope was considered a good example of SLR.Fspi, there was an area on the corner about half way along the study area where the principle of best fit was applied. *F. spiralis* was sparse but was still the dominant algae present.

Two similar biotopes formed an almost continuous band below SLR.Fspi along the length of the rock armour where the stream flowed. SLR.Asc characterised by the seaweed *Ascophyllum nodosum* on very sheltered mid eulittoral rock dominated much of the western end of the study area. Whilst SLR.Fves characterised by the seaweed *Fucus vesiculosus* on sheltered mid eulittoral rock dominated the eastern side and an area in the northwest corner of the site. SLR.Asc was dominated by *A. nodosum* but also contained other brown seaweeds *F. spiralis*, *F. vesiculosus*, the green seaweed *Enteromorpha* sp., barnacles *Semibalanus balanoides*, mussels *Mytilus edulis*, sea anemones *Actinia equine* and amphipods. The epiphytic red algae *Polysiphonia lanosa* was present on the *A. nodosum*. SLR.Fves was dominated by the fucoid *Fucus vesiculosus* and also contained *Enteromorpha* sp., *A. nodosum*, *Ulva* sp., the periwinkle *Littorina littorea*, amphipods, the crab *Carcinus maenas* and *Mytilus edulis*.

Below the combined line of SLR.Asc and SLR.Fves towards the edge of the stream that runs along much of the study area, there was a continuous if at times narrow line of *Enteromorpha* sp. This was assigned a biotope code of SLR.EphX indicating ephemeral green and red seaweeds on variable salinity or disturbed eulittoral mixed substrata. There were a number of gravely / cobble areas scattered on the sediment biotopes. This slightly more stable substrata allowed for the growth of ephemeral algae such as *Enteromorpha* sp. and was also assigned a biotope code of SLR.EphX. The stream itself did not comprise a distinct biotope. However, cobbles contained within the stream supported growths of the red algae including *Ceramium* sp. One area of about 50 m on the beach side of the stream supported a narrow band of the sand mason *Lanice conchilega*. This was assigned a biotope code of LGS.Lan indicating dense *Lanice conchilega* in tide swept lower shore sand.

Along the western end of the rock armour away from the stream, the substrata was more exposed and dry. The dominant seaweeds along this area were the ephemeral algae *Enteromorpha* sp. and *Porphyra* sp. although both were sparse. Other species recorded as present included *Fucus spiralis*, *Fucus vesiculosus* and *Semibalanus balanoides*. A biotope code of MLR.EntPor was assigned indicating *Porphyra purpurea* or *Enteromorpha* spp. on sand scoured mid or lower eulittoral rock.

Liffey Estuary

The two littoral sites examined in the Liffey estuary were structures away from the actual shoreline and were hard substratum sites. A species list was taken for each site, which was also subdivided into obvious zones although a full biotope map was not produced.

Site La was located on a combined wooden and metal structure immediately downstream of the Ringsend Power Station. There were a number of obvious zones recorded. Reasonable water clarity allowed for the identification of abundant plumose anemones *Metridium senile* and red algae just below the surface, forming a distinct band below the low water mark to about 20 cm below. The zone immediately above this, extending above the low water mark was dominated by superabundant mussels *Mytilus edulis* covered with growths of hydroids, and barnacles *Semibalanus balanoides*. The ephemeral green algae *Enteromorpha* sp. and Ulva sp. were also present. A second littoral zone was dominated by healthy growths of the fucoids *Fucus spiralis* (frequent), *Fucus ceranoides* and *Fucus serratus* (both present) and a red algae in poor condition. A single crab *Cancer pagurus* was observed in a hollow. The flora and fauna of the lower littoral zone all extended up into the upper zone. There was a zone of green algae higher up the structure that corresponds to the splash zone.

Site Lb was located on a block structure downstream of the container facility on the south side of the estuary. Below the low watermark to about 20 cm, abundant red algae were observed, together with sessile fauna that were possibly tunicates. The zone extending up from the low water mark was dominated by bryozoan crusts and barnacles which were abundant, the occasional limpet *Patella vulgata*, and algae *Fucus serratus*, *Porphyra* sp., *Enteromorpha* sp. and *Ulva* sp., all of which were recorded as present. The zone above this was also dominated by algal species. *Fucus spiralis* was recorded as common, *Fucus ceranoides* was present, *Enteromorpha* sp. and *Porphyra* sp. were common. Barnacles were abundant beneath the algae. A number of isopods were also observed. Thin hydroid growths were recorded.

Tolka Estuary

Three of the four littoral sites within the Tolka estuary were low in both species diversity and abundance. Only one polychaeta or polychaeta fragment was recorded from each of the sites Lc, Ld and Le. This is only sufficient to assign a more general biotope. The biotope code of LMU.Mu was assigned to each of these sites, and indicates soft mud shores.

Site Lf on the Clontarf (north) side of the estuary recorded significant numbers of both the ragworm *Hediste diversicolor* and the bivalve *Scrobicularia plana*. A biotope code of LMU.HedScr was assigned indicating *Hediste diversicolor* and *Scrobicularia plana* in reduced salinity mud shores.

The edge of the estuary on the south side was dominated by growths of the knotted wrack

Ascophyllum nodosum where the substratum was coarse boulders and rubble. The ephemeral algae *Porphyra* sp. and *Enteromorpha* sp. were also present. The smoother surfaces were dominated by ephemeral algae or by fucoids. The hard substrata upper shore on the north side was also dominated by *Ascophyllum nodosum* with occasional growths of the channelled wrack *Pelvetia canaliculata*, *Fucus vesiculosus* and ephemeral green algae.

Dollymount Strand

The transect down the fine sandy beach of Dollymount Strand on Bull Island was divided into three biotopes. Site Lg on the upper shore did not contain any fauna and was assigned the biotope of LGS.BarSnd indicating barren sand.

Site Lh on the mid shore contained a number of polychaeta species including the catworm *Nephtys* sp. and the spionid *Scolelepis squamata*, and a single bivalve *Angulus tenuis*.

While species abundance was low and no amphipods were recorded, a biotope code of LGS.AP was assigned indicating burrowing amphipods and polychaetes in clean sand.

Site Li on the lower shore contained significant numbers of the bivalve *Angulus tenuis*, a single amphipod *Bathyporeia* sp. and two polychaeta species, *Nephtys* sp. and *Magelona* provide an exact fit for this biotope, the presence in significant numbers of *Angulus tenuis* in particular allows for its assignation.

Sutton Area

The shallow, coarse, mobile sand of site Lj was found to contain only one crab, *Carcinus maenas*. The sediment had a patchy distribution around bedrock outcrops. The bedrock outcrops supported thick growths of the knotted wrack *Ascophyllum nodosum*, together with the fucoids *Fucus serratus*, Fucus vesiculosus and *Fucus spiralis*. The ephemeral green algae *Ulva* sp. and *Enteromorpha* sp. were also recorded. Fauna included abundant barnacles, together with the limpet *Patella vulgata* and the mussel *Mytilus edulis*. The dog whelk *Nucella lapillus* was also recorded.

Overall

None of the species or biotopes recorded during the survey was of specific nature conservation importance or interest. All the species, biotopes and habitats recorded are typical of the east coast of Ireland (Picton & Costello, 1998).

3.6 External Factors Contributing to a Major Accident

3.6.1 Neighbouring Facilities

The proposed facility is to be located on the reclaimed lands of the Poolbeg Peninsula in the administrative area of Dublin City Council.

The area surrounding the proposed Dublin WtE facility is mainly industrial in character, primarily consisting of port related activities such as freight storage, power generation and wastewater treatment. Across the Liffey Estuary, the North Dockland area includes a number of ferry terminals. Residential areas in closest proximity to the site are Irishtown, Ringsend and Sandymount.

The Seveso sites in the port area include:

Table 5 Seveso Sites in the Dublin Port

Company	Industrial Activity
North Port	
CalorGas	LPG storage and filling depot
Minchem	Waste handling and blending facility
Albion Chemical Distribution (Irl) Ltd	Chlorine gas cylinder and drum storage
Irish Shell, Statoil, Esso and Tedcastle	Bulk oil storage
South Port	
Poolbeg ESB Generating Station	Electricity generation
Synergen Dublin Bay Power Plant	Electricity generation

The planning authority must seek technical advice from the Health and Safety Authority (HSA) in assessing planning applications for certain categories of developments where they are to be located within the consultation distance of an industrial facility. SI No 600 of 2001 stipulates consultation distances for certain types of industrial facilities. The consultation distance for non-pressurised bulk storage of flammable materials is 300 m from the site perimeter.

The site of the proposed waste to energy facility lies outside the consultation distance (as specified in SI No 600 of 2001) for all the facilities in the North Port. It lies within the consultation distance of the Synergen Dublin Bay Power Plant (refer to Figure 5).

3.6.2 Earthquake

The risk of earthquakes in the area is very low. "The whole of Ireland is practically free of earthquakes"[3]. Should an earthquake occur, this could cause a major accident through loss of containment of diesel or ammonium hydroxide at the facility. The consequences of these scenarios are reported in section 5.

3.6.3 Aircraft Impact

The frequency of aircraft impact at the proposed site based on the methodology described in CRR-150 1997 "The Calculation of Aircraft Risk in the UK"[4] is calculated as 1.14 x 10^{-6} yr^{-1} (refer to Aircraft Impact Report – Appendix B). This compares with a value of 1.83 x 10^{-8} calculated using methodology from the Canvey Report (1978).

It should be noted that there have been no incidences of small transport, large transport or military aircraft accidents in Ireland in the past 10 years. For this reason, background crash rates for these categories of aircraft were based on UK data as provided in CRR-150 1997.

3.6.4 Subsidence

The facility will be built on reclaimed land, i.e. made ground. However, this has been well compacted, and the facility is to be piled. It is not expected that subsidence will occur, and if it does, it would be of such a limited nature that it would not be expected to result in a major accident at the facility.

3.6.5 Tide Level

Currently the site level varies from about 5mOD Malin in the northern part to about 3.5mOD Malin in the southern part. Various options in relation to site level and ground floor level for the process lines were considered. In order to minimize the amount of excavation required to construct the bunker and balance the amount of soils to be excavated and filled, an optimum site level of about 5mOD Malin was chosen. This also ensures that the site is safe from risk of flooding as it is at least 1 m above the 1/200 year predicted flood level for Dublin (3.4 m Malin AOD[5]).

Following the IPCC 2001 Climate Change Report a value of 480 mm was taken as the design standard for sea level rise in the Dublin area by 2100. However this figure is now under review and a value of 900 mm for sea level rise by 2100 is being use for some recent developments.

Assuming a value of 0.9 m for sea level rise then the 1 in 200 year event in 2100 would have a value of 4.3m OD Malin. The proposed site level is about 5mOD Malin, and therefore the risk from flooding is extremely remote.

4. SAFETY MANAGEMENT SYSTEM

As part of this facility, the operator will implement an environmental management system and safety management system accredited to ISO 14001 and OHSAS 1800.

The operator will obtain independent accreditation to the OHSAS 18001:2004, the international standard for safety management systems.

The main features of the safety management system are to set goals and targets and to have standard operating procedures, staff training, audits, annual report etc.

4.1 Outline of System

The following issues will be covered in the Dublin WtE facility's Safety Management System:

- Organisation and personnel: the roles and responsibilities of personnel involved in the management of major hazards at all levels in the organisation. The identification of training needs of such personnel and the provision of the training so identified. The involvement of employees and, where appropriate, subcontractors.
- Identification and evaluation of major hazards: adoption and implementation of procedures for systematically identifying major hazards arising from normal and abnormal operation and the assessment of their likelihood and severity.
- Operational control: adoption and implementation of procedures and instructions for safe operation, including maintenance of plant, processes, equipment and temporary stoppages.
- Management of change: adoption and implementation of procedures for planning modifications to, or the design of new installations, processes or storage facilities.
- Planning for emergencies: adoption and implementation of procedures to identify foreseeable emergencies by systematic analysis and to prepare, test and review emergency plans to respond to such emergencies.
- Monitoring performance: adoption and implementation of procedures for the ongoing assessment of compliance with the objectives set by the operator's Major-Accident Prevention Policy and Safety Management System, and the mechanisms for investigation and taking corrective action in case of non-compliance. The procedures will cover the operator's system for reporting major accidents of near misses, particularly those involving failure of protective measures, and their investigation and follow-up on the basis of lessons learnt.
- Audit and review: adoption and implementation of procedures for periodic systematic assessment of the major-accident prevention policy and the effectiveness and suitability of the safety management system; the documented review of performance of the policy and safety management system and its updating by senior management.
- Means for prevention, detection, isolation and mitigation of the effects of potential major accidents will be covered by emergency plans (adoption and implementation of procedures to identify foreseeable emergencies).

4.2 Safety Training and Procedures

The operations staff will undergo training in safety procedures. The safety training includes the following WtE specific training:

a) Training and education course in Denmark to obtain competence within working safety specific for WtE facilities

b) Fire fighting including fire fighting with breathing apparatus

c) First aid treatment

d) Emergency evacuation procedures

e) Training in plant start up and shutdown procedures

f) Training in safety plans for maintenance periods

g) Training/education from specific equipment and material suppliers to the facility.

In addition the staff will be trained and educated in the following standard items relating to power plants in general.

a) Marking and closing of work areas

b) Securing of plant before work is initiated

c) Earthing of motors and transformers

d) Work in containers, tanks and on platforms

e) Inspection of movable hoisting tackles and hangers

f) Inspection of electrical manual tools and extension cords

g) Inspection of grinding machines and grinding wheels

h) Inspection of battery system

i) Inspection of measuring instruments for personal safety

4.3 Fire Safety Systems

4.3.1 General

Fire safety will be of key importance in the design, construction and operation of the plant.

This will be ensured by the following key measures:

- The plant will be designed by experienced and skilled staff to internationally recognised design codes and standards. A local fire consultant will provide services in connection with relevant guidance and fire safety standards
- Hazard and operability studies will be undertaken of operating equipment and procedures
- The following fire prevention measures will be implemented in the facility:
  a) In the waste bunker a foam suppression system will be established. There is an established track record with using a foam system for the bunker area.

  b) A pressurised fire hydrant system will be established to comply with the relevant standards and applicable technical guidelines
- The main building will be divided into fire compartments. At present the following individual fire compartments are anticipated:
  a) Ramp, reception hall and waste bunker

  b) Boiler house and flue gas treatment area

  c) Turbine area

  d) Rooms for electrical equipment

  e) Area for handling and storage of equipment (including residues and bottom ash storage areas)

  f) Administration and Service area

At penetrations of fire compartment walls special precautions will be taken, such as fire stopping of pipes and cables, water curtains or sprinkler systems at the primary air intake in the waste bunker and in the duct for the bottom ash conveyor.

- On the site and inside all the process buildings fire hydrants will be located. On the hopper deck in the waste bunker the fire hydrant and foam systems will be located to be able to control a fire in the waste bunker. Furthermore, hand-operated fire extinguishers will be located at strategic locations in the facility.

4.3.2 Firewater Retention

The stormwater drainage system of the facility is connected to an internal Stormwater Storage Tank where the water is collected for reuse in the process. The Stormwater Storage Tank is, however, equipped with an overflow option, which overflows to the combined sewer pipeline. In the event of a fire, the automatic shut-off value would prevent discharge to the combined sewer and water would be diverted to the waste bunker through a higher level overflow.

Should a fire occur, firewater would be collected in the drainage system and drained to the Stormwater Storage Tank. The valve on the overflow to the combined sewer would be closed, and if the Stormwater Storage Tank reaches capacity, firewater will overflow through the higher level overflow to the waste bunker, which will act as a firewater retention tank.

The waste bunker has a capacity of approximately 65,000 m^3. The area may be partially filled with waste, but as the waste can absorb a significant amount of water it is estimated that significant volumes of firewater can be retained in the bunker. The density of the waste is approximately 750 kg/m^3. The firewater retention capacity of the waste bunker is thus a minimum of 25% of the total bunker capacity.

Refer also to section 7.

5. MAJOR ACCIDENTS

5.1 Major Accident Scenarios

The following major accident hazards have been identified:

- Diesel bund fire
- LPG BLEVE (Boiling Liquid Expanding Vapour Explosion)
- Loss of containment of LPG leading to a fireball
- Failure of flue gas treatment equipment
- Loss of containment of FGT residues
- Loss of containment of ammonium hydroxide
- Loss of containment of biocide
- Fire in waste bunker
- Loss of containment of firewater

5.2 Qualitative Assessment of the Consequences of Major Accidents

5.2.1 Diesel Bund Fire

A fire in the diesel bund could result from the loss of containment of diesel into the bund through pipe/tank leakage, rupture of a hose connection from a road tanker wagon or through catastrophic rupture of a tank and subsequent ignition of the material in the bund.

A bund fire could escalate to other parts of the facility.

On release to the environment the lighter components of gas oil will generally evaporate and be photooxidised by reaction with OH radicals [6]. Higher molecular weight components may also be subject to photooxidation.

No data is available on the behaviour of gas oils in standard tests for biodegradability. Although a gas oil would not be expected to be "readily biodegradable" as defined by OECD guideline tests, most of the hydrocarbon species present are known to be degraded by micro-organisms; in a modified Sturm test (OECD method 301B) approximately 40% biodegradation was recorded over 28 days.

5.2.2 LPG BLEVE

An LPG bottle battery will be provided for the ignition of the oil-fired burners. The LPG system will be used for start-up of the oil burners. The LPG system will therefore, during normal operation, be in use for 10 seconds approximately 20 times per year. The location and design of the bottle battery will be in accordance with all relevant Irish codes and standards.

A BLEVE (Boiling Liquid Expanding Vapour Explosion)/Fireball) involving one or more of the LPG cylinders could occur in the event of a fire. Such an event would result in a fireball and generation of projectiles from the ruptured cylinder.

Another major accident scenario is leakage of LPG from a cylinder or the piping system, which would form a flammable or explosive cloud of gas. Ignition of such a cloud would cause a vapour cloud explosion (VCE). A VCE would generate overpressures and possibly cause damage to plant and equipment.

5.2.3 Failure of Flue Gas Treatment Equipment

This scenario envisages the failure of the flue gas treatment equipment and emission of untreated gases for a short period.

Air dispersion modelling was carried out using the United States Environmental Protection Agency's (USEPA) regulatory model AERMOD. The aim of the study was to assess the impact in the ambient environment of emissions from the facility under typical conditions and at the emission limits outlined in Council Directive 2000/76/EC. Modelling was also conducted under abnormal operating conditions to assess any short-term impact due to these infrequent events. Abnormal operating conditions refer to short-term periods in which the limits detailed in EU Directive 2000/76/EC are exceeded.

The study demonstrates that all substances which will be emitted from the proposed facility will be at levels that are well below even the most stringent ambient air quality standards and guidelines. The study constitutes a full cumulative assessment of significant releases from the site taking into account the releases from all other significant industry in the area.

Currently, no internationally recognised ambient air quality concentration or deposition standards exist for PCDD/PCDFs (Dioxins/Furans). Modelled total dioxin particulate deposition flux indicates that deposition levels under typical, maximum and abnormal operations will also be significantly less than that experienced in urban background locations.

