anteagroup

Safety Assessment Grand Bahama

Risk Assessment for Pinder's Point, Lewis Yard and surrounding areas

project number 0415183.00
Final
November 8, 2017

Understanding today.
Improving tomorrow.

anteagroup

Safety Assessment Grand Bahama

Risk Assessment for Pinder's Point, Lewis Yard and surrounding areas

Project number 0415183.00
Final, revision 2.0
November 8, 2017

Authors
M.T.J. Pronk MSc
ir. J.B.R. Van der Schaaf
ir. F. Veldman - de Roo

Client
Minister of State in the office of the Prime Minister, Grand Bahama
Senator The Hon. James Kwasi Malik Thompson
Harold De'Gregory Complex (4th floor)
Freeport, Grand Bahama

Date release	Description revision	For approval	Release
Nov. 8, 2017	final, revision 2.0	J. van der Schaaf	M. Pronk

Table of Contents

1 Management letter

At the request of the former Minister for Grand Bahama, The Hon. Dr. Michael Darville, Antea Group has carried out a safety assessment relating the potential threats of the industrial activities at the Freeport Industrial Park to the people living in Pinder's Point, Lewis Yard and surrounding areas. The assessment took place between February and October 2017. In the safety assessment, Antea Group identified the possible threat from the activities at the Freeport Industrial Park by carrying out desk research (including analyzing and modelling the potential threats) and site visits.

Results of the safety assessment

The assessment shows that impact of the identified incident scenarios from Freeport Industrial Park on Pinder's Point or Lewis Yard is possible. The focus is on the incident scenarios from Buckeye Bahamas Hub, since there is no additional threat to the residents of Pinder's Point, Lewis Yard or other surrounding areas caused by the other companies considered.

The relevant credible incident scenarios at Buckeye Bahamas Hub are heavy fuel fires in the tank pits near the south-side boundary to Pinder's Point and Lewis Yard and the pipe trench to the jetty. The hazard associated with these scenarios is heat radiation. Parts of Pinder's Point and Lewis Yard would be unsafe, in the case of an actual fire in one of the aforementioned locations. Note that the effect distance (at ground level) is mainly restricted to the area inside the boundary of the company, and does not, therefore, heavily impact the residents of Pinder's Point or Lewis Yard.

Note: The chosen approach of the safety assessment is pessimistic. This means that the results represent the worst-case scenarios of the considered incidents. For more details on the scope of the assessment, see section 2.1.

Recommendations

In order to (directly) prevent fatalities and possible injuries among the residents of Pinder's Point and Lewis Yard in the case of an incident at Buckeye Bahamas Hub, Antea Group advises to create a safety buffer zone between the boundary of Buckeye Bahamas Hub and the residents areas of Pinder's Point and Lewis Yard. In the safety buffer zone restrictions on the use of land adjacent to the site concerned is implied. For the residents of Pinder's Point and Lewis Yard, this means the following:

1. Existing houses and constructions (in which residents may be present) within the determined safety buffer zone should be removed (removal);
2. Prevent development of new buildings or constructions (in which residents may be present) within the determined safety buffer zone (stand still).

Then, under the assumption that a tank pit fire incident is quickly detected and repressive measures are effectively taken (including timely alarm, complete evacuation and providing shelter to the residents of the residential areas nearby), there will be no victims (fatalities or injuries) among the residents in the case of an incident at Buckeye Bahamas Hub.

Safety buffer zone

For the separate tank pits at Buckeye Bahamas Hub the safety buffer zone was determined in the safety assessment. In figure 1.1 the safety buffer zone of the south-side tank pits of Buckeye

Bahamas Hub, existing of all the safety buffer zones united and smoothed out, is shown. In attachment III the safety buffer zone of this figure is included in a zoomed-in version. In this version, the individual objects are more recognizable.

Figure 1.1 The safety buffer zone border at the south-side of the border of Buckeye Bahamas Hub, smoothed out.

2 Introduction

The environmental health risks associated with the industrial park located near the communities of Pinder's Point, Lewis Yard, Hunters and Hawksbill of Grand Bahama have long been a source of citizen, activist and leadership concern.

At the request of the Minister of Grand Bahama, the Pan American Health Organization (PAHO) engaged the Institute for Risk Assessment Sciences (IRAS) of Utrecht University in the Netherlands to conduct an environmental health risk assessment [1]. One of the recommendations of the environmental health risk assessment is:

- A professional safety assessment related to the potential threats of fires, quakes, hurricanes and explosions to people living in Pinder's Point and Lewis Yard should be performed.

As a follow-up to this recommendation, the Minister for Grand Bahama asked Antea Group to carry out the necessary safety assessment. This took place between February and May 2017. In the safety assessment, the possible threat from the activities at the Freeport Industrial Park to the residents in Pinder's Point, Lewis Yard and Hawksbill was identified. This was done by carrying out desk research (including analyzing and modelling the potential threats) and site visits. This report contains the results of the safety assessment.

This report describes the work carried out and presents the effect distances of the companies involved. This was done for ten designated company of the Freeport Industrial Park, viz., Polymers international, PharmaChem, Grand Bahama Power Company, Bahama Rock, Freeport Container Port, Bahamian Brewery & Beverage Co., Bradfort Bahamas, Grand Bahama Shipyard, FOCOL and Buckeye Bahamas Hub. Based on the modelled effect distances it was determined which homes/residents of Pinder's Point or Lewis Yard are within the safety distances if there is a major accident at the designated companies at the Freeport Industrial Park. For the homes/residents of Pinder's Point and Lewis Yard which are not within the safety distances if there is a major accident, solutions and recommendations have been given.

This report is structured as follows:
Chapter 2: Introduction to the safety assessment. This contains a description of the scope of the assessment, the executed steps, and the companies and locations involved.
Chapter 3: Criteria
Chapter 4: Necessary background information.
Chapter 5: Results of the safety assessment. These results are given for each designated company and are also combined in an overview.
Chapter 6: Conclusions based on results.
Chapter 7: Recommendations of the safety assessment.

2.1 Scope of the assessment

Certain activities at the Freeport Industrial Park, while benefiting society, can threaten the surrounding area and can lead to major accidents. Such activities may imply restrictions on the use of land adjacent to the sites concerned, because of the need to preserve a suitable buffer zone between the activity sites and, for example, housing developments. In general, a major accident (also called incident) is the release of (a) hazardous substance(s) (loss of containment) which possibly leads to victims in the immediate vicinity of the company. At the Freeport Industrial Park of Grand Bahama, the storage and the use of hazardous materials by the companies pose possible threats to the residents in Pinder's Point and Lewis Yard (also called external safety).

The field of external safety focuses on activities with amounts of hazardous substances (classified by GHS-CLP) which, in case of release (loss of containment), could cause fatalities outside the boundaries of the companies in the short term. At Freeport Industrial Park, major accidents/incidents in the petro-chemical industry can occur because of:

- Fire;
- Explosion;
- Toxic releases.

Because of their influence on the industry

- quakes/blasts and
- hurricanes

have also been evaluated.

Note: In this assessment, it is also considered what effect quakes/blasts can have directly on the residential areas of Pinder's Point, Lewis Yard and the Hawksbill area.