5.2.4 Loss of containment of FGT Residues

FGT residues will be stored in enclosed silos equipped with HEPA filters which will be located inside the main process building. In the unlikely event of loss of containment, the FGT residues would spill to ground within the building.

The residues would be contained within the building, which is totally contained at ground level. Some residue might be entrained in the air and be extracted from the building by the ventilation system. It is not credible that residues would enter surface waters.

5.2.5 Loss of Containment of Ammonium Hydroxide

Loss of containment of ammonium hydroxide could occur from either of the two storage tanks proposed for location within the facility. In the unlikely event of the failure of a storage tank or leakage from a pipe flange or valve ammonia vapour would be released from the surface of the released material, and would be extracted from the building by the extract fans. Ammonia odour might be detectable outside the site boundary.

5.2.6 Loss of Containment of Biocides

Biocide (sodium hypochlorite, i.e. household bleach) will be used for treating cooling water pipes. This material will be stored in a bulk container in a bunded area within the facility. Any leaks from the bulk tank will be retained in the bunded area, and are not likely to give rise to any risk to human health or the environment.

The biocide will be dosed to the cooling water. A conservative dosage plan has been assumed, i.e. that the dosage of biocide takes place 2 hours per day, but at a higher dosage level than 0.2 - 0.4 mg/l. The required dosage during winter time will be lower. Dosing will be by means of a metering pump and small diameter pipe. Failure of the dosing control system could result in continued pumping of biocide to the cooling water. The impact on the environment of continuous dosing of biocide would be local to the proposed cooling water outfall, and could include some diminution in population of aquatic organisms.

5.2.7 Fire in Waste Bunker

A fire in the waste bunker could be caused by, for example, hot ashes igniting combustible materials in the bunker. Contamination of surface water offsite would be prevented by the containment of firewater runoff. Waste will be contained in a bunker with dimensions 75 m x 25 m x 35 m, i.e. a gross volume of approximately 65,000 m^3. Fires would be automatically extinguished using water or foam. The area may be partially filled with waste, but as the waste will absorb a significant amount of water, it is estimated that significant volumes of firewater will be retained in the bunker.

In a fire event, smoke would be vented from the building through the smoke vents. Hot smoke rises, and therefore it is not likely that such smoke would descend to ground level within the immediate vicinity of the facility. Dispersion and dilution of the smoke would occur before it descends to ground level, some distance from the facility.

5.3 Quantitative Assessment of the Consequences of Major Accidents

5.3.1 Major Accident Scenarios Modelled

Modelling was carried out for the following scenarios:

5.3.1.1 Liquid Release Scenarios

- Catastrophic rupture of the diesel bulk tank
  - retention of 100% of tank contents within the bund, heat effects
  - overtopping by 63% of tank contents, heat effects
- LPG BLEVE heat and explosion effects
- LPG fireball
- Catastrophic rupture of the ammonium hydroxide bulk tank
  - retention of 100% of tank contents within the bund, dispersion of vapour
  - overtopping by 68% of tank contents, dispersion of vapour

5.3.1.1.1. Software

The models used were the DNV Technica package PHAST v 6.51 for fires and explosions and Aermod for abnormal emissions.

5.3.1.1.2. Materials

DNV Technica supplied the data for diesel oil.

In order to model the vaporisation of ammonia from the ammonium hydroxide liquid surface, a 25:75 ammonia/water mixture was created.

5.3.1.1.3. Meteorological Conditions

As the western side of the building will be open to allow truck access (open surface area will be approximately 480 m^2) the major accident hazard scenarios have been modelled as outdoor events.

All scenarios were modelled under the following weather conditions, which are representative of weather conditions in Ireland or which have been specified by the Health and Safety Authority:

Table 6 Weather Conditions used in Model

Windspeed (m/s)	Pasquill (Atmospheric) Stability Category
1.5	F
1.5	D
5	D
10	D

5.3.1.1.4. Heat Effects

The model was used to predict the distances to specified thermal radiation levels as follows:

Table 7 Health and Safety Authority (HSA) Thermal Radiation Benchmarks for Land Use Planning

Fatality Risk (%)	TDU*	Thermal Radiation (kW/m²)	Observed Effect	Zone
50	1,800	29.22	50% fatality risk	Inner Zone
1	1,000	18.8	1% fatality risk	Middle Zone
0	500	11.2	Threshold of fatality for vulnerable persons	Outer Zone
0	270	7	1% fatality risk at 75 sec exposure	-
0	130	4	Sufficient to cause pain to personnel if unable to reach cover within 20s; however blistering of the skin (second degree burns) is likely; 0% lethality	-

* Thermal dose units:

$TDU = (kW/m^2)^{4/3}.t$

t = exposure time = 20 sec

The maximum recommended thermal radiation levels recommended by the Institute of Petroleum are [7]:

Table 8 Maximum Recommended Thermal Radiation Levels Recommended by the Institute of Petroleum

Site (Receptor)	Maximum Thermal Radiation Level (kW/m²)
The outer surfaces of adjacent pressure storage vessels:	
Thermally protected	44
Unprotected	8
The outer surfaces of adjacent storage tanks containing flammable products and process facilities:	
Thermally protected	32
Unprotected	8
Filling/discharge points	8
Personnel inside boundary:	
Process area	8
Protected work area	8
Work area	5
Critical area	1.5
Plant boundary:	
Remote area	13
Urban area	5
Critical area	1.5

5.3.1.1.5. Explosion Effects

The model was also used to predict distances to the following overpressures:

Table 9 Overpressures Modelled

Overpressure		Effect
(barG)	(psig)	
0.0207	0.3	"Safe distance" (probability 0.95 no serious damage beyond this value); projectile limit; some damage to house ceilings; 10% window glass broken
0.14	2	Partial collapse of walls and roofs of houses
0.21	3	Heavy machines (3,000lb) in industrial building suffered little damage; steel frame building distorted and pulled away from foundations

5.3.1.1.6. Ammonia Vapour Dispersion End Points

The releases of ammonium hydroxide were modelled to determine the distance to reach the concentrations shown in the table below:

Table 10 Ammonia Vapour Dispersion End Points

Source	Parameter	Averaging Time[2]	Concentration (ppm)
AIHA	ERPG3	1 hour	750
AIHA	ERPG2	1 hour	150
AIHA	ERPG1	1 hour	25
Various	Odour Threshold	1 hour	Reported values vary widely; 0.6 to 53 ppm; geometric mean: 17 ppm (detection)
HSA	Dangerous Dose	30 min	1,775 ppm

The parameters are defined as follows:

Table 11 Air Quality Parameter Definitions

Parameter	Meaning
ERPG3 (Emergency Response Planning Guidelines)	The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.
ERPG2	The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action.
ERPG1	The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to one hour without experiencing other than mild, transient adverse health effects or without perceiving a clearly defined objectionable odour.
OT (Odour Threshold)	Concentration in air that can be (a) detected or (b) recognised by defined percentage of population

The UK Health & Safety Executive defines a Specified Level of Toxicity (SLOT) for land use planning as follows [8]:

- Severe distress to almost every one in the area
- Substantial fraction of exposed population requiring medical attention
- Some people seriously injured, requiring prolonged treatment
- Highly susceptible people possibly being killed

[2] The Averaging Time is to take into account the effects of changes in the wind direction over the course of the release. These changes cause the plume to meander from side to side, and reduce the concentration experienced at a given point below the full, centreline concentration. The average concentration you received at a given point over, say, 5 minutes will be much less than the peak concentration; at the same location for 30 minutes, the average would be lower still. This factoring down of the peak concentration is carried out in the model by the Averaging Time Adjustment—the longer the time window, or Averaging Time, the lower the calculated average concentration will be.

The Toxic Load for a given substance is a function of its concentration in air (c) and the duration of exposure (t). The SLOT Dangerous Toxic Load (SLT DTL) is expressed as follows:

SLOT DTL = ppm^n.min = 3.78 x 10^8
For ammonia, n = 2, therefore, for a 30 min averaging time,

UK SLOT DTL = 3,550 ppm

The HSA defines a dangerous dose for setting the specified area (i.e. that area likely to be affected in the event of a major accident) around upper tier Seveso establishments as ½ UK Dangerous Dose [9]. Therefore,

Dangerous Dose = ½ 3,550 ppm = 1,775 ppm

5.3.1.1.7. Bund Overtopping Modelling

Bunds are designed to contain a leakage of hazardous material from the primary containment unit. However, most bunds will not contain the entire tank inventory for a catastrophic loss of containment event. A number of correlations have been developed for the potential overtopping of the bund wall following the catastrophic rupture of a storage tank.

HSE CRR 324/2001[10], prepared by WS Atkins gives (Appendix E) correlations for calculating bund overtopping. The correlations imply overtopping in all cases where the height of the bund wall is less than the height of the tank:

$$Q = e^{-3.8898(h/H)}$$

where:

Q - fraction of the tank contents that will overtop the bund wall

h = bund wall height

H = tank height.

Clark et al in HSE Research Report No 333 prepared by Liverpool John Moores University (LJMU) [11]

$$Q_C = \exp[-p \times (h/H)]$$

Where p = 3.89 for θ, bund angle = 90º

Thyer, Hirst & Jagger (2002) [12]

$$Q = A + B \times \ln(h/H) + C \times \ln(r/H)$$

Where A, B and C are: 0.044, -0.264 and –0.116 for θ, bund angle = 90º and r = bund radius

HSE Research Report 333

$$Q = A \times \exp[-B \times (h/H)]$$

With values for A and B depending on tank type and bund capacity.

LJMU performed a number of laboratory scale experiments on bund overtopping due to catastrophic tank failure. For the diesel tank h/H = 0.12. For the ammonium hydroxide tank h/H = 0.10. The results of the LJMU experiments for h/H = 0.10 and the overtopping fraction predicted for diesel and ammonium hydroxide tanks are as follows (110% nominal bund capacity):

Table 12 Predicted Bund Overtopping Fractions Using Published Correlations

	Q	Q_C	Q_H	Q_{WS}
LJMU	0.70	0.68	0.59	-
Diesel tank	-	0.63	0.63	0.63
Ammonium hydroxide tank	-	0.68	0.67	0.68

Q is the measured overtopping fraction. Q_C and Q_H are the overtopping fractions predicted using the correlations of Clark and Hirst respectively. Q_{WS} is the overtopping fraction predicted using $Q = e^{-3.8898(h/H)}$ (HSE CRR 324/2001).

5.3.1.1.8. Results

The summary results for the various scenarios are outlined below. In all cases the worst case scenarios have been presented i.e. the weather conditions which produced the greatest downwind distances to specified thermal effects.

Modelling results are depicted graphically in Figures 6 – 18.

Table 13 Outdoor Diesel Bund Fire Distances to Incident radiation Levels

Atmospheric Stability/Wind Speed	Distances (m) to Specified Heat Levels				
	4 kW/m²	7 kW/m²	11.2 kW/m²	18.8 kW/m²	29.22 kW/m²
$F_{1.5}$	32	25	19	13	8
$D_{1.5}$	32	25	19	13	8
D_5	34	28	25	18	9
D_{10}	35	29	25	18	9

Table 14 Outdoor Diesel Fire, 63% Overtopping of Bund, Distances to Incident radiation Levels

Atmospheric Stability/Wind Speed	Distances (m) to Specified Heat Levels				
	4 kW/m²	7 kW/m²	11.2 kW/m²	18.8 kW/m²	29.22 kW/m²
$F_{1.5}$	147	104	53	52	Not reached
$D_{1.5}$	147	104	53	52	Not reached
D_5	169	130	60	52	Not reached
D_{10}	176	145	75	74	Not reached

Table 15 Rupture of Diesel Tank Distances to Overpressures

Major Accident	Distances (m) to Specified Overpressures		
	0.0207 barG	0.14 barG	0.21 barG
Bunded Diesel	No hazard	No hazard	No hazard
63% Bund Overtopping	No hazard	No hazard	No hazard

Table 16 LPG BLEVE Distances to Incident Radiation Levels

Major Accident	Distances (m) to Specified Heat Levels		
	29.22 kW/m²	18.8 kW/m²	11.2 kW/m²
LPG BLEVE	78	99	129

Table 17 LPG BLEVE Distances to Overpressures

Major Accident	Distances (m) to Specified Overpressures		
	0.0207 barG	0.14 barG	0.21 barG
LPG BLEVE	133	34	26

Table 18 Catastrophic Rupture of Ammonium Hydroxide Tank, 100% Ammonium Hydroxide Retained in Bund, Distances to Specified Concentrations

Atmospheric Stability/Wind Speed	Distances (m) to Specified Concentrations				
	ERPG 3	ERPG 2	ERPG 1	Odour Threshold	Dangerous Dose
$F_{1.5}$	664	1,871	5,516	6,968	601
$D_{1.5}$	171	520	1,592	2,046	151
D_5	115	285	908	1,117	79
D_{10}	148	217	625	800	136

Table 19 Catastrophic Rupture of Ammonium Hydroxide Tank, 68% Ammonium Hydroxide Overtops Bund, Distances to Specified Concentrations

Atmospheric Stability/Wind Speed	Distances (m) to Specified Concentrations				
	ERPG 3	ERPG 2	ERPG 1	Odour Threshold	Dangerous Dose
$F_{1.5}$	3,054	12,000	50,136	50,986	1,595
$D_{1.5}$	917	3,510	13,416	17,873	480
D_5	423	1,632	6,494	8,583	202
D_{10}	515	1,109	4,368	5,807	449

5.3.1.2 Fire in Waste Bunker

The potential impact of a fire in the waste bunker was assessed.

The USEPA software model Screen3 was used to determine the ground level concentrations (GLCs) of dioxins that would result from different size fires in the waste bunker. The capacity of the waste bunker is approximately 48,750 tonnes of waste.

The three fire scenarios analysed were:

- 1 tonne of waste burned over 30 minutes
- 50 tonne waste burned over 1 hour
- 1,000 tonne waste burned over 10 hours

These scenarios were selected through reference to the hazard evaluation report for the Indaver waste management facility at Ringaskiddy, Cork [13]. The model was used to predict the concentration of dioxins at ground level for various distances from the source. The model was used for the default range of weather conditions in SCREEN3:

It was assumed that 72.8 ng I-TEQ per kg dioxins are released per tonne of municipal waste burned [13]. This is the emission rate estimated by the US EPA for backyard fires involving domestic waste.

1 tonne Waste Fire

The highest predicted ground level dioxin concentrations for a 1 tonne, 50 tonne and 1,000 tonne fire are presented in Table 20.

In order to predict the worst case amount of dioxins inhaled by a person from the 1 tonne fire event, a number of assumptions are made [13]:

- A 1 tonne fire is an annual event (this assumption is highly conservative, as shown below)
- Fire would be brought under control in 1 hour
- Wind is unidirectional for the duration of the fire. This is a conservative approach as in reality the wind direction would change over the course of the event, giving a lower average concentration at any particular point
- Plume temperature is 20ºC. This is a conservative approach to take as it reduces the dispersion that would take place in a hot buoyant plume, giving higher GLCs
- Release of smoke occurs through the smoke vents on the roof of the building. Smoke vents comprise 1% of roof area over the waste bunker
- Total dioxins produced by the fire remain suspended in the plume as it disperses downwind
- Person takes no evasive action i.e. remains at the point of maximum concentration of the duration of the fire
- Person inhales the maximum predicted GLC for 50% longer than the actual duration of the fire i.e. for 45 min
- The average person inhales 20 m^3 air/day
- 75% dioxins inhaled are retained
- Average bodyweight = 70kg

The highest predicted GLC of dioxin downwind of the fire is 1.891×10^{-6} ng/m³ at a distance of 206 m from the waste bunker. This is at the worst case weather condition. The scenario is modelled for a range of wind speeds and stability categories. The results reported are for the worst case combination of wind speed and stability factor.

Estimation of Dioxin Intake by Inhalation

The quantity of air inhaled over 45 min

$= 0.626\ m^3$

Therefore, total dioxins inhaled over 45 min in the worst case

$= 0.626\ m^3 \times 1.891 \times 10^{-6}\ \mu g m^{-3}$

$= 1.18 \times 10^{-6} \mu g$

Dioxins retained

$= 75\%\ (1.18 \times 10^{-6} \mu g) = 8.86 \times 10^{-7} \mu g$

Dioxins retained per kg bodyweight

$= 3.47 \times 10^{-11}\ \mu g/kg$

$= 3.47 \times 10^{-5}\ pg/kg$

The Word Health Organisation (WHO) ceiling for dioxin Tolerable Daily Intake (TDI) is 1.0 pg. I–TEQ per kg bodyweight [13]. Therefore, the maximum intake by inhalation of dioxins at ground level is 2.88×10^4 times lower than the value that the WHO has set as the maximum ceiling TDI for humans. This is the minimum safety margin for all weather conditions modelled.

50 and 1,000 tonne Waste Fires

Assumptions made for the 50 and 1,000 tonne scenarios are as follows:

- 50 tonne fire is a 1 in 20 year event. 1,000 tonne fire is a 1 in 70 year event. These assumptions are highly conservative, as shown below.
- Wind is unidirectional for the duration of the fire. This is a particularly conservative approach to take for the longer fire duration scenarios
- Plume temperature is 500ºC
- The roof above the waste bunker area caves in. Thus the area of release of smoke from the fire is the same as the surface area of the waste bunker
- Total dioxins produced by the fire remain suspended in the plume as it disperses downwind
- Person takes no evasive action remains at the point of maximum concentration of the duration of the fire
- Person inhales the maximum predicted GLC for 50% longer than the actual duration of the fire i.e. for 90 min for the 50 tonne scenario and 11 hours for the 1,000 tonne scenario
- The average person inhales 20 m^3 air/day
- 75% dioxins inhaled are retained
- Average bodyweight = 70kg

For the 50 tonne fire scenario, the maximum intake by inhalation of dioxins at ground level is 1.19×10^4 times lower than the value that the WHO has set as the maximum ceiling TDI for humans. This is the minimum safety margin for all weather conditions modelled.

For the 1,000 fire scenario, the maximum intake by inhalation of dioxins at ground level is 2.10 x 10^3 times lower than the value that the WHO has set as the maximum ceiling TDI for humans. This is the minimum safety margin for all weather conditions modelled.

Table 20 Fire in Waste bunker Scenarios, Distances to Maximum 1-hour Concentrations

Fire in waste bunker scenario	Maximum 1-hour concentration at or beyond the site boundary (μgm^{-3})	Weather Conditions (wind speed (m/s)/stability category)	Distance from point of release (m)	Dioxins Retained by Receptor (pg/kg bodyweight/day)	Safety Margin
1 tonne fire	1.891×10^{-6}	C_1	206	3.47E-05	2.88E+04
	1.630×10^{-7}	D_{10}	304	2.99E-06	3.34E+05
50 tonne fire	4.570×10^{-5}	C_1	213	8.38E-05	1.19E+04
	3.980×10^{-6}	D_{10}	311	7.30E-06	1.37E+05
1000 tonne fire	9.106×10^{-5}	C_1	213	4.77E-04	2.10E+03
	8.08×10^{-6}	D_{10}	311	4.24E-05	2.36E+04

Based on the scenarios modelled, the risk posed to human health by dioxin inhalation from a fire in the waste bunker is deemed to be insignificant.

5.3.1.2.1. Estimate of Likelihood of Fire

The Dutch guidance document ***Risico-Analyse Methodiek CPR-15 Bedrijven*** (Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, Den Haag, October 1997) suggests values for the area, duration and relative probability for warehouse fire scenarios, as a function of the fire-fighting provisions for the warehouse. These suggested values for fire in an area with an automatic foam suppression system are given below.

Table 21 Warehouse Fire Durations and Relative Probabilities

Fire Surface Area (m^2)	Fire Duration (mins.)	Relative Probability of Scenario
20	10	0.89
50	10	0.09
100	10	0.01
300	30	0.005
900	30	0.004
1500	30	0.001

The relative probability of the scenario is the probability that the fire develops in the way described by the scenario, given that a fire has started in the warehouse. For a warehouse with this type of fire protection, the default frequency for a fire starting in the warehouse is **8.8 x 10^{-4}** per year. The frequency for a given scenario, taking the default frequency for a fire starting in the warehouse, would then by given by 8.8 x 10^{-4} * $\mathbf{P_{relative}}$, where $\mathbf{P_{relative}}$ is the relative probability taken from Table 21.

For a fire in the waste bunker over the entire waste surface area (approximately 1,900 m^2), the predicted frequency would be:

8.8 x 10^{-4} x 0.001 = 8.8 x 10^{-7} per year

It is assumed that a 1 tonne fire will burn in 30 minutes. The surface area of a fire is given by

Mass of waste consumed/(duration of fire x burn rate of waste)

The TNO Yellow Book gives a burn rate for gasoline of 0.055 kg/m^2s. The burn rate of waste in the bunker is assumed to be half the gasoline burn rate i.e. 0.0275 kg/m^2s.

Therefore,

Surface area of fire = 1,000/(30 x 60 x 0.0275) = 20 m^2

Risico-Analyse Methodiek CPR-15 Bedrijven predicts a frequency for such an event of

8.8 x 10^{-4} x 0.89 = 7.8 x 10^{-4} per year

Therefore, the assumed frequency of 1 occurrence per year is highly conservative.

Surface area of a 50 tonne fire = 505 m^2

The predicted a frequency for such an event is 8.8 x 10^{-4} x 0.005 = 4.0 x 10^{-6}

Surface area of a 1,000 tonne fire = 1,010 m^2

The predicted a frequency for such an event is 8.8 x 10^{-4} x 0.004 = 3.52 x 10^{-6}

Therefore, the assumed frequencies per year of the 50 and 1,000 tonne fire events of 1 in 20 years and 1 in 70 years respectively are highly conservative.

5.3.1.3 Failure of Flue Gas Treatment Equipment

The results of modelling of emissions due to failure of flue gas treatment equipment are presented in Chapter 8 of the EIS for the facility.

Modelling of the loss of containment of FGT residues was not considered necessary as most residues would be contained within the building.

6. PREVENTION AND MITIGATION OF ACCIDENTS

6.1 Prevention Measures

6.1.1 Diesel Bund Fire

Diesel oil has a relatively high flash point (>52°C) i.e. a flammable air/vapour mixture would not be formed above the liquid surface at ambient temperatures.

All tanks at the facility will be designed to internationally recognised standards.

Transfer of diesel to the storage tanks will take place in the bund as per Standard Operating Procedure (SOP). Tank valves will be located within the bund. Regular visual inspection of the bund will take place for leaks.

The building drainage system is a closed or contained system. Therefore contamination of surface water from loss of containment of diesel will be prevented.

In the event of loss of containment, and failure of the bund, a spill of diesel oil would be contained within the building as the building and the isolated drainage system act as tertiary containment.

6.1.2 LPG BLEVE (Boiling Liquid Expanding Vapour Explosion)

The automatic fire suppression system would extinguish small fires, and engulfment of the LPG cylinders in a fire is highly unlikely.

The LPG cylinders will be deigned to internationally recognized standards. They will be protected by barriers from mechanical damage due to impact.

6.1.3 Failure of Flue Gas Treatment Equipment

Failure of the FGT treatment equipment will be prevented through the monitoring and maintenance programme, as well as a system of instrumentation and automatic response.

6.1.4 Loss of Containment of FGT Residues

FGT residues will be transported in sealed, road tanker wagons suitable for transport of such products.

FGT silos will be equipped with HEPA filters to prevent fugitive emissions.

6.1.5 Loss of Containment of Ammonium Hydroxide

Ammonium hydroxide storage tanks will be designed to internationally recognised standards. The tanks will be located in a bunded area. The bund would limit the surface area from which ammonia could evaporate.

6.1.6 Loss of Containment of Biocides

Biocide for cooling water treatment will be stored in a bulk container in the facility. The biocide bulk storage tank will be designed to internationally recognised standards. It will be located in a bund of capacity at least 110% of the tank volume. Small leaks and total loss of inventory will be retained by the bund wall.

Continuous dosing of biocide will be prevented by a stand-alone independent dosage monitoring system that will indicate an alarm if pre-set dosage limits are exceeded.

6.1.7 Fire in Waste Bunker

The plant will be designed by experienced and skilled staff to internationally recognised design codes and standards. HAZOP studies will be undertaken of the facility's equipment and procedures.

6.2 Mitigation Measures

6.2.1 Diesel Bund Fire

The heat effects of a diesel bund fire on the surrounding environment would be mitigated by the fact that the bund will be enclosed in the building.

6.2.2 LPG BLEVE (Boiling Liquid Expanding Vapour Explosion)

The effects of explosion overpressure on the surrounding environment would be mitigated by the location of the tanks within the building. Explosions of the scale possible from an LPG cylinder battery would be partially attenuated by the building and directed to a safe location.

6.2.3 Loss of Containment of LPG Leading to a Fireball

Gas detection will be provided for the LPG battery. The area will be well ventilated to prevent the accumulation of vapours in the event of leakage.

6.2.4 Failure of Flue Gas Treatment Equipment

In the event of failure of flue gas treatment equipment an alarm would sound and the system shut down as fast as is consistent with safe practice.

6.2.5 Loss of Containment of FGT Residues

In the event of loss of containment of FGT residues, Workplace Safety Instructions would be followed. These Instructions provide the following information with regard to FGT residues:

- Composition/facts on constituents
- Risk identification
- First aid instructions
- Fire extinguishing
- Precautions by accidental discharge
- Handling and storage
- Exposure control/personal safety equipment
- General and chemical characteristics
- Stability and reactivity
- Toxicological information
- Environmental information
- Disposal
- Transport information
- Information concerning regulations
- General information/applications

6.2.6 Loss of Containment of Ammonium Hydroxide

Ammonium hydroxide will be isolated from surface waters by primary containment (storage tanks), secondary containment (bund) and tertiary containment (the facility's closed drainage system).

In the event of spillage of ammonium hydroxide all possible sources of ignition would be shut off. All unprotected personnel would be evacuated from the area and the spill cleaned up immediately. Personal protective equipment would be worn during the clean up operation in order to prevent skin and eye contact and breathing in vapours. Dilute acid (e.g. acetic, sulphuric or hydrochloric) would also be used to neutralise the spill. An absorbent (e.g. soil, sand or other inert material) would then be used to soak-up the liquid. The neutralised and absorbed material would be collected and sealed in suitable, properly labelled containers for disposal.

6.2.7 Loss of Containment of Biocides

In the event of failure of the bund wall, any spills will be retained in the storm water retention tank.

6.2.8 Fire in Waste Bunker

An "Emergency Procedure Strategy" or "EPS", incorporating the requirements identified in a Hazard and Operability (HAZOP) assessment for the facility, will be prepared. The EPS shall ensure that resources are available to respond to emergencies at all times during the operational period and that suitably qualified personnel will be available at all times to manage the response of the emergency services.

The waste storage bunker would provide capacity to store a minimum of 16,250 m^3 of water and collapsed foam[3]. The storm water drainage system of the facility is connected to a storm water tank where the water is collected for reuse in the process. The storm water tank is, however, equipped with an overflow option, which will overflow to the waste bunker.

Adequate firewater retention capacity will be provided for at the facility by the Stormwater Storage Tank and waste bunker.

[3] 65,000 m^3 x 750kg/m^3 = 48,750,000 kg waste, leaving spare capacity for 16,250,000 kg (16,250 m^3) of firewater.

7. FIREWATER CONTAINMENT

7.1 Firewater Generation

The retention capacity required for firewater is calculated in accordance with EPA (Draft) Guidance on firewater retention [13].

Rainfall data from the Meteorological Office weather station at Dublin Airport show the following:

Mean annual precipitation	732.7mm [(1)]
1-hour precipitation event 20-year return	23mm [(2)]
24-hour precipitation event 20-year return	63mm [(2)]

(1) Met Eireann's website 30 year metrological data 1968-1996; http://www.met.ie/climate/dublinairport.asp (as at 20/12/2006)

(2) Met Eireann; Extreme Rainfall Return Period

Good stormwater drain design practice is based on a run-off requirement of 50 mm. The EPA in its draft Guidance Note recommends that firewater run-off volume during a fire be based on the maximum 24-hour event for 20-year return period, or 50 mm, whichever is greater. As the quantity of rainwater during the maximum 24-hour event, 20-year return period is greater, it is used to calculate the firewater retention volume required.

The impermeable and permeable areas of the site are as follows:

Main Building Roof	18,165 m^2
Site Internal Roads	15,369 m^2
Grassy Area	17,253 m^2

Rainwater run-off volume is of interest for the purposes of this report, as a large percentage of the proposed facility is green/vegetated area. The rainfall which flows to the site stormwater drainage system is to be included in any firewater retention calculations, according to the EPA Draft Guidance Note.

Run-off volume is calculated as:

$$R = P \times P_j \times Rv \quad [4] \qquad \text{(Equation 1)}$$

This calculation is adapted from a method used to measure stormwater pollutant loads.

Where: R = run-off (inches)

P = rainfall (inches)

P_j = Fraction of rainfall events that produce run-off (usually 0.9)

Rv = Run-off coefficient

[4] http://www.stormwatercenter.net/monitoring%20and%20assessment/simple%20meth/simple.htm (2/1/2007)

Rv can be obtained from:

$$Rv = 0.05 + 0.9Ia \quad \text{(Equation 2)}$$

Where: Ia = Impervious fraction

Substituting (2) into (1), and assuming Pj equals 1 (since Pj is the fraction of annual rainfall events that produce run-off, and the event in question is the 20-year, 24-hr return, a large rainfall value). The equation becomes:

$$R = 0.05P + 0.9 \times Ia \times P \quad \text{(Equation 3)}$$

The impervious area of the site (paved areas and building roof area) is 33,534 m^3. The green site area is 17,253 m^2 . Thus Ia, the impervious fraction is:

$$Ia = \frac{33{,}534}{33{,}534 + 17{,}253} = 0.66$$

Thus, the fraction of rainfall that results in run-off during a 20-year, 24-hour return event can be obtained by rearranging equation [3] and substituting the value of Ia as follows:

$$\frac{R}{P} = 0.05 + 0.9 \times 0.66 = 0.64$$

i.e. 64% of rainfall falling on the site during a 20-year, 24-hour return event would flow to stormwater drainage.

Therefore, the following volumes of rainwater would go to the site stormwater drainage system:

Table 22 Site Precipitation Run-off Volumes

Area	Volume of rainwater (m^3) during 24-hour precipitation event 20-year return period (area (m^2) x rainfall (m))	Run-off Coefficient	Volume of Rainwater Run-off (m^3)
Main building	1,235	0.64	790
Grassy/vegetated areas	1,173	0.64	751
Hardstanding areas	1,045	0.64	669
TOTAL			**2,210**

The EPA Draft Guidance Note assumes that a fire is suppressed 'within a reasonable period of time'. The maximum duration of a fire event at the site is taken to be 2 hours.

Assuming an unlimited supply of fire suppression water on-site, the volume of firewater that will be used over a 2 hour period will be limited only by pumping capacity provided. The capacity to be provided is as yet undecided.

Assuming a discharge rate of 2 m^3/min from each fire hydrant, if water is applied to a fire through 4 hoses for 2 hours, this would create a total of approximately 960 m^3 of potentially contaminated firewater to be retained on site, in addition to 2,210 m^3 of rainfall calculated in Table 22, a total of 3,170 m^3.

Additional fire suppression water would be brought on-site by Dublin Fire Brigade.

7.2 Firewater Retention

There will be no direct discharge to surface water of rainwater, sewage or process wastewater from the facility. The stormwater drainage system of the facility will be connected to an internal stormwater tank where the water will be collected for reuse in the process. The stormwater tank will be equipped with an overflow option, which will overflow to the waste bunker. In the event of a fire/emergency, an automatic shutoff valve will prevent discharge to the tank and divert firewater to the waste bunker. The tank will be equipped with a monitoring station to continuously monitor pH-values.

Ammonium hydroxide and diesel will be isolated from surface waters by primary containment (storage tanks), secondary containment (bunds) and tertiary containment (the facility's closed drainage system).

A fire on-site could be caused by, for example, hot ashes igniting combustible materials in the waste bunker. Contamination of surface water offsite would be prevented by the containment of firewater run-off. Waste will be contained in a bunker with dimensions 75 m x 25 m x 35 m i.e. a gross volume of approximately 65,000 m^3. Fires would be automatically extinguished using water or foam. At the time of a fire, the bunker may be partially filled with waste. However, as the waste will absorb a significant amount of water, it is estimated that significant volumes of firewater would be retained in the bunker (65,000 m^3 x 750kg/m^3 = 48,750,000 kg waste, leaving spare capacity for 16,250,000 kg (16,250 m^3) of firewater). This is over five times the quantity of firewater and coincident 20-year return 24 hour rainwater that would to arise.

Hence, adequate firewater retention capacity will be provided for at the facility by the stormwater storage tank and waste bunker for potentially contaminated firewater.

8. EMERGENCY RESPONSE

8.1 Emergency Plans

1. It will be ensured that:
   - the operator draws up an internal emergency plan for the measures to be taken inside the establishment
   - the operator supplies the competent authorities with the necessary information to enable it to draw up external emergency plans
2. The emergency plans will be established with the objectives of:
   - containing and controlling incidents so as to minimise the effects, and to limit damage to man, the environment and property,
   - implementing the measures necessary to protect man and the environment from the effects of major accidents,
   - communicating the necessary information to the public and to the services or authorities concerned in the area,
   - providing for the restoration and clean-up of the environment following a major accident.
3. The emergency plans will contain the information set out in Annex IV / Seveso II Directive.
4. Without prejudice to the obligations of the competent authorities, it will be ensured that the internal emergency plans provided for in this Directive are drawn up in consultation with personnel employed in the establishment.
5. It will be ensured that internal and external emergency plans are reviewed, tested, and where necessary revised and updated by the operator at suitable intervals of no longer than three years. The review will take into account changes occurring in the establishments concerned or within the emergency services concerned, new technical knowledge and knowledge concerning the response to major accidents.
6. It will be ensured that the operator puts the emergency plans into effect without delay for this purpose:
   - when a major accident occurs, or
   - when an uncontrolled event occurs which by its nature could reasonably be expected to lead to a major accident.

8.2 Systems and Procedures

8.2.1 Emergency Services

Throughout the construction and operations period there will be a 24 hour per day, 7 day per week emergency service. This service will include immediate action in the case of e.g.:

a) Fire alarm

b) Accidents on site

c) Spillages

d) Malfunction of dewatering pumps during construction.

The services will be equipped with vehicles, radio communications, equipment and trained personnel so as to be able to deal effectively and promptly with any risk, threat or hazard to persons, livestock or property arising from the construction and operation phases.

8.3 Emergency Access and Egress Arrangements

Site emergency exits and escape routes are marked on the Figure 19. In the event of a large spill of ammonium hydroxide or diesel on site, or when an uncontrolled event occurs, which by its nature could reasonably be expected to lead to a major accident, all people on-site will move to the emergency exit upwind of the spill. Evacuated personnel will move to the nearest nominated personnel emergency assembly point. A windsock will be provided on site to indicate wind direction. On calm days, the nearest emergency exit will be used.

Internal design of the building is not sufficiently advanced to assess internal escape routes, therefore only escape routes from the site are considered here.

9. REFERENCES

1. O.J. L 10, 14.1.1997, p. 13

2. O.J. L 345, 31.12.2003, p. 97

3. Seismicity and Earthquake Hazard in the UK, Roger Musson (British Geological Survey)

4. Health & Safety Executive, UK. Assessment of the Dangerous Toxic Load (DTL) for Specified Level of Toxicity (SLOT) and Significant Likelihood of Death (SLOD)

5. Greater Dublin Strategic Drainage Study, Regional Drainage Policies Vol 5 Climate Change. Dublin City Council, March 2005

6. CONCAWE (1996) *Gas oils (diesel fuels/heating oils)* product dossier no. 95/107

7. (*Liquefied Petroleum Gas: Volume 1: Large Bulk Pressure Storage and Refrigerated LPG: Model Code of Safe Practice Part 9*, Table 1)

8. Health & Safety Executive, UK (1997). The Calculation of Aircraft Crash Risk in the UK. Contract Research Report 150/1997.