In this assessment, the threat of fatalities and injuries from major accidents are calculated in terms of maximum effect distances for fatalities and injuries. Therefore, the hazards for the above stated incidents are:

- Fire: Radiation (kW/m^2);
- Explosion: Overpressure (barg);
- Toxic releases: Exposure of toxic substances (concentration in mg/m^3).

If the effect distance (1% fatalities, possible injuries) of a company under consideration does not reach the areas of Pinder's Point and Lewis Yard, there is no potential threat for the residents. If this is the case, no further steps are needed. However, if the effect distances reach the residents, there is a potential threat of fatalities if there is a major accident. In this case measures (called Lines of Defence) need to be taken.

The chosen approach of the safety assessment is pessimistic. This means the following:

- The focus is on accidents (incidents): Only sudden releases (of large amounts) of hazardous substances, no continuous releases (of small amounts) of hazardous substances.

- The focus is on short term exposure (1 hour) to heat radiation or toxic concentrations of hazardous substances (chemicals, specifically styrene). The exposure to smoke, which will be unhealthy and threatening, is not a part of this assessment.
- The focus is on immediate health effects (a few days maximum) and not on long term effects.
- In calculating the physical effects an exemplary substance is used, which gives more conservative results than the actual used substances. For instance, in this assessment N-nonane has been used as an exemplary substance for calculating the physical effects of crude-oil.

Additionally, the criteria for the selection of the incident scenarios, physical effects and threshold limits are based on the European Seveso III Directive[1] and the implementation of this directive in the Dutch Law.

Therefore, in total, the results from the calculations of this safety assessment are pessimistic. This means that the results represent the worst-case scenarios of the considered incidents. So, when one of the incidents as described in this assessment would actually occur in real life, the physical effects are at most equally large as the calculated results of this assessment.

2.2 Assessment steps

The safety assessment was carried out by going through the following steps:

Step 1 Desk research;
Step 2 First site visit;
Step 3 Analysis and modelling of potential threats; developing solutions;
Step 4 Second site visit;
Step 5 Drafting the final report;
Step 6 Third visit;
Step 7 Finishing the final report.

Steps 1 to 5 were carried out between February and April of 2017, steps 6 and 7 were carried out in October 2017.

In the first step, preliminary research was done on the policies of Grand Bahamas regarding external safety and on the agreements and deviations of these policies from the European and Dutch policies on external safety. Furthermore, it has been investigated which stakeholders (both public and private) and which companies (including their hazardous products and substances) needed to be taken into account. The results of this step are presented in chapter 2 of this report.

During the second step, the first site visit took place. In this step Machiel Pronk and Jaap van der Schaaf visited the Grand Bahamas from February 14 till 18, 2017. During this visit each company, which had been selected as relevant in step 1, was visited on site. In addition, the mutual expectations were determined, the information from the preliminary research was checked,

[1] Directive 2012/18/EU of the European Parliament and of the council of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC. This is also known as the Seveso III Directive.

complemented and (if necessary) adjusted. A feasibility discussion took place on the possible recommendations and solutions coming out of this assessment. The results of this step were taken as input for the following step(s).

In the third step the potential threats, as determined in step 1 and 2, were modelled and analyzed. In assessing the threat for external safety for each separate company we used the following method:

1. Make an inventory of hazardous substances;
2. Determine the containments of the hazardous substances including the amount (m^3), the pressure (barg), the phase (solid/liquid/gas) and the temperature of the substances;
3. Make a sub-selection of the relevant installations which may cause lethal effects outside the boundaries of the corresponding company, if incidents occur at the installation;
4. Calculate the effect distance for fatalities and possible injuries, and present it on a map.

By executing a standardized sub selection method, we were able to analyze which scenario of a loss of containment (LOC) situation can cause damage outside the boundary of the company under consideration. This selection has been made for three types of hazards, namely:

- Fire radiation (kW/m^2);
- Explosion overpressure (barg);
- Exposure of toxic substances (concentration in mg/m^3).

For each hazard type, the scenario with the largest effect has been modelled in Phast (version 6.7). Phast is the world's most comprehensive process industry hazard analysis software tool for all stages of design and operation. Phast examines the progress of a potential incident from the initial release to far-field dispersion including modelling of pool spreading and evaporation, and flammable and toxic effects. For external safety, the results of Phast are normally given in distance (meters) according to the criteria of fatality and possible injuries.

The results of some scenarios showed that residents of Pinder's Point or Lewis Yard are present within the effect distances. For these scenarios solutions have been developed and recommendations have been given. The results of step three are given in chapters 5 and 7.

In the fourth step the second site visit took place. In this step Machiel Pronk and Jaap van der Schaaf visited the Grand Bahamas from March 22 till 26, 2017. During this visit the provisional results of the safety assessment were presented and the consequences for the Ministry for Grand Bahama, the residents of Pinder's Point and Lewis Yard and the companies involved were discussed. In addition, insights into preventive measures were shared. The results of this step are used as input in the final step.

In the fifth step the final report is set up (first a draft version). All gathered information, gained insights and obtained results in step 1-4 are concisely presented. It can be used for further decision making and defining of the next steps regarding risk management for the Island of Grand Bahama. This report is the result of this last step of the assessment.

In the sixth step the third visit to Grand Bahama took place. On May 10, 2017 general elections were held. The draft version of the final report was discussed with the newly elected Ministry for Grand Bahama, i.e. the Minister of State for Grand Bahama Senator The. Hon. James Kwasi Malik Thompson, and the Grand Bahama Environmental Association.

In the seventh step the draft version of the final report is finished, resulting in the final report. In finishing the final report the feedback of the Ministry of Grand Bahama and the Grand Bahama Environmental Association on the draft version of the final report has been taken into account. In the final report, only changes were made to the introduction chapter and attachment IV compared to the draft of the final report.

2.3 Companies and locations involved

In this assessment, the following companies are involved:

A. Polymers International;
B. PharmaChem;
C. Grand Bahama Power Company;
D. Bahama Rock;
E. Freeport Container port;
F. Bahamian Brewery & Beverage Co.;
G. Bradfort Bahamas;
H. Grand Bahama Shipyard;
I. FOCOL;
J. Buckeye Bahamas Hub.

The locations of these companies are presented in Figure 2.1.

The selection criteria for companies in this study is the presence of hazardous substances in bulk or large amounts, large accessory effect distances or attention has been solid to the company in a previous study.

For this study, the relevant communities near the companies listed above are the communities of:

1. Pinder´s Point;
2. Lewis Yard.

The locations of these communities are also presented in Figure 2.1.

In the next sections the listed companies are further described. These explanations contain a short description of the companies' work sphere and the dangerous substances used, the maximum possible (external safety related) accident that can occur and the scenarios evaluated in this assessment. How the maximum possible accidents and the scenarios are derived in this assessment is explained in chapters 3 and 4.

Figure 2.1 Locations of the companies and residential areas involved.

days a week operation.

The EPS is made from Styrene monomer that is imported by sea by product tankers. The Styrene is pumped from the dock to one of the three chilled storage tanks. The storage tanks are placed in a bund that can contain the full-tank volume.