9. Health and Safety Authority (2004). Setting the Specified Area – Paper on the Approach of the HSA

10. HSE (2001) Effects of secondary containment on source term modelling,Prepared by WS Atkins Consultants Ltd for the Health and Safety Executive, Contract Research Report No 324/2001

11. HSE (2005) An experimental investigation of bund wall overtopping and dynamic pressures on the bund wall following catastrophic failure of a storage vessel, Prepared by Liverpool John Moores University for the Health and Safety Executive 2005, Research Report No 333

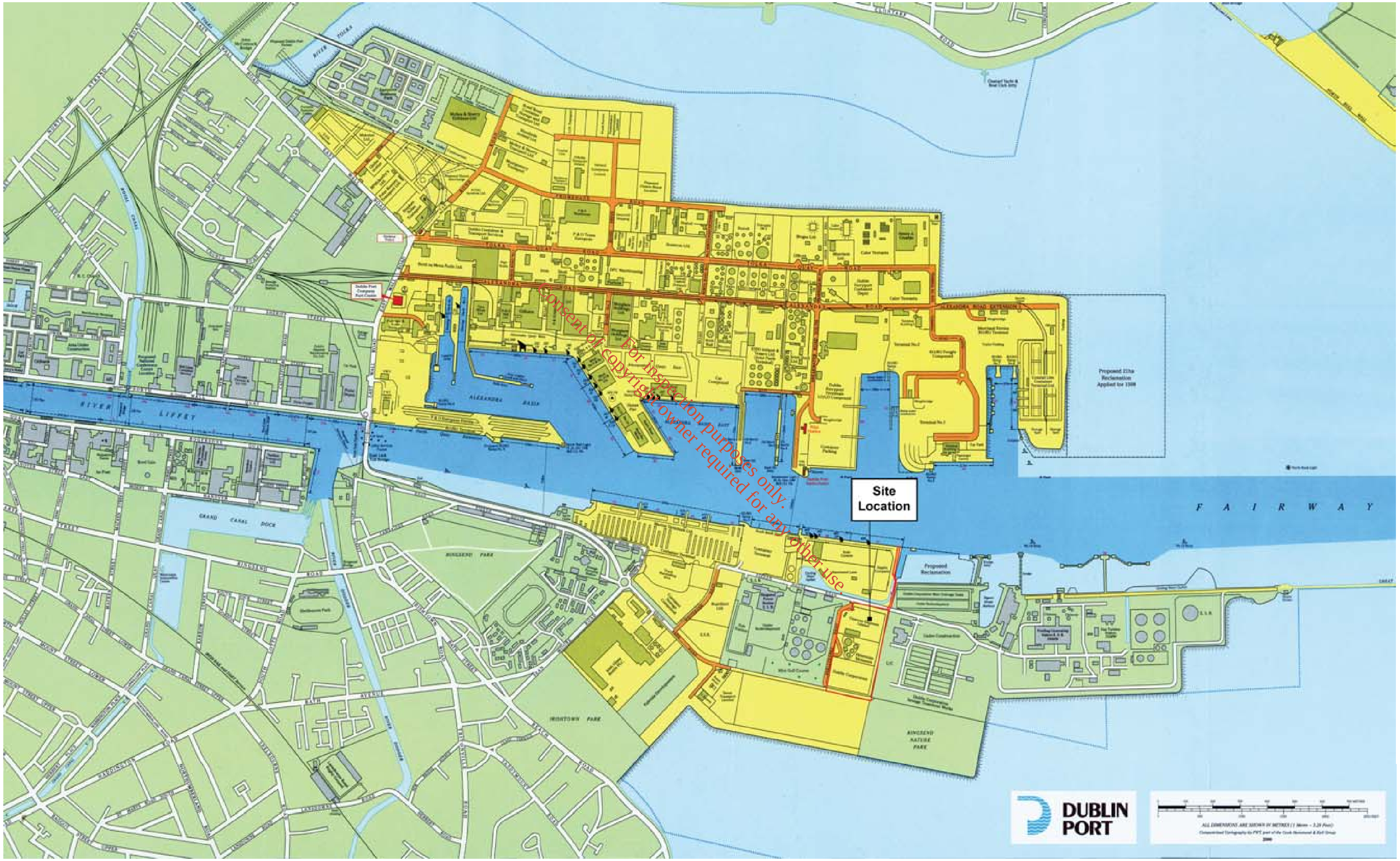
12. Thyer, A.M., Hirst, I.L. & Jagger, S.F. (2002) *Bund overtopping - the consequence of catastrophic tank failure*, Journal of Loss Prevention in the Process Industries, vol. 15, no. 5, pp. 357-363 (7)

13. Byrne O'Cléirigh (2002) Report on Hazard Identification & Evaluation for Major Accident Prevention Waste Management Facility, Ringaskiddy Indaver Ireland

14. EPA (Draft) Guidance Note to Industry on Requirements for the Establishment of Fire Water Retention facilities (2 August 1995).

FIGURES

Figure 1 Site Location



Reproduced with Permission of Dublin Port Company

Figure 2 Biotopes of the Western Section of the Irishtown Study Area. Littoral Core Samples C1, C2, C4 are shown as red dots

Figure 3 Biotopes of the Eastern Section of the Irishtown Study Area. Littoral Core Samples C3, C4 are shown as red dots

Figure 4 A Close up of a Section of Biotopes Illustrating Typical Biotopes Present Along the Irishtown Study Area

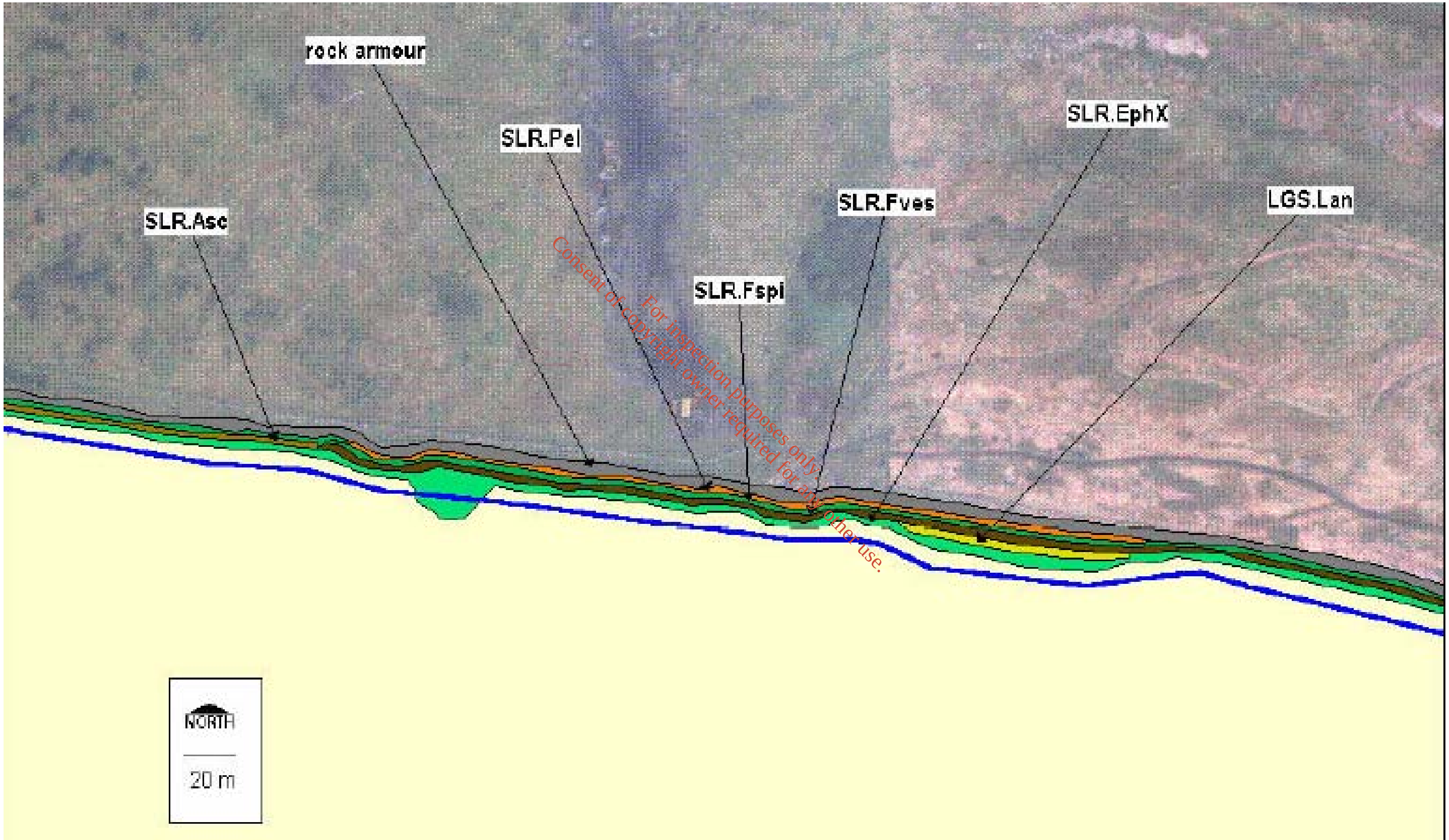
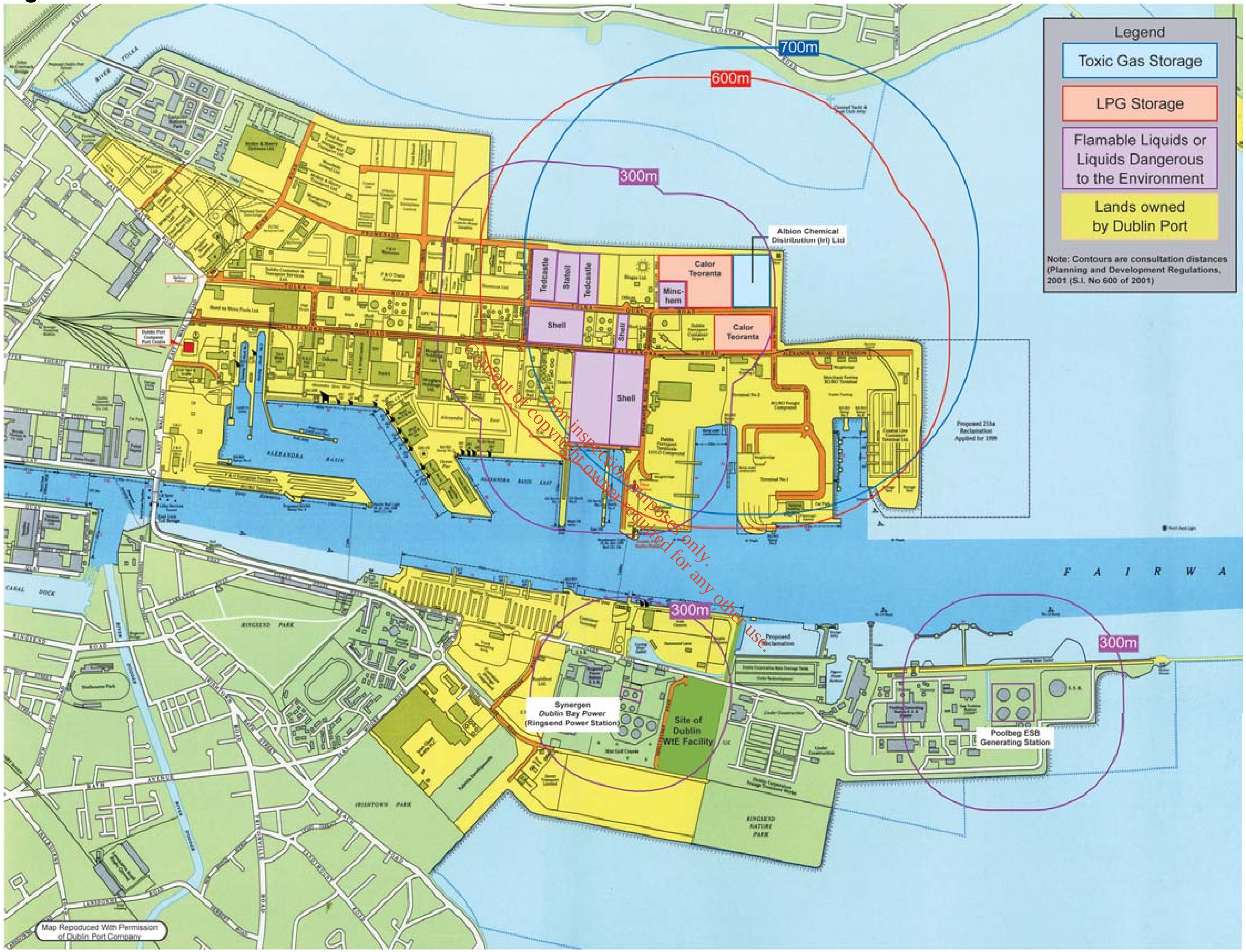


Figure 5 Consultation Distances of Seveso Sites in Dublin Port



Reproduced with Permission of Dublin Port Company

Figure 6 Diesel Bund Fire, Maximum Distances to Incident Radiation Levels

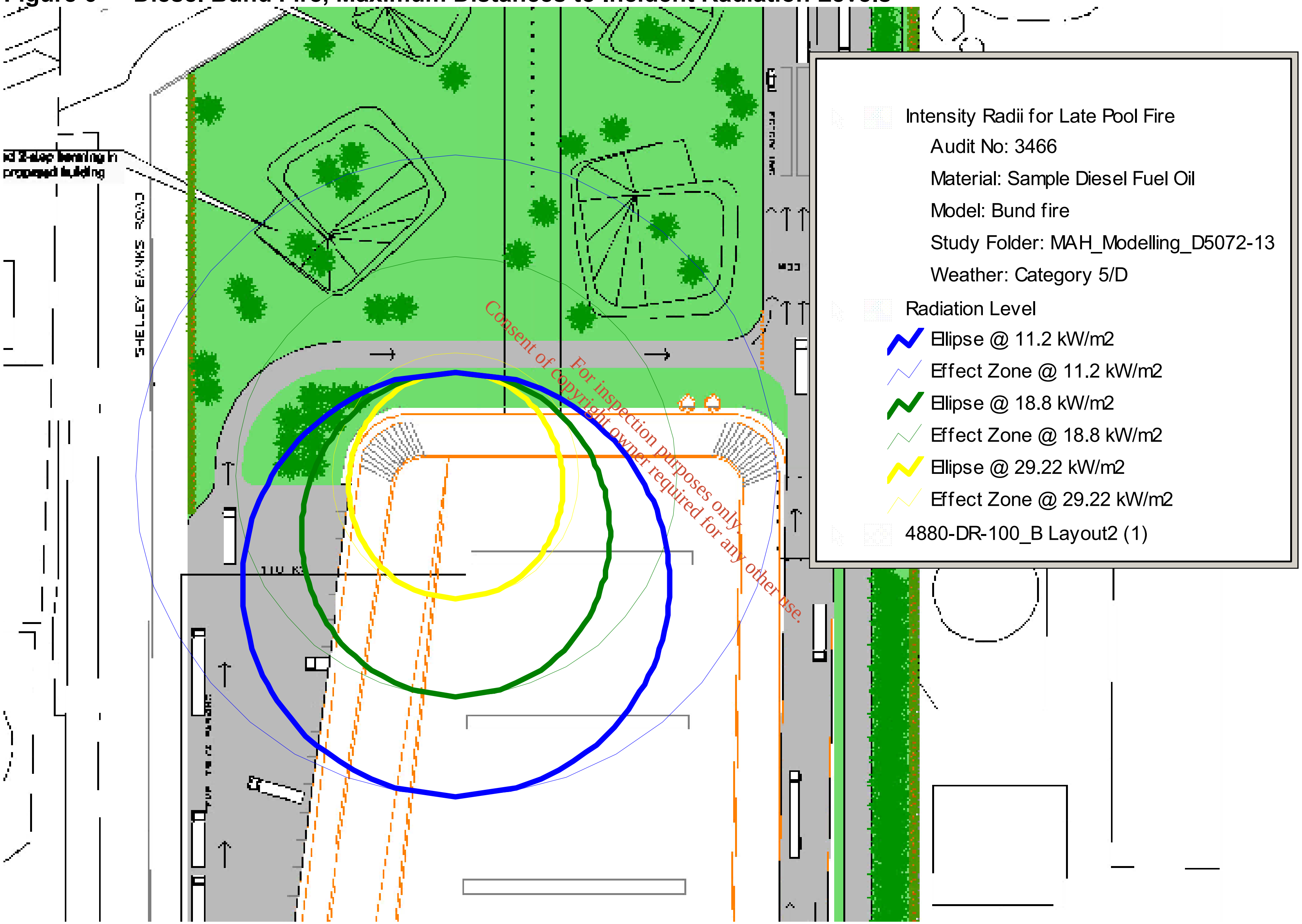


Figure 7 Diesel Fire, 63% Overtopping of Bund, Maximum Distances to Incident Radiation Levels

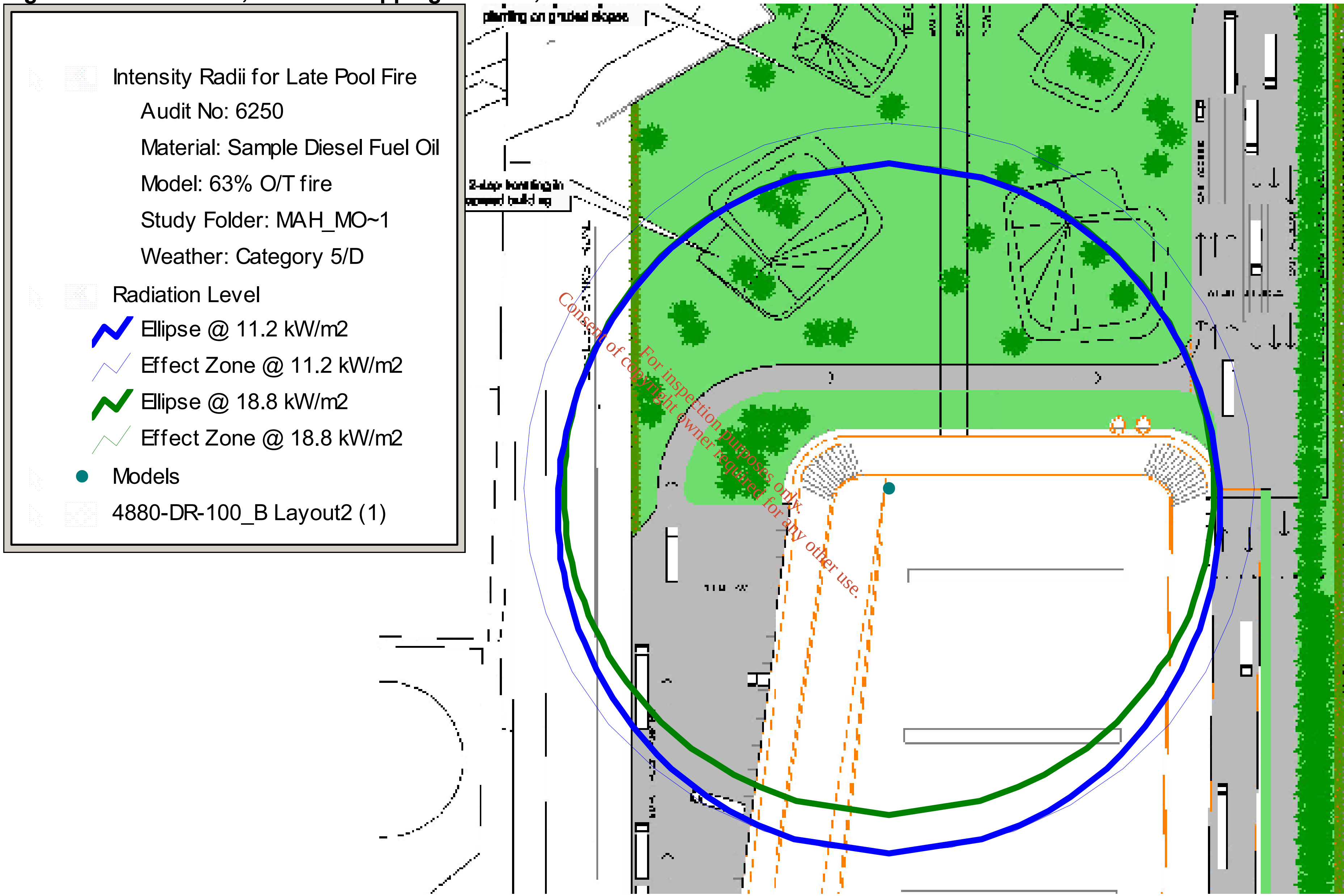
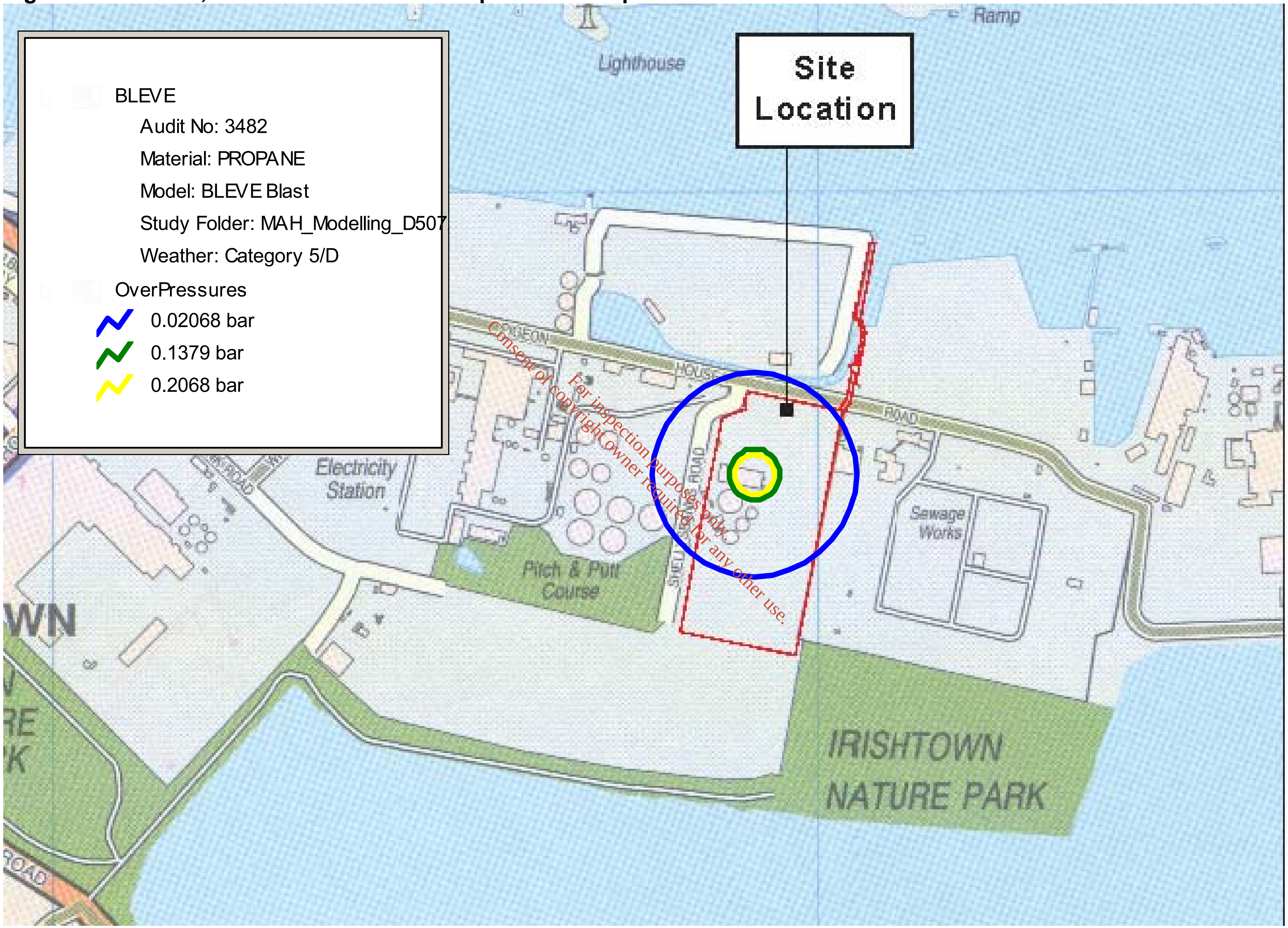


Figure 8 BLEVE, Maximum Distances to Specified Overpressures



Ordnance Survey Ireland Licence No EN 0002807 ©Ordnance Survey Ireland and Government of Ireland

Figure 9 BLEVE Fireball, Maximum Distance to 29.22 kW/m^2

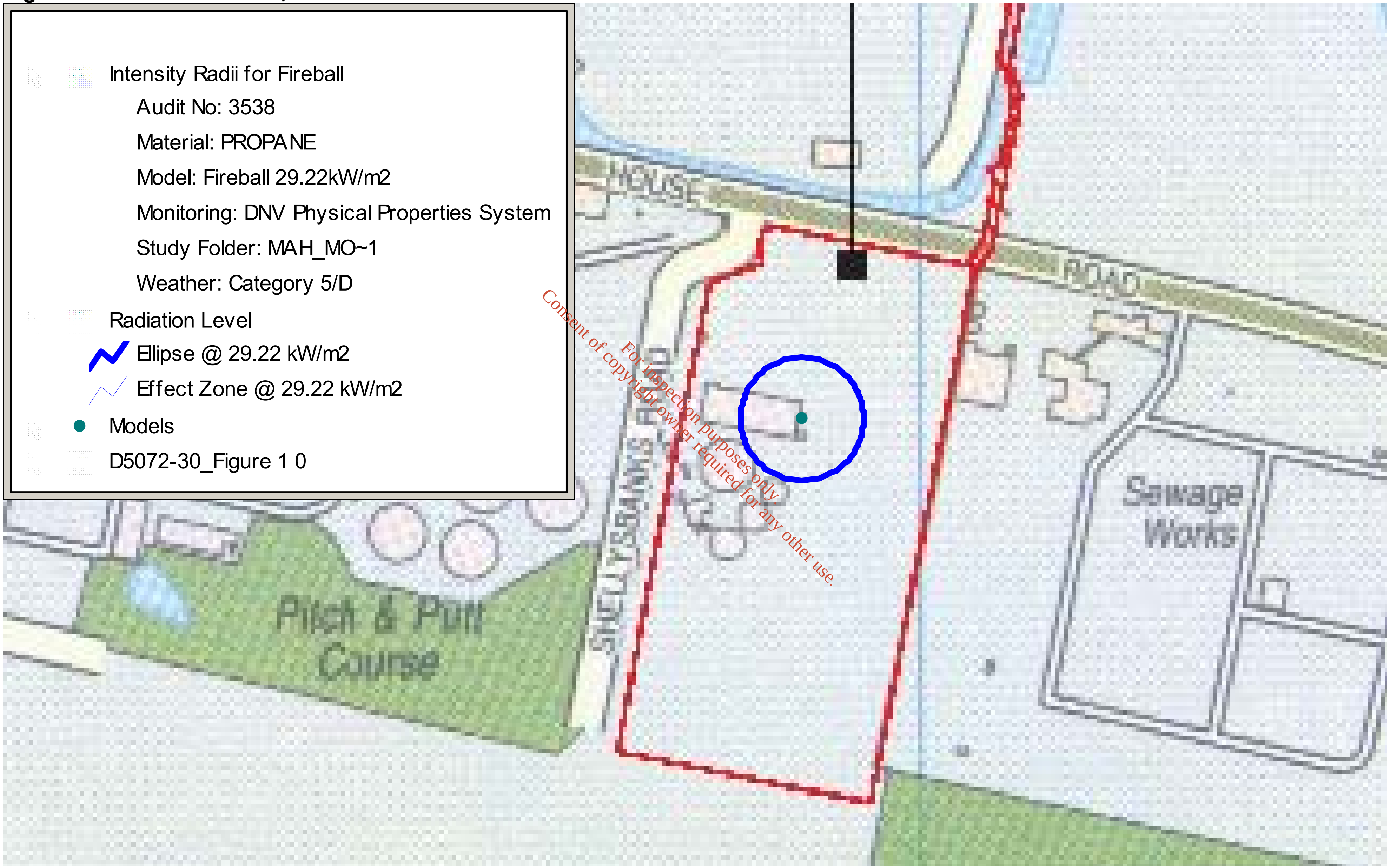


Figure 10 BLEVE Fireball, Maximum Distance to 18.8 kW/m²

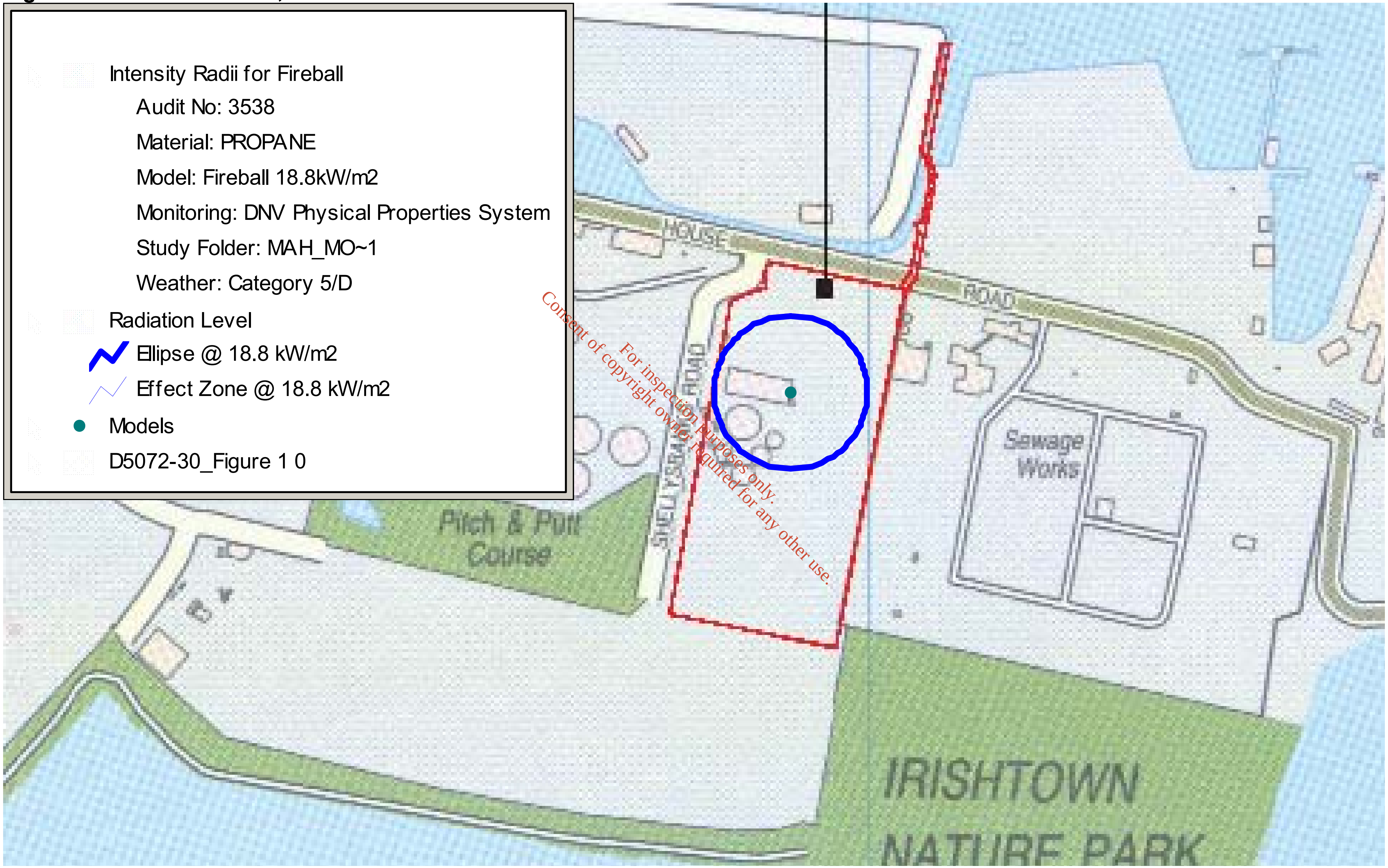
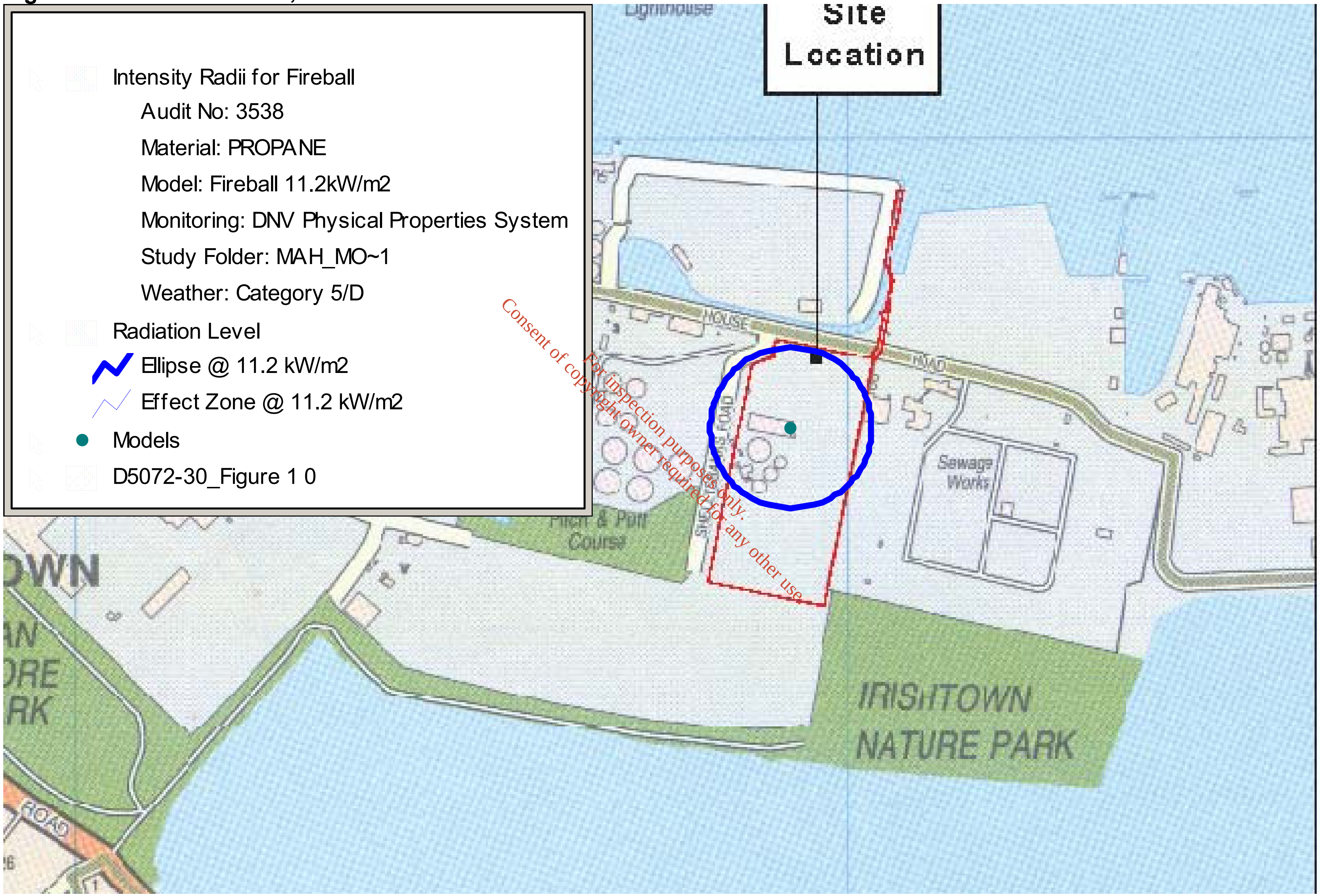
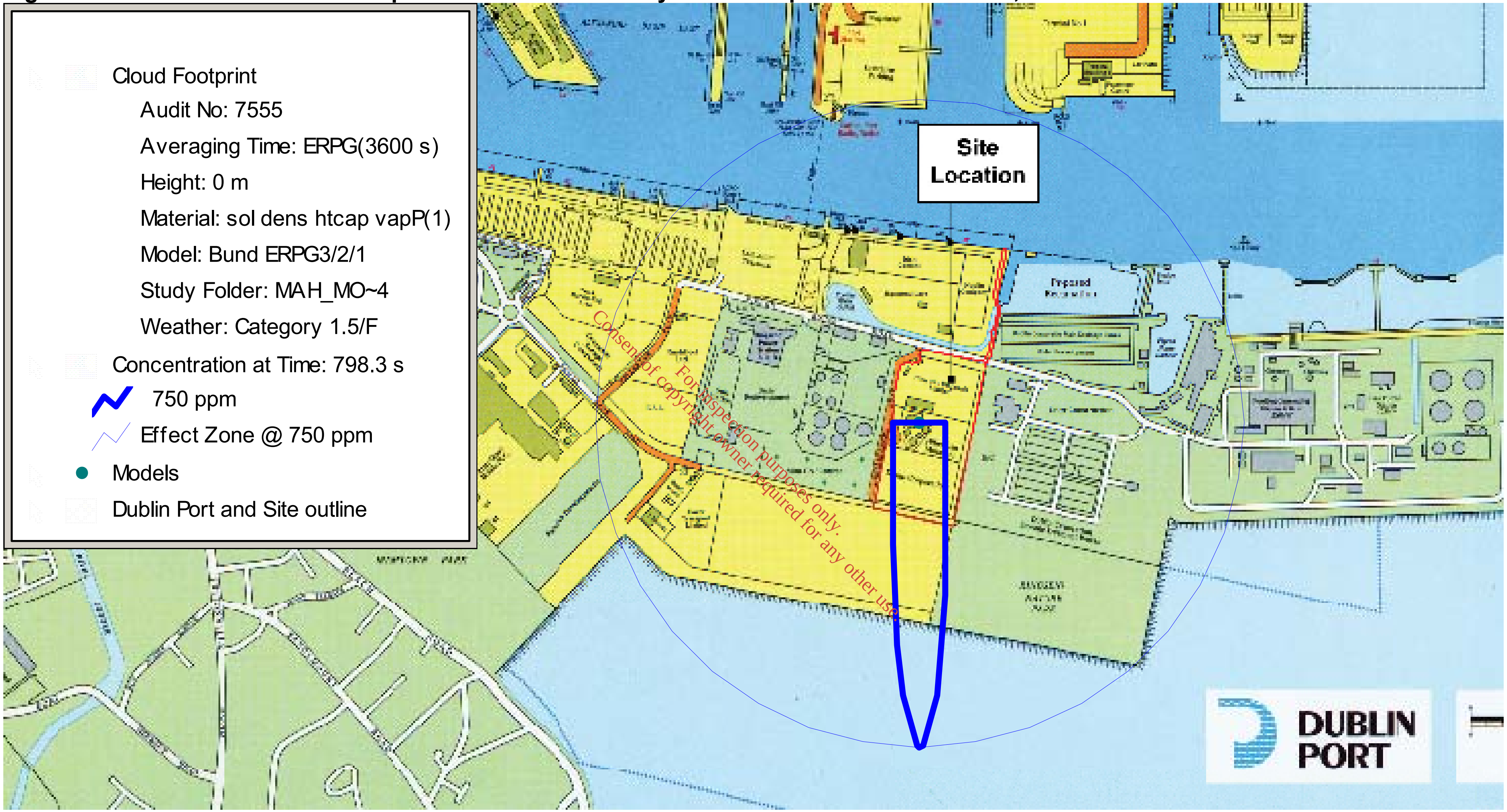