Maximum possible accident
The maximum possible accident that can happen is failure of a styrene storage tank (remote possibility). We have evaluated the largest tank in the largest tank-pit. This is the tank, and corresponding tank-pit, which is the nearest to Pinder's Point and Lewis Yard. The relevant hazard associated with Styrene is toxicity.
Given the amount of material and the location relative to Pinder's Point, Lewis Yard and also the Hawksbill area, the storage of Pentene is not relevant.

Scenarios
The scenarios evaluated are:
1. Failure of and fire in the largest Styrene tank (tank-fire);
2. Failure of and fire in the largest Styrene tank (tank-pit fire);
3. Failure of the Styrene tank, no ignition: dispersion of vaporized Styrene.

2.3.2 B. PharmaChem Technologies

Description
PharmaChem technologies is a chemical manufacturing facility that specializes in the production of Tenofovir Disoproxil Fumarate (TDF). This API (Active Pharmaceutical Ingredient) is used in HIV treatment. The facility is a 24 hours a day, 7 days a week operation.

The volume of the production reactors is relatively small. They are located inside the production building (Plant 2 is in use). A new production building is under construction at the south-side of the existing buildings.

Maximum possible accident
The maximum possible (external safety-related) accident that can happen is failure of a solvent tank in a tank pit resulting in a tank pit fire. In the assessment, such a fire was evaluated for the tank pit nearest to Pinder's Point and Lewis Yard.
Another large scenario is a liquid pool fire inside the reactor building. We evaluated such a fire in the large new building (that is now under construction).
The relevant hazard associated with TDF production is flammability.

Scenarios
The scenarios evaluated are:
1. Failure of and fire in solvent storage tank (tank-pit fire);
2. Failure of a reactor inside the new reactor building, resulting in an inside pool-fire and building in fire.

2.3.3 C. Grand Bahama Power Company

Description
The Grand Bahama Power Company Limited is a facility for power generation, transmission and distribution of electricity. The power is generated by diesel engines. The facility is a 24 hours a day, 7 days a week operation.

Maximum possible accident
The maximum possible accident that can happen is failure of a diesel storage tank (remote possibility). We have evaluated the largest tank / tank-pit. That tank is the near the old part of the facility east of Pinder's Point and Lewis Yard. The relevant hazard associated with diesel is flammability.

Scenarios
The scenario evaluated:
1. Failure and fire of the largest heavy Diesel tank (tank-pit fire).

2.3.4 D. Bahama Rock

Description
The Bahama Rock Limited facility mines and processes more than 6 million tons of aggregate material each year. The day to day work includes land clearing, dredging materials, preparing (drill holes) for blasting and controlled blasting.

The preparation for the controlled blasting process starts with the drilling of shot holes at a depth of 80 feet, which are fitted with a 4½ inch cardboard tube to maintain the integrity of the hole in the porous limestone. The cardboard cased holes are filled with solid oxidizer, liquid ammonium nitrate to approximately 14 feet below the surface grade. The packing of the tube continues by filling it with 0 -1½ inch sized stones to stem and muffle the sound of the blast.

It operates 2-12 hour shifts, 24 hours a day, 7 days a week.
Maximum possible accident
In Appendix I the impact of the blasts by Bahama Rock on the environment is discussed. From this analysis, it is concluded that the operations of Bahama Rock do not harm the buildings of Pinder's Point/Lewis Yard and also will not cause domino effects which can affect the residents of Pinder's Point/Lewis Yard. For more details, see chapter 5 results and Appendix I.

Scenarios
No incident scenarios were evaluated for this facility.

2.3.5 E. Freeport Container Port

Description
The Freeport Container Port Limited is owned by Hutchinson Port Holdings. The facility is operated in conjunction with the Freeport Harbour Company.

Freeport Container Port (FCP) operates a computerized 24 hours a day facility with state-of-the-art security.
Freeport Container Port commenced operations in 1997. It is located on Grand Bahama Island and is situated about 100 miles from the port of Miami, Florida. It is currently the deepest container terminal in the region and serves as a major container transfer hub for the eastern seaboard of the US and the principal east/west line-haul routes through the region.
FCP is capable of handling the largest container vessels in the world. Upon completion of the US$ 250 million Phase V Development, FCP will have total quay length of 1,536 meters, a yard area of 63 hectares, a depth alongside of 15.5 meters, nine post-Panamax cranes and one super-post-Panamax quay crane.

Maximum possible accident
Given the distance between the container port and the Pinder's Point / Lewis Yard area, the small percentage of dangerous cargos.that are transshipped, the relatively small packaged products (tank containers), the effects of an accident will not reach the Pinder's Point / Lewis Yard area.

Scenarios
No scenarios were evaluated for this facility

2.3.6 F. Bahamian Brewery and Beverage Co.

Description
The Bahamian Brewery and Beverage Company Limited was commissioned in 2007 and produces beverages. The dangerous materials used are predominantly meant for cleaning. They are stored as packages. Not in bulk. They pose no threat to the area outside the fence. Also, the CO_2 plant poses no threat to the surrounding area, in the case that something goes wrong.

Maximum possible accident
The cooling at the brewery is not done by a cooling machine with ammonia as a cooling agent. That would be the only way in which a brewery could cause external safety effects in the case of an accident.

Scenarios
No scenarios evaluated for this facility.

2.3.7 G. Bradford Marine

Description
The Bradford Marine Bahamas facility is a yacht and vessel repair facility whose scope of work includes painting, surface refurbishment, lifting, hauling, welding, engine repair, etcetera.

Maximum possible accident
There are small scale storages of hazardous materials (diesel fuel tanks, paints, acetylene for cutting steel, etcetera). They are not stored in bulk. Incidents will not pose threats to the area outside the fence.

Scenarios
No scenarios evaluated for this facility.

2.3.8 H. Grand Bahama Shipyard

Description
The Grand Bahama Shipyard is a ship repair facility with large docks, primarily aimed at large cruise ships and other larger vessels. The scope of work includes painting, surface refurbishment, lifting, hauling, welding, engine repair etcetera.

Maximum possible accident
There is relatively small scale storage of hazardous materials (diesel fuel tanks, paints, acetylene for cutting steel, etcetera). They are not stored in bulk. Incidents will not pose threats to the are outside the fence.

Scenarios
No scenarios evaluated for this facility.

2.3.9 I. Freeport Oil Company (FOCOL)

Description
Freeport Oil Company (FOCOL) is a fuel storage and distribution facility that manages the following products: Jet Fuel, Motor Gasoline, Diesel and LPG.

The main operation of the facility consists of nine above ground storage tanks that are located at the North-Eastern section of the main facility. The storage tanks are all located inside a tank-pit (secondary containment).

Maximum possible accident
Given the distance between the FOCOL facility and the Pinder's Point/Lewis Yard area and with the scale of the tank storage, the effects of an accident (tank fire, tank-pit fires) will not reach the Pinder's Point/Lewis Yard area.

Scenarios
No scenarios evaluated for this facility.