Figure 11 BLEVE Fireball, Maximum Distance to 11.2 kW/m^2



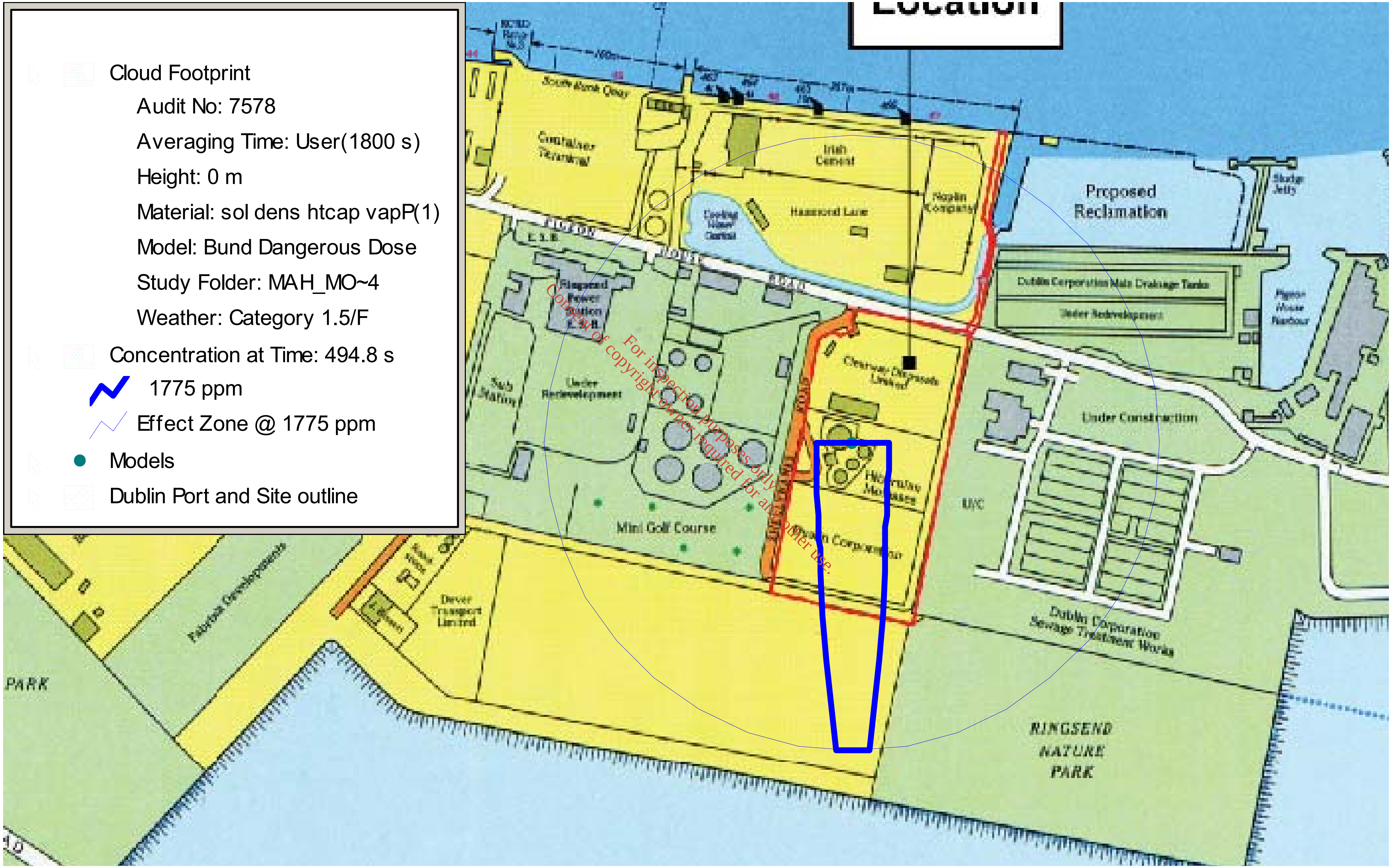
Ordnance Survey Ireland Licence No EN 0002807 ©Ordnance Survey Ireland and Government of Ireland

Figure 12 Release of Ammonia Vapour from Ammonium Hydroxide Liquid Surface in Bund, Maximum Distance to ERPG3



Reproduced with Permission of Dublin Port Company

Figure 13 Release of Ammonia Vapour from Ammonium Hydroxide Liquid Surface in Bund, Maximum Distance to Dangerous Dose



Reproduced with Permission of Dublin Port Company

Figure 14 Release of Ammonia Vapour from Ammonium Hydroxide Liquid Surface in Bund, Maximum Distance to ERPG3 at 0 sec

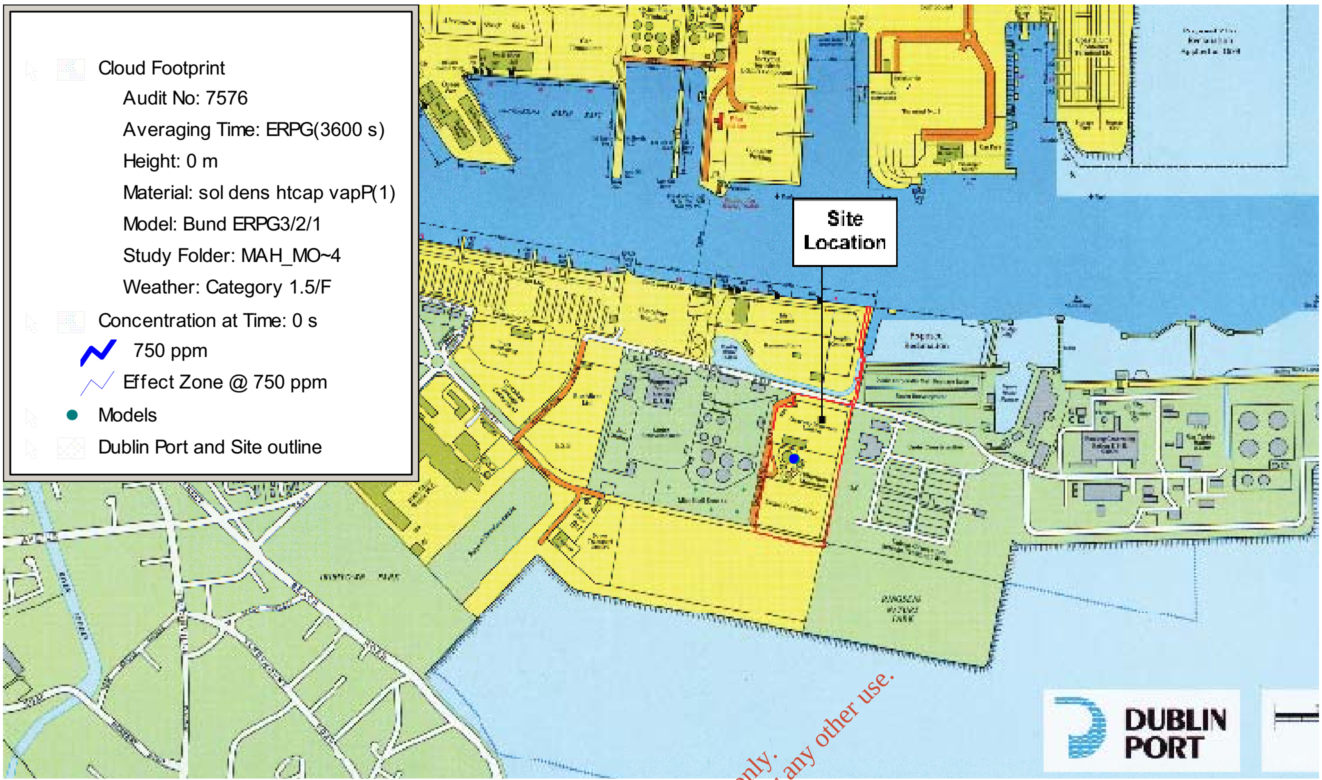


Figure 15 Release of Ammonia Vapour from Ammonium Hydroxide Liquid Surface in Bund, Maximum Distance to ERPG3 at 7.983 sec

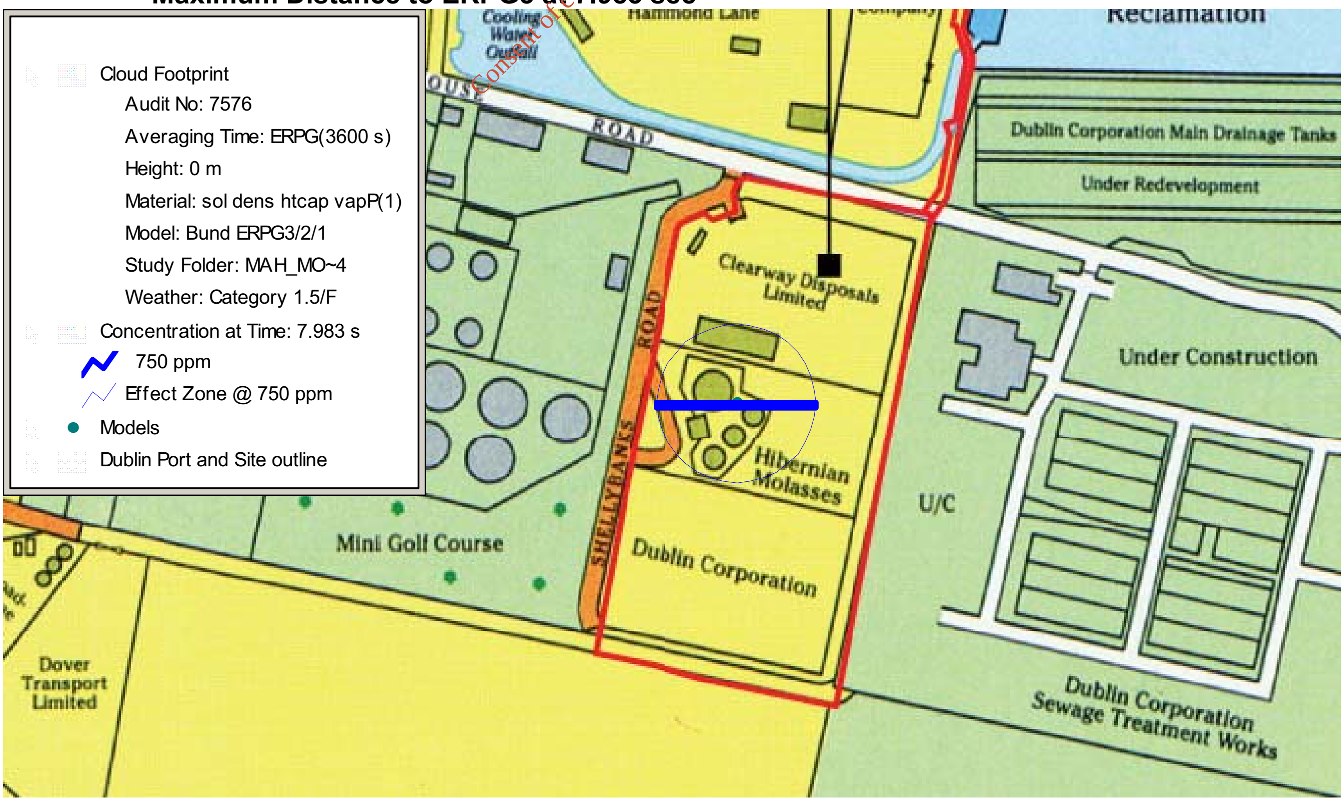


Figure 16 Release of Ammonia Vapour from Ammonium Hydroxide Liquid Surface in Bund, Maximum Distance to ERPG3 at 167.6 sec

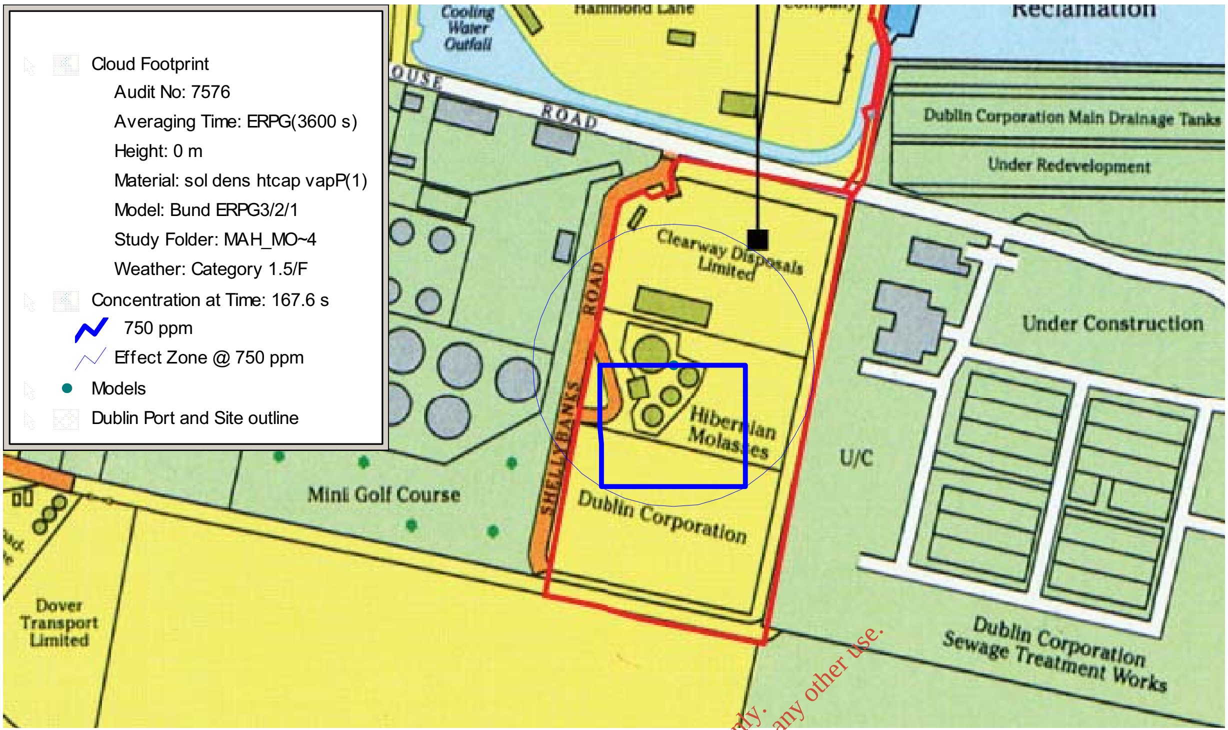


Figure 17 Release of Ammonia Vapour from Ammonium Hydroxide Liquid Surface in Bund, Maximum Distance to ERPG3 at 343.3 sec

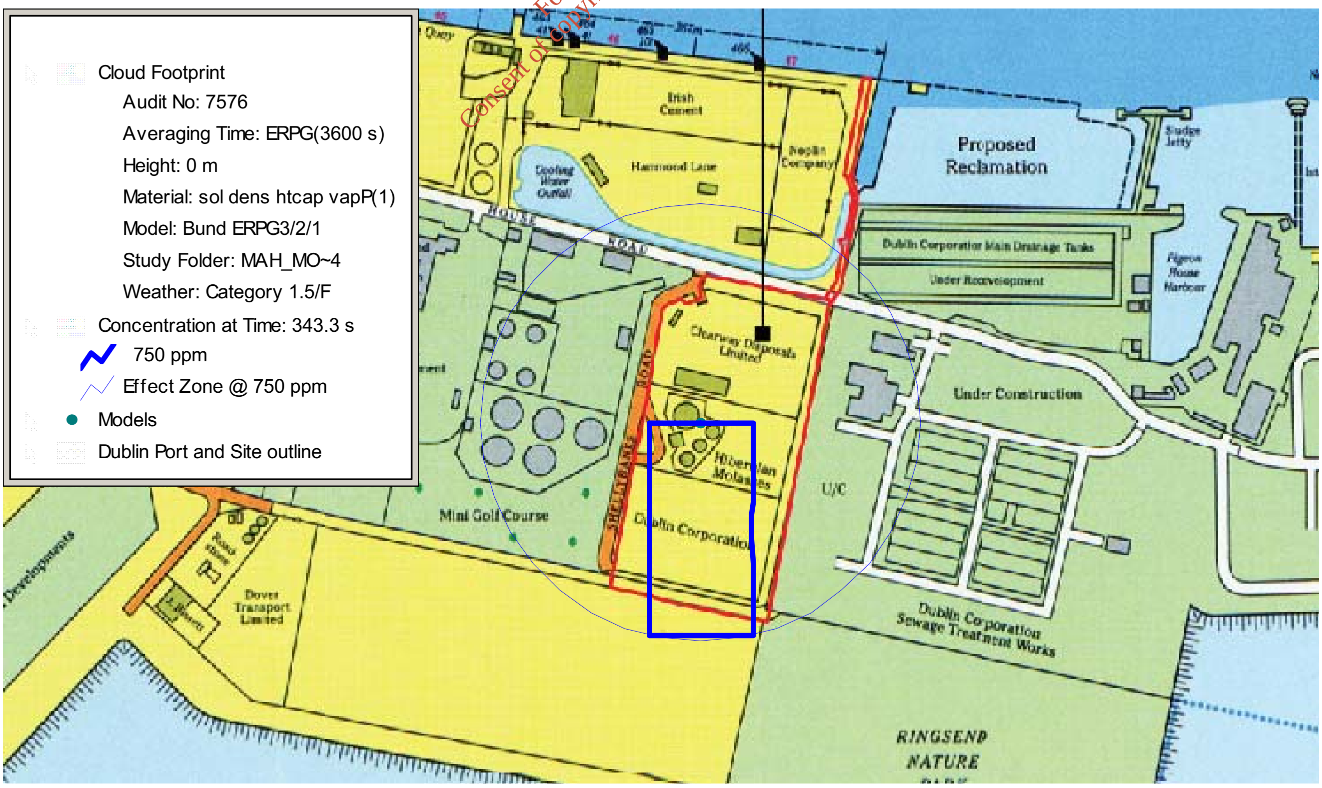


Figure 18 Release of Ammonia Vapour from Ammonium Hydroxide Liquid Surface in Bund, Maximum Distance to ERPG3 at 606.7 sec