2.3.10 J. Buckeye Bahamas Hub

Description
Buckeye Bahamas Hub is a petroleum products terminal. Buckeye Bahamas Hub currently has over 26 million barrels of storage capacity and eight berths, including two VLCC-capable berths. Storage includes capacity for crude oil, fuel oil and VGO, diesel fuel, and gasoline and components. These products are imported from locations around the world and stored or blended at Buckeye Bahamas Hub for export, including to regional consumers, key import locations in the Americas, and long-haul markets in Asia. The facility is a 24 hours a day, 7 days a week operation.

Maximum possible accident
The maximum possible accident that can happen in the terminal near the fence is tank failure and subsequently a tank fire or a tank-pit fire. We evaluated the tanks and tank pits nearest to Pinder's Point and Lewis Yard.

Scenarios
The scenarios evaluated are:
1. Failure and fire in the largest heavy oil (floating roof) storage tank (tank-fire);
2. Pipe failure and trench fire in the pipe-trench from terminal to the jetty;
3. Failure and fire in all the tank-pits along the fence near Pinder's Point/Lewis Yard.

3 Criteria

To determine the impact criteria of this assessment, it is important to clarify what or whom needs to be protected against the impact of certain incidents. In this safety assessment, the residents of Pinder's Point, Lewis Yard and the Hawksbill area are the relevant subjects which need to be protected from the industrial activities at the Freeport Industrial Park. The focus of protection and the impact criteria of this assessment are discussed in the following sections.

3.1 Focus of protection

The goal of a safe environment is to protect people from incidents involving hazardous substances. This includes the possibility of survival. Survival in this case means sufficient fresh air to breath and, depending on the effect of the incident, protection against heat radiation, temperature and toxicity.

Self-reliance
Protection includes the possibility for people to rescue and remove themselves to a safe environment. People who are unable to do this need to have protection which is attuned accordingly. For instance, less mobile people, such as people in wheelchairs, the elderly and children, may need help to rescue themselves or need to be brought to safety by others. Restrained mobile people always need to be brought to safety by others during an incident.

There are a lot of factors which determine if people are capable of rescuing themselves or if they can be brought to safety by others. Among these factors are:

- Is the person concerned awake or asleep?
- Is the person concerned mobile, less mobile or restrained mobile?
- Is the person concerned alone or in a group of people?
- Is there a group of vulnerable people or less self-reliant people (such as children in a school, or clients/patients in a clinic or hospital)?
- Is the person concerned familiar or unfamiliar with the environment?
- Is the person young or old?
- Is there a trained emergency organization with sufficient capacity?

Self-reliance in case of fire is determined by the sentience, the threat and the actions of people after detecting an incident and identifying the flight possibilities.

Protection by fleeing or hiding
In the consideration of a safe environment it should be recognized that people can be present both inside or outside buildings. The protection offered by a building may be sufficient to survive for a shorter or longer period of time.

Reaching a safe environment may be achieved by fleeing, hiding or a combination of these. In finding a shelter to hide, two possibilities are distinguished:

1. hiding in a temporary safe place (also called 'shelter in place');
2. hiding in a longer-lasting safe place (also called 'safe haven').

In case of finding protection, the following holds:

- Flight is the activity by which people try to reach a safe environment unaided;
- Evacuation is the activity in which people are helped by others to reach a safe environment;
- A 'shelter in place' is an environment in which people are sufficiently protected in order to survive for a shorter period of time;
- A 'safe haven' is an environment in which people are sufficiently protected in order to survive for a longer period of time until the environmental conditions are back to normal.

3.2 Impact criteria

As stated in chapter 2, the following incidents and accompanying hazards are considered:

- Fire: Radiation (kW/m^2);
- Explosion: Overpressure (barg);
- Toxic releases: Exposure of toxic substances (concentration in mg/m^3).

Note: Another hazard accompanying the incident of fire, is smoke. Smoke contains unhealthy/toxic combustion products and exposure to these products needs to be avoided. However, the location of smoke and the exact hazards are more difficult to predict than for radiation. The distribution and the concentration of smoke in the air is dependent of the wind (only the down-wind area is threatened by smoke), atmospheric conditions (more or less turbulence), the nature of the burning substance and the heat of the fire. For instance, a hot fire produces a lot of thermal 'lift' (i.e. plume rise). This causes smoke to rise quickly to great altitude and the environment close to the fire is in less danger. At a certain distance, the smoke will reach ground level again, but this smoke is diluted and its harmfulness is reduced. The advice from the government to close all doors and windows, and to shut down all indoor ventilation, is in this case in place. Smoke is not considered further in this assessment.

In this assessment, the impact criteria used in risk evaluations of large incidents involving hazardous substances, executed in compliance with European legislation[2], are applied.
In the following sections the impact criteria of the above stated incident types are explained.

3.2.1 Fire

The criteria for heat radiation is given in table 3.1. The heat radiation impact criteria[3] are given in both SI units and in imperial units.

Table 3.1 Heat radiation impact criteria

---

[2] Directive 2012/18/EU of the European Parliament and of the council of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC. This is also known as the Seveso III Directive.

[3] The impact criteria levels in Europe are in SI units (i.e. kW/m^2; kilowatts per square meter). In the Bahamas the imperial units are applied (i.e. $BTU/(h*ft^2)$; British thermal unit per hour, per square foot). Therefore, the impact criteria levels for heat radiation have been conversed from kW/m^2 to $BTU/(h*ft^2)$. The conversion factor is 1 kW/m^2 = 316,9983 $BTU/(h*ft^2)$. However, the above stated levels are round down or up to fifties.

Heat radiation				
Level		Impact		
kW/m^2	$BTU/(h*ft^2)$	Persons	Buildings	Constructions
35	11.100	Unsafe, 100% exposed death	On fire, cooling needed	Cooling essential
10	3.200	Unsafe, 1% exposed death / severe wounds	To be cooled	To be cooled
3	950	Safe when protected (inside building, protective clothing)	-	-
1	300	Safe	-	-

For the denoted heat criteria in table 3.1 the following holds:

0 - 1 kW/m^2
In the region between 0 and 1 kW/m^2 (i.e. between 0 and approximately 300 $BTU/(h*ft^2)$) it is not necessary to flee or evacuate. This is a safe environment.

1 - 3 kW/m^2
In the region between 1 and 3 kW/m^2 (i.e. between approximately 300 and 950 $BTU/(h*ft^2)$) it is safe to flee or evacuate without extra protection (clothing or other shielding).

Outside of the 3 kW/m^2 region
Outside of the 3 kW/m^2 region (i.e. outside the approximately 950 $BTU/(h*ft^2)$) the following holds:

- It is safe to flee if protective clothing is worn and the direction of flight/evacuation is away from the fire;
- Less mobile people are helped to flee or are evacuated by mutual aid; and
- Restrained mobile people have sufficient shelter within their houses to wait for notified aid workers to help them flee or evacuate.

3 – 10 kW/m^2
In the region between 3 and 10 kW/m^2 (i.e. between approximately 950 and 3.200 $BTU/(h*ft^2)$) heat radiation can be hazardous to unprotected people. In this region, heat radiation is not high enough to be hazardous to buildings or constructions. Therefore, buildings and constructions may provide a 'shelter in place' for fleeing or evacuated people. Note that it is too dangerous to start fleeing or evacuating people in an environment which is already 10 kW/m^2 (i.e. approximately 3.200 $BTU/(h*ft^2)$). Besides, people will most likely be reluctant to attempt to flee or evacuate in such environments.

10 – 35 kW/m^2
Brick or concrete walls can resist a heat radiation of 35 kW/m^2 (i.e. 11.100 $BTU/(h*ft^2)$). This does not hold for wood. Wood can resist at most 10 kW/m^2 (i.e. 3.200 $BTU/(h*ft^2)$). Hence, constructions and houses with window frames, gutters and/or roofs made out of wood cannot

protect or shelter people against heat radiation of 10 kW/m^2 or higher. In general it is stated that in the region between 10 and 35 kW/m^2 (i.e. between approximately 3.200 and 11.100 $BTU/(h*ft^2)$, respectively) the heat radiation is sufficient to cause escalation or transference to other buildings or constructions. Exposure to 35 kW/m^2 for people is 100% fatal. In other words, areas of constructions or houses with wooden parts are not safe environments.

3.2.2 Explosion

In the performance of step 3 of this safety assessment (see also section 2.2), it became clear that, because of the environmental storage conditions, the (flammable) hazardous substances under consideration cannot reach the region between their lower explosion levels (LEL's) and upper explosion levels (UEL's). Therefore, the incident type 'explosion' is not further considered in this report.

3.2.3 Toxic release

The criteria for toxic load is given in table 3.2. Note that each toxic substance has specific intervention values (i.e. Awareness Value (AV), Alarming Limit Value (ALV) and Life Threatening Value (LTV)). These values are determined by excessive research and are regularly updated. In this safety assessment, the intervention values are derived from [4]].

Table 3.2 Toxic load impact criteria

Toxic load		
Level	**Meaning**	**Impact on persons**
LTV	Life Threatening Value	Unsafe: **Death possible** within days after 1 hour exposure
ALV	Alarming Limit Value	Unsafe: Severe health problems possible after 1 hour exposure
AV	Awareness Value	People can get **worried** because of smell

4 Theoretical background information

This chapter contains useful technical background information used in this safety assessment. Firstly, the bow-tie model is explained. This model has been applied in analyzing the processes. Secondly, emergency and risk management are discussed. These provide the safeguards which are/could be put in place. Next, a model used to identify the incident scenarios is explained. This model has been applied in analyzing the emergency management activities that are, or need to be, activated in order to safeguard the residents and combat the incident. Finally, the approach to incidents and the emergency intervention as a system is illustrated.

4.1 Bow-tie model

In order to identify a hazardous situation, the use of the bow-tie model has been proven effective. It is an analytical technique which consists of two parts (see also figure 4.1):

- The first part is a 'causes' line (left side of the figure). An LOC situation is often an accumulation of events. It starts with a basis cause which leads to, if not effectively stopped (i.e. safely terminated), a Loss of Containment (LOC) situation.
- The second part is an 'effects/consequences' line (right side of the figure) which starts at the LOC situation and leads to, if not effectively stopped (i.e. safely terminated), the (maximum) effect of the LOC (i.e. possible unsafe termination).

The goal is to safely terminate the incident, preferably before the LOC situation takes place.

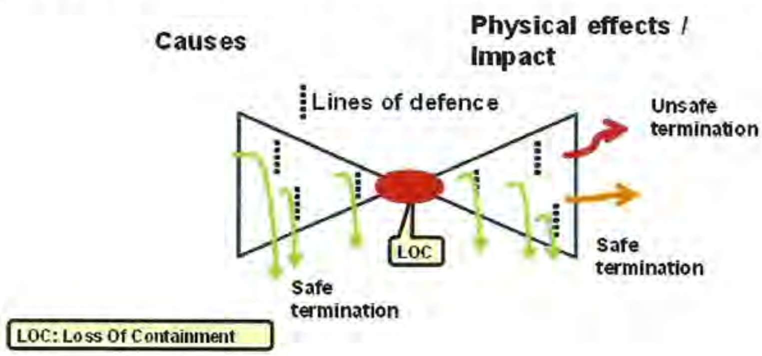


Figure 4.1 Bow-tie model.

Relevant incident scenarios
The right side of the bow-tie is also known as an effect tree. An effect tree is a flow diagram which starts at the LOC situation, indicates the possible progresses of the scenario and ends at the possible damaging effects of the incident. In this way, all possible damaging effects associated with a LOC situation can be identified. Another example of an effect tree, besides the right side of the bow-tie model, is the flow diagram of figure 4.2 [3]. This has been applied in this assessment to identify the relevant incident scenarios. Note that the red-circled elements in figure 4.2 indicate the relevant damaging effects, which are the basis of the relevant incident

scenarios of this assessment (see also section 3.3). These incident scenarios are further discussed for each designated company in chapter 5.

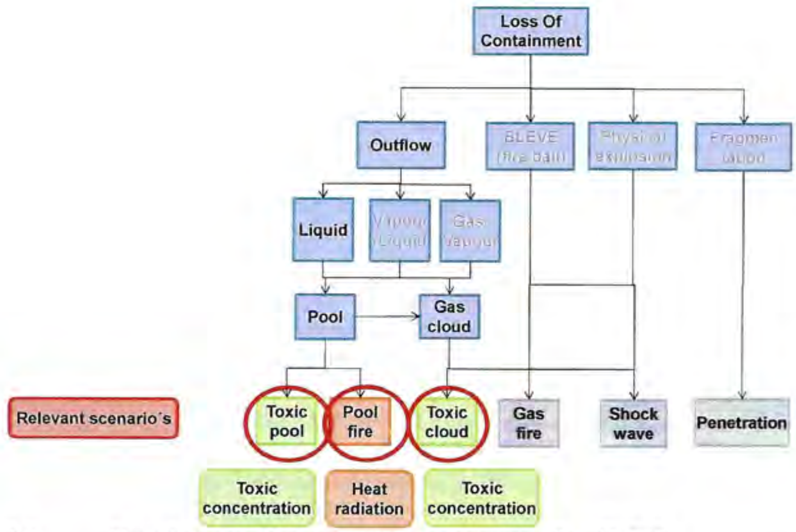


Figure 4.2 Flow diagram effect trees instantaneous outflow/BLEVE.

In figure 4.3 a schematic, simplified representation of the course of the relevant incident scenarios is given [2].

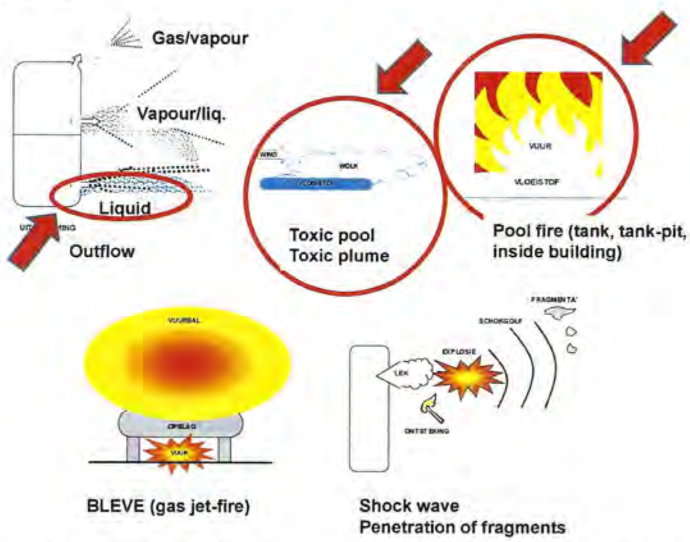


Figure 4.3 Schematic, simplified representation of the incident scenarios.