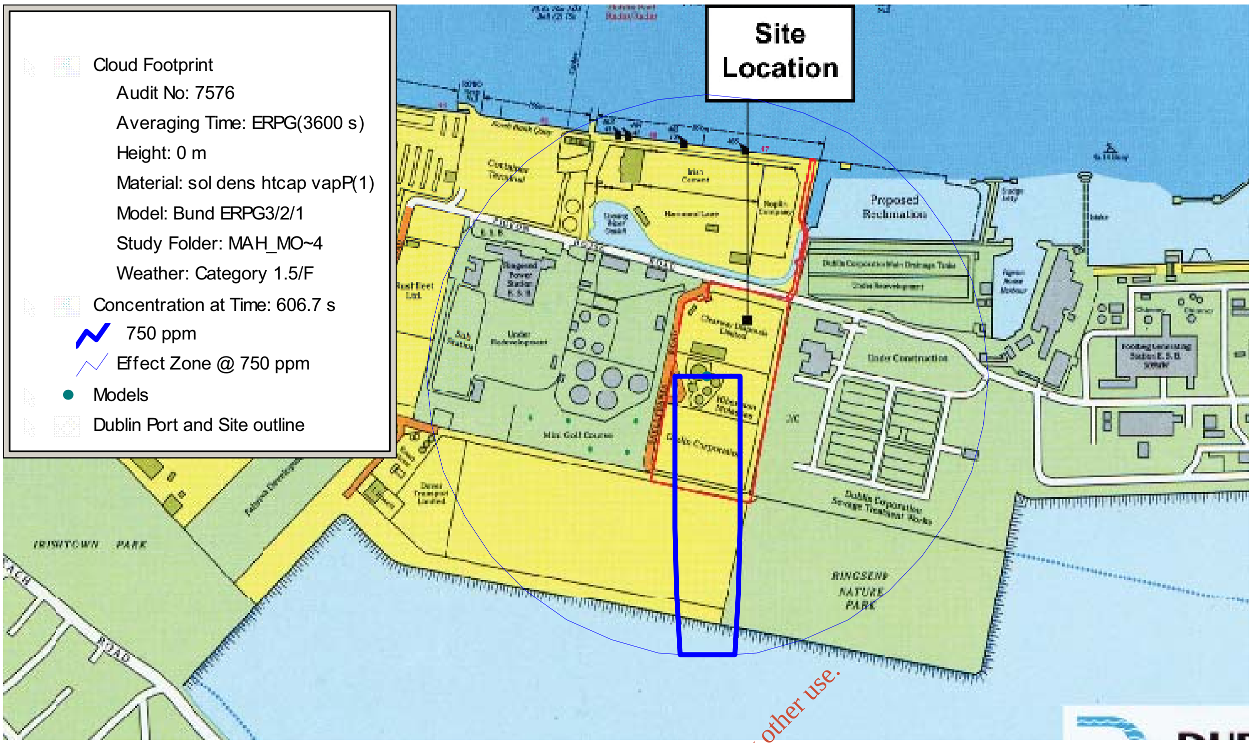
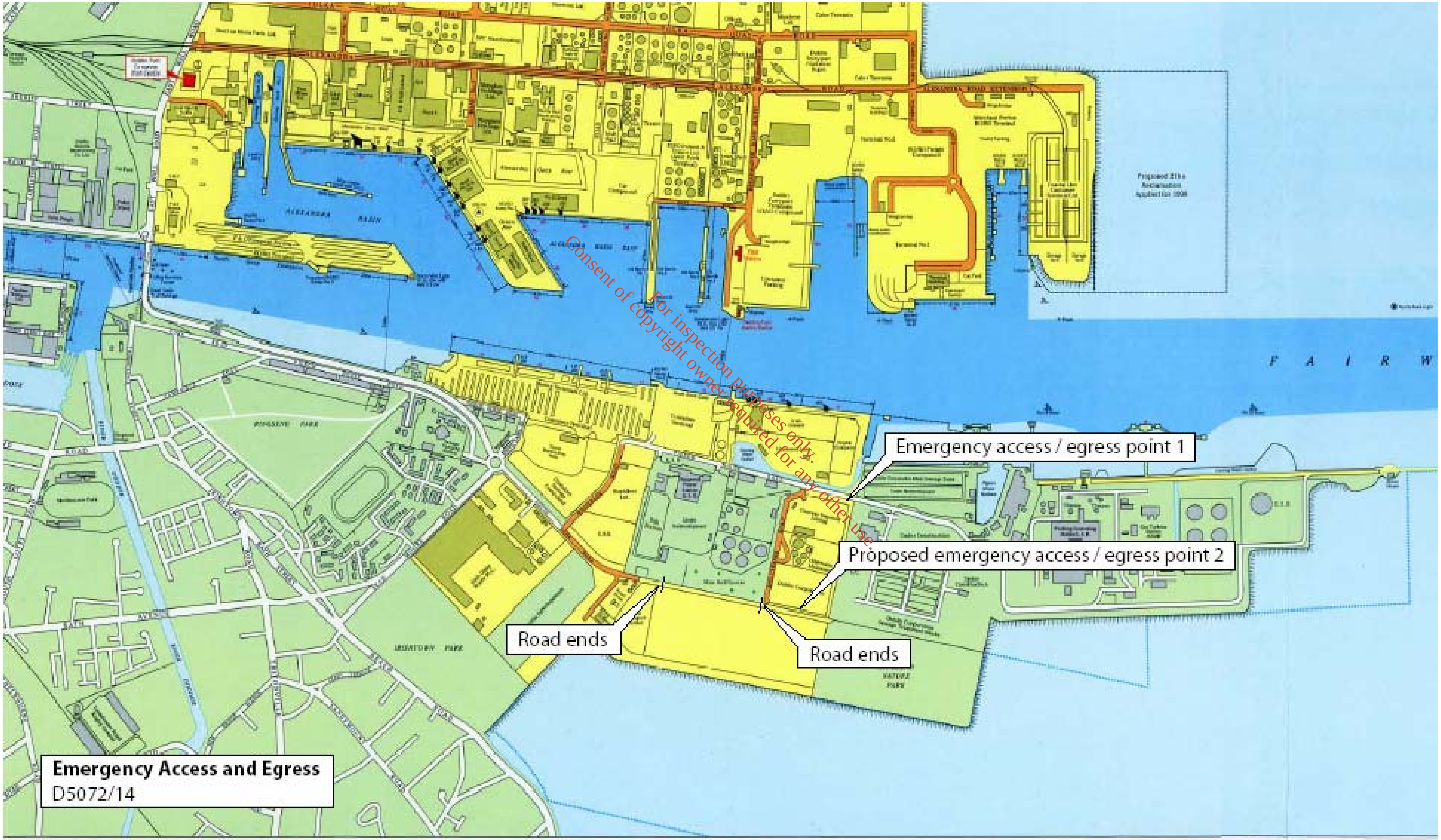


Figure 19 Site Proposed Emergency Access and Egress



APPENDIX A

DWtE Facility Dangerous Substances Inventory

A1. DANGEROUS SUBSTANCES INVENTORY

Tank No	Substance	CAS No	Risk Phrases	Classification	Physical Form	Contents of Container	Units	Litre/tonne	Maximum Quantity in Storage (tonnes)
Named Substances									
	LPG (propane)	74-98-6	R12	F+	Liquid/Gas	2	tonnes	1	2
	Diesel oil	68334-30-5	R40, R65, R66, R51/53	Xn, N	Liquid	100	tonnes	1	100
Dangerous to the Aquatic Environment - N - R 50/53									
	Ammonia (25% w/w NH_4OH)	1336-21-6	R34, R50	N, C	Liquid	100	tonnes	1	100
	Ammonia (25% w/w NH_4OH	1336-21-6	R34, R50	C, N	Liquid	80	tonnes	1	80
	Total								180
Dangerous to the Aquatic Environment - N - R 51/53									
	Taski Bruco Accel Z94 (12706.17)	64425-86-1; 107-98-2; 67-63-0; 1310-58-3	R38, R41, R51	Xi, N	Liquid	0.005	tonnes	1	0.005
	APC residues	301-04-2	R33, R61, R62, R48/22, R51/53	N, Xn	Powder	500	tonnes	1	500
	Total								500
Flammable (R10)									
	Total								
Highly Flammable (R11)									
	Acetone (8804.00)	67-64-1	R11, R36, R66, R67	F	Liquid	0.005	tonnes	1	0.005

Tank No	Substance	CAS No	Risk Phrases	Classification	Physical Form	Contents of Container	Units	Litre/tonne	Maximum Quantity in Storage (tonnes)
	Mistral Spray, dark/grey 650 °C	64742-95-6; 67-64-1; 123-86-4; 74-98-6; 106-97-8	R11, R36, R52/53	F, Xi, N	Liquid	0.005	tonnes	1	0.005
	Tangit Reiniger	109-99-9; 67-64-1	R11, R19, R36, R66, R67	F, Xi	Liquid	0.005	tonnes	1	0.005
	Plastmo PVC-glue 2966	108-94-1; 109-99-9	R11, R19, R36/37	F, Xi	Liquid	0.005	tonnes	1	0.005
	Total								0.02
Extremely Flammable (R12)									
	Polymer	106-97-8; 74-98-6	R12	F+	Liquid	0.1	tonnes	1	0.1
	Acetylene	74-86-2; 67-64-1	R5, R6, R12	F+	Gas	0.025	tonnes	1	0.025
	Kema GM-12 Lubrication	74-98-6; 106-97-8; 110-54-3	R12, R52/53	F+, N	Liquid	0.005	tonnes	1	0.005
	Total								0.13
Oxidising (R7, R8, R9)									
	Oxygen, gasform	7782-44-7	R8	O	Compressed Gas	0.025	tonnes	1	0.025
	Total								0.03

APPENDIX B

DWtE Facility Aircraft Impact Report

Health and Safety Authority

Dublin Waste to Energy Facility Ringsend

Aircraft Impact Report

Dublin Waste to Energy Facility Ringsend

Aircraft Impact Report

January 2007

CONTENTS

1. INTRODUCTION

The HSA requested in its letter dated 4 October 2006 that Section 3.6.3 – Aircraft Impact – data based on Canvey be reworked using methodology in HSE Publication (CRR series) "The Calculation of Aircraft Crash Risk in the UK" 1997.

This Report, reference 150, addresses the risk of impact by aircraft under two headings:

- Background risk
- Airfield related risk

Aircraft are categorised as follows:

- Light civil aircraft (category 1) - fixed wing aircraft generally falling into the Civil Aviation Authority (CAA) classification of less than 2.3 te maximum take-off weight authorised (MTWA). This category also includes military light aircraft used for training which are less than 2.3 te MTWA.
- Helicopters (category 2) - all civil and military helicopters.
- Small transport (category 3) - fixed wing aircraft covering the mass range 2.3 te to 20.0 te MTWA, including civil and military transport aircraft.
- Large transport aircraft (category 4) - any other fixed wing aircraft, civil or military, not covered in the light aircraft, small transport or military combat and jet trainer categories.
- Military combat and jet trainers (category 5) - all military fixed wing aircraft with MTWA up to 40 - 50 te used for, or capable of, aerobatic style flying.

The background risk is computed in CRR 150-1997 by determining the number of aircraft crashes over a ten year period (1985-1994). The rate is calculated based on reported accidents, screened as follows:

1.1 Screening Criteria

The screening process applied in CRR-150 1997 excludes accidents if they satisfy any of the following criteria:

1. The aircraft was clearly involved in either the landing or take-off phases of flight, or was involved in some other airfield-related activity such as flying "in circuit". As a general rule, this excludes accidents occurring within about 5 miles of airfields. However, some judgement is necessary as different aircraft types have different landing and take-off characteristics. For example, the take-off and initial climb phases of flight for a light aircraft may be completed within a relatively short distance from the airfield when compared to a large transport aircraft.
2. The accident occurred as a result of a forced landing in which the pilot had some degree of control over the choice of landing site. In these cases it is reasonable to assume that the pilot would avoid built-up areas or any large structure on the ground.
3. The accident was associated with crop-spraying and it occurred within, or close to, the confines of the area being sprayed.
4. The accident involved a helicopter hovering close to the ground.
5. The accident involved injuries to passengers caused by turbulence.

Thus only accidents which involve uncontrolled impacts away from airfields are included in the background crash rate. It is clear that the safety of a major industrial installation would not be compromised by an accident arising from any of the above circumstances, with the possible exception of airfield-related incidents (see Section 2).

For military aircraft, only accidents defined as being damage category 4 or 5 were considered. The screening criteria described above were then applied. A damage category 4 accident is defined in CRR-150 1997 as one in which the aircraft could not be repaired in situ and a damage category 5 accident is one in which the aircraft was destroyed or lost.

In Ireland, reports on aircraft accidents and incidents are prepared by the Air Accident Investigation Unit (AAIU) Department of Transport. Reports for the years 1997-2006 (a 10 year period, the same as in CRR 150-1997) were downloaded from the AAIU website (www.aaiu.ie) and were examined to identify "accidents which involve uncontrolled impacts away from airfields".

13 such accidents were identified, of which 9 involved helicopters, and 4 involved light aircraft. One of the helicopter accidents was operated by the Irish Air Corps. No such accidents were identified that involved small transport, large transport or military aircraft.

In the assessment of background crash rates HSE Report CRR 150-1997 assumes that:

"aircraft crashes may be represented as a Poisson process". This means that:

(i) The process is assumed to be stationary;

(ii) The events which constitute the process are assumed to be statistically independent;

(iii) The events do not occur simultaneously.

It may be argued that aircraft crashes do not satisfy these criteria, particularly with regard to (i) and (iii) above. However, aircraft crash rates are influenced by factors which change over a relatively long period of time, so it may be said that over a 10-year period the process is effectively stationary. Also, mid-air collisions are counted as 2 separate events, provided 2 impacts with the ground could be identified. This avoids a potential underestimate of crash rate and is not that significant as only a small proportion of accidents are caused by mid-air collisions.

A benefit of using the Poisson process in determining background crash rates is that the chi-squared distribution can be used to determine the mean value to any given level of confidence. If r is the number of crashes occurring in time period T, the chi-squared distribution relates the probability α that the mean is greater than or equal to a value θ , where

$$\theta = \frac{X^2_{1-\alpha,2(r-1)}}{2T}$$

As is the usual practice in aircraft crash studies, the crash rates are calculated at the 50% confidence level (α = 0.5)."

1.2 Military Combat Aircraft

In HSE Report CRR 150-1997, it is stated:

> "The distribution of MCA crashes over the UK is such that a uniform background crash rate is not present and areas of high crash concentration have been defined."

The methodology used to calculate the crash rate was based on the location of a site i.e. within or close to one of the three high crash concentration zones shown in the Report.

Table 1 MCA Zones

If the site lies within one of these zones	9.7×10^{-5} km^{-2} yr^{-1}
If the site is outside these zones but within 40 km of the boundary of a zone (x = distance from zone)	$f(x) = 9.24 \times 10^{-5} e^{-x/15} + 4.6 \times 10^{-6}$
If the site is situated elsewhere	0.46×10^{-5} km^{-2} yr^{-1}

Fortunately, the incidence of military aircraft crashes in the State is extremely low, and apart from the helicopter crash referred to above, none have been reported in the last 10 years.

Hence it is not possible to define areas of "high crash rate concentration" in the State. It was therefore decided to use the "low risk" rate of 0.46×10^{-5} km^{-2} yr^{-1}.

Therefore, based on 9 helicopter crashes and 4 light aircraft crashes in the 10-year period 1997-2006, and a land area of Ireland of approximately 70,280 km², the following background crash rates were estimated:

Table 2 Background Crash Rates

Aircraft Category	Background Crash Rate (km^{-2} yr^{-1})
Light aircraft	6.65×10^{-6}
Helicopters	1.38×10^{-5}
Small transport	1.16×10^{-6}
Large transport	2.03×10^{-6}
Military combat aircraft	4.60×10^{-6}
Total	2.82×10^{-5}

2. AIRFIELD-RELATED

To calculate the crash rate attributable to airfield, HSE Report CRR 150-1997 uses the following general approach. The frequency, g, with which unit ground area at position (r,θ) relative to the runway would suffer an impact as a result of N runway movements per year, is given by:

$$g = NRf(r,\theta)$$

in which R is the probability per movement of a landing or take-off accident and f(r,θ) expresses the probability of unit ground area at (r,θ) suffering an impact, given that an accident has occurred. The above equation should be used for each relevant aircraft category.

For light aircraft:

$$f(r,\theta) = 0.08e^{-r/2.5}e^{-\theta/60}$$

The following correlations are used in CRR 150-1997 for the probability of a landing or take-off accident, FL(x,y) and FT(x,y) respectively, at location (x,y):

$$F_L(x,y) = \frac{x+3.275}{3.24} e^{\frac{=(x+3.275)}{1.8}} \left[\frac{56.25}{\sqrt{2\pi}} e^{-0.5(125y)^2} + 0.625 e^{-\frac{|y|}{0.4}} + 0.005 e^{-\frac{|y|}{5}} \right]$$

and

$$F_T(x,y) = \frac{x+0.6}{1.44} e^{\frac{=(x+0.65)}{1.2}} \left[\frac{46.25}{\sqrt{2\pi}} e^{-0.5(125y)^2} + 0.9635 e^{-4.1|y|} + 0.08 e^{-|y|} \right]$$

These equations are valid for fixed-wing aircraft over 2.3 te maximum take-off mass (i.e. category 3, 4 and 5 aircraft). Equivalent expressions have not been derived for light aircraft.

CRR 150-1997 states that there are shortcomings in the above expressions which attempt to predict the probability of a crash at a given location. When calculating the crash rate attributable to airfields CRR 150-1997 recommends that the following guidelines be used:

- Only give consideration to airfields within 10 km of the site of interest unless the airfield is particularly busy (> 20,000 movements annually), or if the runway orientation is unfavourable for the site (i.e. the runway is pointing roughly in the direction of the site).
- For light aircraft, equation (6) should be used for the calculation of impact probability.
- For category 3, 4 and 5 aircraft, equations (7) and (8) should be used. For any site close to the extended runway centreline (within about 500 m), the impact probability should be based on the integrated forms of these equations given in Appendix 2 of CRR 150-1997. The equations should be integrated over a suitable area centred on the site or building of interest.

The airfield-related crash rate attributable to MCA aircraft was not calculated for the purpose of this report as the only military airspace in the Dublin region, Casement Aerodrome, Baldonnel, is located 15.9km from the site of interest.

2.1 Helicopters

CRR 150-1997 states:

> "Helicopter accidents on landing and take-off are confined to a small area around the helipad, extending up to 200 m only from the centre of the helipad. Most accidents (93%) occur within 100 m of the helipad and the remaining 7% occur between 100 - 200 m. This gives a ground impact rate per km² per accident of 29.6 between 0 - 100 m and 0.74 between 100 - 200 m. For most sites therefore, no consideration needs to be given to helicopter crashes associated with helipads, provided there are no helipads within 200 m of the site."

No helipads have been established within 200 m of the site of the proposed facility and hence no helipad-related crash rate has been used.

2.2 Landing and Take-Off Reliabilities

The aircraft reliabilities (i.e. the probability of an accident on landing or take-off) given in CRR 150-1997 are listed in Table 3.

Table 3 Aircraft reliabilities

Aircraft category	Reliability (crashes per movement)
Light aircraft	1.2×10^{-6}
Helicopters	2.3×10^{-6}
Small transport	1.8×10^{-6}
Large transport	5.9×10^{-6}
Military combat	3.6×10^{-6}

Therefore, for the purpose of assessing the crash rate in Ireland, the following airfield related crash rates have been calculated, based on aircraft movements in 2005:

Table 4 Airfield related crash rates

Aircraft Category	Crash rate (km^{-2} yr^{-1})
Light aircraft	1.45×10^{-6}
Small transport	3.35×10^{-8}
Large transport	8.31×10^{-8}
Total	**1.57×10^{-6}**

3. CRASHES BELOW AIRWAYS

CRR 150-1997 argues that the calculation of both background crash rate and of airway related crash rate may be overly conservative. The report suggests that airfield-related incidents should be more clearly defined and should be based on flight phases rather than distance from the airfield, to prevent double counting. However, for completeness, the methodology and calculation of airway-related crash rates is given in the following section.

CRR 150-1997 gives estimates of in-flight reliabilities (i.e. the probability of an accident en-route) as follows:

Table 5 In-flight reliabilities

Aircraft category	Reliability (crashes per flight kilometer)
Light aircraft	1×10^{-7}
Helicopters	1×10^{-7}
Small transport	3.9×10^{-10}
Large transport	4.7×10^{-11}
Military combat	2×10^{-8}

In Ireland, the airways are divided into upper and lower zones. The lower airway constitutes the area below 24,000 feet (~7.3km) and the upper airway constitutes the area above 24,000 feet.