The red-circled parts of figure 4.3 indicate the relevant outflow and relevant incident scenarios of this assessment (see also section 3.3.)

4.2 Emergency and Risk management

Incidents must be controllable and combatable. So, in order to safely terminate incidents Lines of Defence (LODs; see also figure 4.1), i.e. technical or organizational measures, are applied. Such measures can either be preventive or repressive.

LODs belonging to the left side of the bow-tie model are preventive measures. Both the companies and the government can play a role in the implementation of such measures. Examples of preventive LODs which companies can organize themselves are:

- safe design of the installations (technical);
- safe operation (organizational);
- safety management systems (organizational).

Examples of preventive LODs in which the government can play a role are:

- permits (organizational);
- inspections (organizational).

Safe termination in this case means that the successions of causes leading to a LOC situation has been stopped and that the risky state has been safely contained.

LODs designed to safely terminate the LOC situation before the actual hazard occurs, i.e. loss of substance without ignition (fire or explosion) or evaporation (toxic plume), belonging to the right side of the bow-tie model are repressive measures. In organizing these measures both the companies and the government play a role.
Examples of repressive LODs which companies can or must organize themselves are:

- (early) detection of the LOC (technical);
- stopping/limiting the source (technical);
- intervening in the process (technical);
- activating protective installations/equipment (such as water or foam; technical);
- preparing for possible incidents (organizational);
- notifying the authorities (organizational).

Repressive LODs in which the government and the company can together play a role are focused on emergency relief such as:

- having and practicing a Preparedness Response Plan (organizational);
- having industrial accident scenarios (organizational);
- mutual aid (organizational).

Safe termination in this case means, besides preventing the actual hazard occurring as stated above, that the LOC situation is prevented from developing to its maximum effect.

In reality, all causes, which may lead to a LOC situation, should be taken into account in the design of the installations by enabling detection (automatically and/or by hand) and control of dangerous situations (incidents and near misses). Although most LOC situations are controlled by measures, it remains possible that a LOC situation can occur and lead to external effects (effects outside the boundaries of the company involved). Rarely do such external effects cause human injury or does external safety become an issue. Nonetheless, external emergency preparedness and an effective organization are paramount.

In order to determine the scale and the quality of the repressive measures that need to be taken, we often talk about *normative scenarios*. Normative scenarios are scenarios with significant risks and are used to set the norm of the safety management of a company. In chapter 5 the normative scenarios for the Freeport industrial park are given.

4.3 Risk situation as a system

The course of the physical part of an incident, from the source to possible victims, can be approached as a system [2]. This is represented in figure 4.4. Below figure 4.4 each element is discussed individually. This system can be used to set up an Emergency Response Plan.

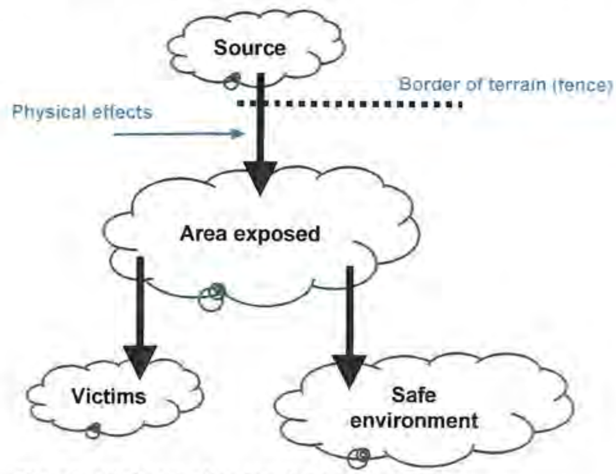


Figure 4.4 The physical part of an incident as a system.

Source
When an incident occurs, the source is considered to be the location where the incident has taken place. From this location, the unwanted physical effects of the incident arise in the surrounding area.

Area exposed
The area exposed is considered to be the study area around the source, outside the site boundary of the company, which can be exposed to physical effects. The locations within the area exposed where vulnerable people and objects are located are of most interest for external safety.

The size of the area exposed can be estimated and is determined by:
- The type of the physical effect (fire, explosion or toxic load);
- The extent of the source;
- The hazardous material involved and the amount;
- The distance from the source;
- Weather conditions (wind speed, wind direction, turbulence).

Safe environment
People in the safe environment are not exposed to the physical effects of the incident because of shelters (inside house with windows and doors closed, for instance) and/or evacuation. The safe environment is, by definition, the area outside the area exposed and may be also cover locations within the area exposed.

Victims (external safety)
Victims are the people who are hurt through the effects of the incident and who are in need of medical help to reduce their injuries or to be stabilized. Also, fatalities fall into this category. Note that 'victims' are defined as being inside the area exposed, but outside the site boundary of the company involved. The casualties within the company where the incident has occurred, are not considered victims in the sense of external safety. (They are victims in the sense of internal safety, which is not the scope of this assessment).

For the reduction of the damage in the area exposed, and according to the number of victims and the severity of the injuries, the incident control organization can intervene in the acute phase of the incident at five levels:

1. Source control: The extent of the source is controlled (i.e. minimized) or the chance of ignition (fire or explosion) or evaporation (toxic plume) is reduced.
2. Effect control: The extent of the LOC situation is controlled (i.e. minimized), i.e. the extent of the amount and/or the concentration of the hazardous substance that is released and has negative effects for the environment is controlled (i.e. minimized).
3. Dose reduction: The dose, which is a combination of the concentration and the duration of the exposure of the hazardous substance, to which the residents are exposed, is reduced. This reduction can be achieved by stimulating protective measures such as staying indoors, shutting doors and windows, and shutting down ventilation indoors.
4. Reduction in number of people exposed: The (potential) number of people in the area exposed is reduced by stimulating flight or evacuation.
5. Casualty treatment: The casualties caused by the incident are minimized by medically treating the victims.

In figure 4.5 this is presented as a system (comparable to figure 4.4).

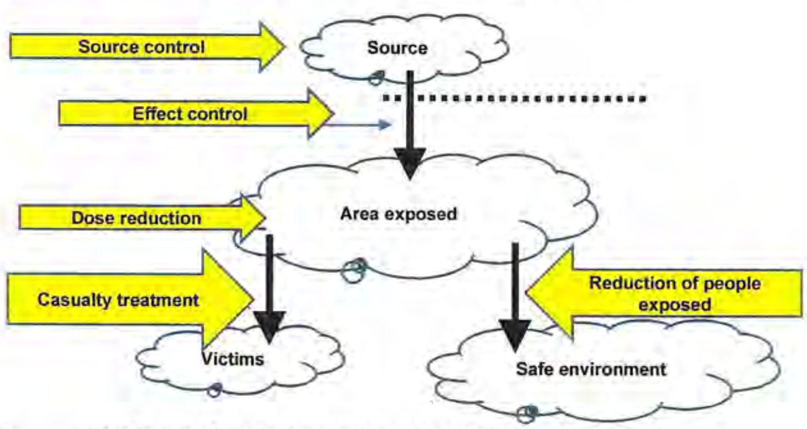


Figure 4.5 Five levels of acute emergency intervention as a system.

5 Results

This chapter contains the results of the analysis and modelling of the safety assessment.

5.1 Introduction

As described in chapter 2, in assessing the threat for external safety for each of the designated companies we have used the following method:

1. Make an inventory of hazardous substances;
2. Determine the containments of the hazardous substances including the amount (m^3), the pressure (barg), the phase (solid/liquid/gas) and the temperature of the substances;
3. Make a sub-selection of the relevant installations which may cause fatal effects outside the boundaries of the corresponding company, if incidents occur at the installation;
4. Calculate the effect distance for fatalities and (possible) injuries and present it on a map.

5.1.1 Relevant incident scenario's

By following the steps of this method, the relevant incident scenarios for the Freeport Industrial Park were identified and modelled. An overview of the relevant incident scenarios is given in table 5.1.

Table 5.1 Relevant incident scenarios for the safety assessment.

Relevant incident scenarios			
Company	**Hazardous substance**	**Hazard**	**Incident scenario's**
1. Polymers International	Styrene	Fire and toxic release	1. Tank fire 2. Pit fire 3. Toxic exposure from pit
2. PharmaChem Technologies	Solvent	Fire	1. Tank pit 1 fire 2. Tank pit 2 fire 3. Fire in new building
3. Grand Bahama Power Company	Heavy fuel	Fire	1. Tank pit 1 fire 2. Tank pit 2 fire
4. Buckeye Bahamas Hub	Heavy fuel	Fire	1. Tank fire 2. Tank pit (pool size 42.000 m^2) fire 3. Pipe trench fire 4. Tank pit (pool size 10.000 m^2) fire 5. Tank pit (pool size 290 m x 290 m) fire 6. Tank pit (pool size 370 m x 370 m) fire 7. Tank pit (pool size 135 m x 135 m) fire

For each incident scenario in table 5.1 there is a scenario description, with the details of the scenario and the results of the modelling (including the presentation of the effect distances on the map). This can be found in the technical background document (TBD) associated with this safety assessment report[4].

Note:

1. The scenarios in table 5.1 are the normative scenarios for the Freeport industrial park (see also section 4.2).
2. The modelling has been executed in Phast (version 6.7).
3. For more technical background information on tank (pit) fires see [5] and [6].

5.1.2 Effect distances

In the presentation of the radiation results (of fully developed fires), i.e. of the effect distances on the map, the various lines and colors have the following meanings:

- - - - **Dotted green line**: 1 kW/m² (i.e. 300 BTU/(h*ft²)) radiation contour, down-wind.
——— **Solid green line**: 1 kW/m² (i.e. 300 BTU/(h*ft²)) radiation contour, up-wind.
- - - - **Dotted yellow line**: 3 kW/m² (i.e. 950 BTU/(h*ft²)) radiation contour, down-wind.
——— **Solid yellow line**: 3 kW/m² (i.e. 950 BTU/(h*ft²)) radiation contour, up-wind.
- - - - **Dotted red line**: 10 kW/m² (i.e. 3.200 BTU/(h*ft²)) radiation contour, down-wind.
——— **Solid red line**: 10 kW/m² (i.e. 3.200 BTU/(h*ft²)) radiation contour, up-wind.

Note:

1. The radiation contours are associated with fully developed fires.
2. The dotted line, the down-wind contour, is always larger than the solid line of the same color, the up-wind contour.
3. The 35 kW/m² (i.e. 11.100 BTU/(h*ft²)) radiation contours are not shown on the maps.

Most of the time at the Freeport Industrial Park the sea wind blows in the direction of Buckeye Bahamas Hub, where most relevant incident scenarios are located. Hence, most of the time the up-wind radiation contours are relevant. Nevertheless, the results in this chapter are given for the worst-case situation, namely down-wind weather conditions (represented by dotted contours). For Buckeye Bahamas Hub, the up-wind weather conditions (represented by the solid contours) are also given. Furthermore, the radiation results are given for standard weather type[5] D5.

In the presentation of the toxic exposure results, i.e. of the effect distances on the map, the various symbols/lines and colors have the following meanings:

Blue filled ellipse: Toxic plume (windward)
- - - - **Dotted green line**: Awareness Value (AV) contour.
- - - - **Dotted orange/yellow line**: Alarming Limit Value (ALV) contour.

[4] "Technical Background Document for the Safety Assessment Grand Bahama, Antea Group, November 8, 2017."
[5] D5 is neutral weather type with wind speed of 5 m/s (i.e. approximately 16,5 ft/s).

- - - - **Dotted red line**: Life Threatening Value (LTV) contour.

Note that the toxic exposure results in this chapter, i.e. third scenario of Polymers International (scenario 1.3 of the TBD), are calculated for both standard weather types[6] D5 and F1,5. The presented results, i.e. the effect distance on the map, is given for weather type D5.

5.2 Overview results

In figure 5.1 an overview of the results, i.e. the effect distances presented on a map, is given. The overview is an indication of what the results of the modelled incident scenarios look like. Note that not all the results are contained in the overview figure. This is done in order to keep the figure clear and transparent.

In the overview of figure 5.1 scenarios 1.2, 1.3, 2.2, 2.3, 3.1, 4.2 and 4.3 are presented.

Figure 5.1 Overview of the safety assessment results.

This overview already shows that residents of Pinder's Point or Lewis Yard are present within the effect distances of some scenarios. This is further discussed in chapter 6.

[6] F1,5 is a stable weather type with wind speed of 1,5 m/s (i.e. approximately 5 ft/s).

5.3 Polymers International

For Polymers International the relevant incident scenarios, which are normative (with maximum impact) from the external safety point of view, are:

1. A tank fire with styrene (scenario 1.1 in the TBD);
2. A tank pit fire with styrene (scenario 1.2 in the TBD) and
3. A toxic cloud of styrene from a pool in the tank pit (scenario 1.3 in the TBD).

The calculated effect distances of the fire incident scenarios are given in table 5.2 and of the toxic release incident scenarios in table 5.3. For more details of the scenarios and the presentation of the effect distances on the map for each single scenario, please see the Technical Background Document (TBD) of this Safety Assessment, Appendix IV sections 1.1 till 1.3.

Table 5.2 Effect distances of fire incident scenario's Polymers International.

Polymers International					
Scenario	**Nature of effect**	**Effect criterion**		**Effect distance at ground level**	
		kW/m²	**BTU/(h*ft²)**	**Meters**	**Feet**
1.1 Styrene - tank fire	Liquid pool fire	35	11.100	Not reached	Not reached
		10	3.200	Not reached	Not reached
		3	950	26	85
		1	300	68	223
1.2 Styrene - pit fire	Liquid pool fire	35	11.100	Not reached	Not reached
		10	3.200	20	66
		3	950	80	262
		1	300	140	459

Table 5.3 Effect distances of toxic release incident scenario Polymers International.