The calculation of the crash rate in the lower airway is based on the assumption that crashes are normally distributed about the airway centreline, with a standard deviation equal to the airway altitude. CRR 150-1997 calculates the crash rates below airways from:

$$C_A = \frac{N_A R_A \text{afac}}{\text{alt}}$$

Where alt is the mean altitude of the airway in km, afac is the area factor, N_A is the annual number of movements on the airway and R_A is the aircraft in-flight reliability.

The annual number of movements per aircraft category is not recorded for each airway in the Dublin region. Therefore the following conservative assumptions were made:

- All aircraft in the lower airway is small transport aircraft;
- All aircraft in the upper airway is large transport aircraft.

Based on the total number of movements in the lower airway in the Dublin region provided by the IAA for 2005 the crash rate attributable to the lower airway is calculated as:

$$C_A(km^{-2}yr^{-1}) = 6.35 \text{ x } 10^{-7}$$

There is considerable variation in daily aircraft movements in the upper airway in the Dublin region. As such, the IAA do not record this data. The calculation of the crash rate in the upper airway is therefore based on the following estimations provided by the IAA:

- Average annual upper airpsace movements in the Dublin region: 36,500;
- Average aircraft altitude: 35,000 feet.

Based on the above data, the crash rate attributable to the upper airway is calculated as:

$$C_A(km^{-2}yr^{-1}) = 6.35 \text{ x } 10^{-8}$$

It should be noted that value for total aircraft en-route movements in Irish Upper Airspace is an approximation only. The IAA do not record this data is a format applicable to the calculation given in CRR-150 1997.

The addition of the crash rates attributable to both the upper and lower estimated above still provides a value two orders of magnitude lower than the background crash rate. Therefore, the background crash rate and airfield related crash rate are used as a more conservative approach.

4. OTHER AERIAL FEATURES

According to CRR-150 1997, the principal contributors to aircraft crash rates at most sites in the UK are the background crash rate and airfields. Airways generally make only a very small contribution. CRR 150-1997 lists other aerial features that may affect the crash rate. They are:

- Provost Marshal Prohibition Zones
- Restricted and Prohibited areas
- AAISs and MTAa/MTRAs
- Danger areas
- Military Avoidance Areas
- Terminal Control Areas (TMAs) and Control Zones (CTRs)
- Military Aerodrome Traffic Zones (MATZ)

The effect of these features on the crash rate at a given site is difficult to quantify. If a crash risk assessment is being carried out, CRR-150 1997 recommends that checks should be made to establish if any of these features are present, so that the possibility of a reduced or enhanced crash rate can be highlighted.

4.1 Provost Marshal Prohibition Zones

Provost Marshal Prohibition (PMP) zones are in place around all nuclear power plant sites in the UK. CRR-150 1997 defines PMP zones as cylinders of airspace, usually two nautical miles (3.7 km) in radius and 2000 feet high in which all military flying is banned at all times.

There are no PMP zones in Ireland.

4.2 Restricted and Prohibited Areas

Restricted and prohibited areas are in place around many establishments such as military bases. Both civil and military traffic are excluded from prohibited areas at all times; restricted areas may be entered under certain conditions, usually provided prior agreement is obtained.

In Ireland, prohibited areas are assigned by the Irish Aviation Authority (IAA) in pursuance of Article 11 and Article 16 of the Irish Aviation Authority (Rules of the Air), Order 2004, (S.I. No. 72 of 2004). A full list of prohibited areas is given below.

Table 6 Prohibited areas

Area	Status	Applicable Periods
EIP8 at Portlaoise, Co Laois	Prohibited	24hrs per day
EIP9 at Limerick City	Prohibited	24hrs per day
EIP10 at the Curragh Military Camp at Co Kildare	Prohibited	24 hrs per day
EIP11 at the Phoenix Park, Dublin	Prohibited	24 hrs per day
EIP18 at Mountjoy Prison, Dublin	Prohibited	24 hrs per day

Two IAA 'prohibited' sites are located in the Dublin area. EIP18 Mountjoy Prison is located 4.9km from the proposed site. Its exclusion area has a radius of 0.5 nautical miles from ground level to 550 feet at 53 21 44N, 06 16 01W and does not affect the proposed site. EIP11 Phoenix Park is located 6.6km from the proposed site. It has an exclusion zone of radius 1nm at 53 21 34N, 06 18 59W from ground level to 1000 feet which also does not affect the proposed site.

A 'Restricted Area' is defined in the Irish Aviation Authority (Aircraft and Small Rockets) Order, S.I No. 25 of 2000 as 'an airspace of defined dimensions designated by the Authority above the land areas of the State or the territorial waters thereof, within which the flight of aircraft is restricted by the Authority in accordance with specified conditions'. The IAA may also establish 'Temporary Restricted Areas' primarily to enable restrictions of Flying Regulations to be put in place for security reasons, to cover Radar outages or to meet other requirements.

There are no restricted areas in the vicinity of the proposed site.

4.3 AIAAs and MTAs/MTRAs

CRR-150 1997 defines Areas of Intense Aerial Activity (AIAAs), Military Training Areas (MTAs) and Military Temporary Reserved Airspace (MTRAs) as "areas used by military aircraft for training purposes”. Casement Aerodrome, Baldonnel is the only such area in the Dublin region. However, the Aerodrome is located 15.9km from the site for the proposed WtE facility and does not, therefore, warrant consideration.

4.4 Danger Areas

Danger Areas are defined by the Irish Aviation Authority (IAA) in pursuance of Article 11 and Article 16 of the Irish Aviation Authority (Rules of the Air), Order 2004, (S.I. No. 72 of 2004) as “an airspace of defined dimensions within which activities dangerous to the flight of aircraft may exist at specified times”. Aircraft are required to avoid these areas either permanently or during notified hours of activity. A reduced civil aircraft crash rate is therefore likely within the areas themselves, as the level of civil activity should be reduced. In Ireland, ‘danger areas’ are designated by the IAA. A full list is provided in Table 7.

Table 7 Danger Areas

Area	Status	Applicable Periods
EID1 at Gormanstown, Co. Louth	Danger	24hrs per day
EID5 at Glen of Imaal, Co. Wicklow	Danger	24hrs per day
EID6 at Kilworth, Co. Cork	Danger	24 hrs per day
EID13 in the Sea/Coastal Area South South West of Cork	Danger	24 hrs per day
EID14 Sea Area South West of Kerry	Danger	24 hrs per day

None of these danger areas are located within 10km of the proposed site.

4.5 Military Avoidance Areas

These areas are described in CRR-150 1997 as areas that cover the major built-up regions in the UK. Low-flying military aircraft are excluded from these areas, other than for landing at specific airfields or for landing during an emergency.

As described earlier, the lack of MCA crashes in recent years over Ireland confirms the fact that very little low-level flying takes place within such areas.

4.6 Terminal Control Areas (TMAs) and Control Zones (CTRs)

These are areas defined around major airports or airport clusters in which enhanced levels of flying activity are to be found. It may seem appropriate to increase the crash rate in these areas to allow for the enhanced activity, however CRR-150 1997 does not recommend this for the following reasons. Firstly, the treatment of busy airfields described earlier should mean that the proposed site will have a crash rate that takes account of the airfield activity. Secondly, although it may be expected that the concentration of activity in TMAs and CTRs would tend to increase the crash rate, there is no evidence to support this. It may be the case that enhanced levels of air traffic control in these areas compensates for the increased activity and prevents an increase in crash rate.

The calculation of the crash rate attributable to the Dublin Airport airfield is considered in Section 2 of this report. Therefore, no amendment of the crash rate has been applied.

4.7 Military Aerodrome Traffic Zones

CRR-150 1997 defines these areas as "areas established at various military airfields which provide a volume of airspace within which increased protection may be given to aircraft in the circuit, approach and climb-out phases of flight". It is not recommended that special treatment be given to these areas; the crash rate at any affected site should be accounted for via the treatment of airfields described earlier.

4.8 Local Flying Areas (LFAs)

Local Flying Areas (LFAs) are mostly used by light aircraft for leisure flying or training. They generally allow flying within a certain area and up to specific altitudes. CRR-150 1997 does not consider it necessary to increase the light aircraft crash rate to allow for LFAs, since the background crash rate will include crashes attributable to this type of activity. However it advised to increase the light aircraft crash rate for sites within busy LFAs.

The proposed site is not within an LFA.

5. AIRCRAFT IMPACT FREQUENCY

Having calculated a crash rate in terms of crashes km^{-2} yr^{-1}, it is also necessary to calculate the impact frequency at the site of interest. To do this, the effective target area of the structure needs to be found. CRR-150 1997 states that the calculation of the target area for a structure of finite height should take the following parameters into account:

- Aircraft descent angles
- Plan area of the structure
- Possibility of skidding
- Pilot avoidance

Descent angle distributions which take account of pilot avoidance were derived by Jowett from studies of accident reports for all fixed wing aircraft in the UK. These values are quoted in CRR-150 1997 and are also used for the purpose of this report.

CRR-150 1997 gives the effective target area of an unshielded cuboid structure subject to isotropically distributed aircraft approach directions as:

$$A_E = lw + \frac{2}{\pi} h(w+l) \sum_{i=1}^{i=n} f_i \cot\theta_\iota$$

in which h, 1 and w are the cuboid dimensions and f_i is the proportion of crashing aircraft having descent angle θ_i . Evaluating the summation of $f_i \cot\theta$ using the descent angles derived by Jowett, the above expression simplifies to:

$$A_{E_1} = lw + 0.8h(w+l)$$

for light aircraft, small and large transport aircraft and MCA accidents initiated over 2000 feet; or

$$A_{E_2} = lw + 3.6h(w+l)$$

for MCA accidents initiated below 2000 feet; or

$$A_{E_3} = lw + 0.62h(w+l)$$

for helicopters.

Therefore using the conservative approach i.e. assuming the site is a completely unshielded cuboid structure, the effective target area of the proposed site is calculated as:

Table 8 Effective target areas

Aircraft Category	Effective Target Area, A_E (km^2)
Light aircraft, small and large transport aircraft, MCA incidents initiated over 2000 feet	0.0397
Helicopters	0.0366

The impact of skidding is not assessed in this report owing to the proximity of the site to Dublin Bay. In the event of a potential accident, it may be assumed that the pilot would always endeavour to direct the aircraft into the water.

The procedure for calculation of impact frequencies involves determining the crash rates for each aircraft category and then multiplying by the appropriate effective target area to give an impact frequency for each relevant category. These are summed to give the total impact frequency. Using the most conservative approach i.e. background crash rates and airfield related crash rates, the total impact frequency was calculated as:

Table 9 Impact frequencies

Aircraft Category	Impact Frequency (yr^{-1})
Light aircraft, small and large transport aircraft, MCA incidents initiated over 2000 feet	6.36×10^{-7}
Helicopters	5.06×10^{-7}
Total	**1.14×10^{-6}**

It should be noted that these are estimates based on the dimensions of the facility assuming a cuboid site area as described in CRR-150 1997. Using the proposed total site area of 0.055 km^2 and the total crash rate, the total impact frequency is calculated as $2.98 \times 10^{-5} \times 0.055 = 1.64 \times 10^{-6}$

6. OTHER ASPECTS OF AIRCRAFT CRASH

6.1 Debris from Airborne Aircraft

According to CRR-150 1997, reports of debris-sourced incidents should be screened to exclude the following:

- Incidents in which both the aircraft type and flight phase are unknown;
- Incidents in which the object is simply described as “a substance”;
- Incidents in which the object is a banner or banner towing cable;
- Incidents in which the object could not be identified as having fallen from an aircraft;
- Incidents in which the object fell within the confines of an airfield (i.e. associated with landing, take-off or maintenance) and
- Incidents which did not occur over the UK (Ireland).

In Ireland, there have been only 2 reported incidents of debris (aircraft parts) from airborne aircraft in the past 10 years. However, both events were reported in the vicinity of airfields and are therefore excluded after the screening process described above.

It is evident therefore that an aircraft sourced debris incident is very rare in Ireland.

6.2 In-Flight Break-Up of Aircraft

For an in-flight break-up of an aircraft to affect a site, CRR-150 1997 describes the specific sequence of events that would have to occur for safety to be affected as follows:

- The aircraft is travelling along an air route which takes it more or less over the site;
- At a specific point along the air route an incident occurs. Corrective action by the aircrew is not possible or fails. Control of the aircraft is lost and break-up of the aircraft occurs;
- The initial altitude and velocity of the aircraft, and hence the trajectory of the larger aircraft fragments, are such that large fragments fall onto the site. The break-up of the aircraft can therefore only occur within a certain section of the airway if the fragments are to present a hazard to the site;
- The fragments fall onto parts of the site which have the potential to affect safety.

Given the sequence of events that would have to occur for this scenario to be a possibility, CRR-150 1997 recommends that it is unlikely to merit further consideration. CRR-150 1997 also states that given that the frequency of airway initiated incidents is low at the outset, the further combination of factors needed for an in-flight break-up of aircraft to affect any given site means that it is a very unlikely event. In addition, further failures may also be necessary for any resulting impact to lead to an incident with significant consequences for safety.

7. CONCLUSION

Based on the methodology described in CRR-150 1997, the impact frequency for the proposed site is calculated as 1.14×10^{-6} yr^{-1}. This compares with a value of 1.83×10^{-8} calculated using methodology from the Canvey Report (1978). It should be noted that there have been no incidences of small transport, large transport and military aircraft accidents in Ireland in the past 10 years. For this reason, background crash rates for these categories of aircraft were based on UK data as provided in CRR-150 1997. In addition, the facility is not under a normal flight path to or from the airport and overflying occurs only in unusual weather conditions, or if the main runway is out of use. Therefore, the overall impact frequency calculated for the purpose of this report is a conservative figure.

8. APPENDIX

Table 10 Dublin airport aircraft movements by category and runway 2005

Arrivals	Category 1	Category 2	Category 3	Category 4	Category 5
RUNWAY 10	73	0	2,380	18,852	0
RUNWAY 11	130	0	305	38	0
RUNWAY 16	61	0	728	4,615	0
RUNWAY 28	315	0	6,205	54,137	0
RUNWAY 29	322	0	1,666	357	0
RUNWAY 34	31	0	164	1,064	0

Departures	Category 1	Category 2	Category 3	Category 4	Category 5
RUNWAY 10	63	0	2,183	18,677	0
RUNWAY 11	120	0	529	57	0
RUNWAY 16	56	0	677	4,124	0
RUNWAY 28	361	0	6,654	55,026	0
RUNWAY 29	290	0	1,209	119	0
RUNWAY 34	45	0	193	1,060	0

8.1 Background Crash Rate

Using the equation described in Section 1:

$$\theta = \frac{X^2_{1-\alpha,2(r-1)}}{2T}$$

where r is the number of crashes occurring in time period T and land area is 70,280 km^2.

Table 11 Background crash rates calculated from AAIU data

Aircraft Category	**No. of Crashes (r) in 10 Years (T)**	**Crash Rate (km^{-2} yr^{-1})**
Light aircraft	4	6.65 x 10^{-6}
Helicopters	9	1.38 x 10^{-5}
Small transport	0 (UK - 2)	1.16 x 10^{-6}
Large transport	0 (UK - 4)	2.03 x 10^{-6}

8.2 Airfield Related

Using the equations described in Section 2 for light aircraft

$g = NRf(r,\theta)$

$$f(r,\theta) = 0.08e^{-r/2.5}e^{-\theta/60}$$

where g is the frequency with which unit ground area at position (r, θ) relative to any runway would suffer an impact as a result of N runway movements per year

Table 12 Airfield related parameters – light aircraft

Runway	r (km)	θ	g
11	11.4	60.7512	6.82 x 10^{-8}
29	10.8	64.4914	5.08 x 10^{-7}
16	11.4	36.0944	4.25 x 10^{-8}
34	9.45	35.9922	3.16 x 10^{-7}
10R	10.9	53.2674	9.12 x 10^{-8}
28L	9.45	64.1985	2.67 x 10^{-7}
10L	12.4	45.5769	6.44 x 10^{-8}
28R	10.65	63.7979	9.14 x 10^{-8}

Using the equations described in Section 2 for the probability of a landing or take-off accident, FL(x,y) and FT(x,y) for small and large transport aircraft, at location (x,y):

$$F_L(x,y) = \frac{x+3.275}{3.24} e^{\frac{=(x+3.275)}{1.8}} \left[\frac{56.25}{\sqrt{2\pi}} e^{-0.5(125y)^2} + 0.625e^{-\frac{|y|}{0.4}} + 0.005e^{-\frac{|y|}{5}} \right]$$

$$F_T(x,y) = \frac{x+0.6}{1.44} e^{\frac{=(x+0.65)}{1.2}} \left[\frac{46.25}{\sqrt{2\pi}} e^{-0.5(125y)^2} + 0.9635e^{-4.1|y|} + 0.08e^{-|y|} \right]$$

Table 13 Airfield related parameters – small & large transport

Runway Number	FL(x,y) Small Transport	FT(x,y) Small transport	FL(x,y) Large transport	FT(x,y) Large transport
10R	2.28E-06		2.28E-06	
10R		8.17E-10		8.17E-10
28L	9.41E-07		9.41E-07	
28L		7.86E-09		7.86E-09
10L	1.12E-06		1.12E-06	
10L		6.05E-11		6.05E-11
28R	3.37E-07		3.37E-07	
28R		1.29E-09		1.29E-09
11	9.14E-07		9.14E-07	
11		4.16E-10		4.16E-10
29	7.19E-07		7.19E-07	
29		7.67E-10		7.67E-10
16	6.90E-07		6.90E-07	
16		1.79E-08		1.79E-08
34	3.15E-06		3.15E-06	
34		3.70E-10		3.70E-10

8.3 Airway Related

Using the equation described in Section 3

$$C_A = \frac{N_A R_A \text{afac}}{\text{alt}}$$

where alt is the mean altitude of the airway in km, afac is the area factor, N_A is the annual number of movements on the airway and R_A is the aircraft in-flight reliability.

Table 14 Airway related parameters

Airway	X (km)	Altitude	N_A	afac	R_A	C_A
Lower	0.375	3.65	15,048	0.395	3.9×10^{-10}	6.35×10^{-7}
Upper	0.375	10.67	36,500	0.395	4.7×10^{-11}	6.35×10^{-8}

8.4 Aircraft Impact Frequency

Using the equation described in Section 5 for the effective target area of an unshielded cuboid structure subject to isotropically distributed aircraft approach directions:

$$A_E = lw + \frac{2}{\pi} h(w+l) \sum_{i=1}^{i=n} f_i \cot\theta_i$$

in which h, 1 and w are the cuboid dimensions and f_i is the proportion of crashing aircraft having descent angle θ_i .

Aircraft Category	**Length (m)**	**Height (m)**	**Width (m)**	**A_E (km^2)**	**Crash Rate (km^{-2} yr^{-1})**	**Impact Frequency (yr^{-1})**
Light aircraft, small and large transport aircraft, MCA incidents initiated over 2000 feet	200	52	130	0.0397	1.6×10^{-5}	6.36×10^{-7}
Helicopters	200	52	130	0.0366	1.38×10^{-5}	5.06×10^{-7}
Total				**0.0763**	**2.98×10^{-5}**	**1.14×10^{-6}**