Polymers International						
Scenario	**Nature of effect**	**Effect criterion for styrene**			**Effect distance at ground level**	
		Level	**Concentration**		**Meters**	**Feet**
			ppm	**mg/m³**		
1.3 Styrene - toxic exposure from pit	Toxic plume	LTV	1.081	4.700	20	66
		ALV	124	540	50	164
		AV	0,55	2,4	1080	3542

Conclusions for Polymer International:

- In the case of a fire (tank or pit), there is no impact on the residents of Pinder's Point or Lewis Yard.
- In the case of a toxic release of styrene, no toxic loads with dangerous levels for human health reach Pinder's Point, Lewis Yard or the Hawksbill area.
- Additionally, it is not possible for the Awareness Value (AV; i.e. lowest impact criteria for toxic load) to reach the residential areas of Pinder's Point, Lewis Yard or Hawksbill under the most common weather conditions (D5). Only under exceptional weather conditions (F1,5) it might be possible that residents smell styrene, in the case of an incident with a pool of styrene in the tank pit at Polymers International. Nevertheless, in that exceptional case it is only the smell of styrene, which may result in public concern, but the concentration is not hazardous to human health. Note that it will be most noticeable (in smell, no health effects) in the Hawksbill area when the wind direction is coming from the West or North-West.

5.4 PharmaChem Technologies

For PharmaChem Technologies the relevant incident scenarios, which are normative (with maximum impact) from the external safety point of view, are:

1. A tank pit fire with solvent (scenario 2.1 in the TBD);
2. A tank pit fire with solvent (scenario 2.2 in the TBD) and
3. Fire in the new building with solvent (scenario 2.3 in the TBD).

The calculated effect distances of the fire incident scenarios of are given in table 5.4. For more details of the scenarios and the presentation of the effect distances on the map for each single scenario, please see the TBD of this Safety Assessment, sections 2.1 till 2.3.

Table 5.4 Effect distances of fire incident scenario's PharmaChem Technologies.

PharmaChem Technologies					
Scenario	**Nature of effect**	**Effect criterion**		**Effect distance at ground level**	
		kW/m²	**BTU/(h*ft²)**	**Meters**	**Feet**
2.1 Solvent - tank pit 1 fire	Liquid pool fire	35	11.100	3	10
		10	**3.200**	20	66
		3	**950**	45	148
		1	**300**	80	262
2.2 Solvent - tank pit 2 fire	Liquid pool fire	35	11.100	7	23
		10	**3.200**	25	82
		3	**950**	45	148
		1	**300**	75	246

2.3 Solvent - fire in new building	Liquid pool fire	35	11.100	3	10
		10	**3.200**	24	79
		3	950	65	213
		1	300	120	394

Conclusions for PharmaChem Technologies:

- In the case of a fire (tank pit or building), there is no impact on the residents of Pinder's Point or Lewis Yard.

5.5 Grand Bahama Power Company

For Grand Bahama Power Company the relevant incident scenarios, which are normative (with maximum impact) from the external safety point of view, are:

1. A tank pit fire with heavy fuel (scenario 3.1 in the TBD);
2. A tank pit fire with heavy fuel (scenario 3.2 in the TBD).

The calculated effect distances of the fire incident scenarios of are given in table 5.5. For more details of the scenarios and the presentation of the effect distances on the map for each single scenario, please see the TBD of this Safety Assessment, sections 3.1 and 3.2.

Table 5.5 Effect distances of fire incident scenario's Grand Bahama Power Company.

Grand Bahama Power Company					
Scenario	**Nature of effect**	**Effect criterion**		**Effect distance at ground level**	
		kW/m²	**BTU/(h*ft²)**	**Meters**	**Feet**
3.1 Heavy fuel - tank pit 1 fire	Liquid pool fire	35	11.100	Not reached	Not reached
		10	**3.200**	24	79
		3	950	58	190
		1	300	88	289
3.2 Heavy fuel - tank pit 2 fire	Liquid pool fire	35	11.100	Not reached	Not reached
		10	**3.200**	10	33
		3	950	38	125
		1	300	38	125

Conclusions for Grand Bahama Power Company:

- In the case of a tank pit fire, there is no impact on the residents of Pinder's Point or Lewis Yard.

5.6 Bahama Rock

As described in section 2.3.4, no incident scenarios were evaluated for this facility.

5.7 Freeport container port

As described in section 2.3.5, no incident scenarios were evaluated for this facility.

5.8 Bahamian Brewery & Beverage Co.

As described in section 2.3.6, no incident scenarios were evaluated for this facility.

5.9 Bradfort Bahamas

As described in section 2.3.7, no incident scenarios were evaluated for this facility.

5.10 Grand Bahama Shipyard

As described in section 2.3.8, no incident scenarios were evaluated for this facility.

5.11 FOCOL

As described in section 2.3.9, no incident scenarios were evaluated for this facility.

5.12 Buckeye Bahamas Hub

For Buckeye Bahamas Hub the relevant incident scenarios, which are normative (with maximum impact) from the external safety point of view, are:

1. A tank fire with heavy fuel (scenario 4.1 in the TBD);
2. A tank pit (pool size 42.000 m^2, i.e. 137.795 ft^2) fire with heavy fuel (scenario 4.2 in the TBD);
3. A pipe trench fire with heavy fuel (scenario 4.3 in the TBD);
4. A tank pit (pool size 10.000 m^2, i.e. 32.808 ft^2) fire with heavy fuel (scenario 4.4 in the TBD);
5. A tank pit (pool size 290 m x 290 m, i.e. 951 ft x 951 ft) fire with heavy fuel (scenario 4.5 in the TBD);

6. A tank pit (pool size 370 m x 370 m, i.e. 1.214 ft x 1.214 ft) fire with heavy fuel (scenario 4.6 in the TBD);
7. A tank pit (pool size 135 m x 135 m, i.e. 443 ft x 443 ft) fire with heavy fuel (scenario 4.7 in the TBD);

The calculated effect distances of the fire incident scenarios are given in table 5.6. For more details of the scenarios and the presentation of the effect distances on the map for each single scenario, please see the Technical Background Document (TBD) of this Safety Assessment, Appendix IV sections 4.1 till 4.7, and to Appendix II.

Note: When interpreting the given results, it should be kept in mind that in Pinder's Point and Lewis Yard the wind is predominantly up-wind.

Table 5.6 Effect distances of fire incident scenario's Buckeye Bahamas Hub.

Buckeye Bahamas Hub					
Scenario	**Nature of effect**	**Effect criterion**		**Effect distance at ground level**[7]	
		kW/m²	**BTU/(h*ft²)**	**Meters**	**Feet**
4.1 Heavy fuel - tank fire	Liquid pool fire - down-wind	35	11.100	Not reached	Not reached
		10	**3.200**	Not reached	Not reached
		3	**950**	65	213
		1	**300**	138	453
	Liquid pool fire - up-wind	35	11.100	Not reached	Not reached
		10	**3.200**	Not reached	Not reached
		3	**950**	Not reached	Not reached
		1	**300**	Not reached	Not reached
4.2 Heavy fuel - tank pit fire (pool size 42.000 m², i.e. 137.795 ft²)	Liquid pool fire - down-wind	35	11.100	Not reached	Not reached
		10	**3.200**	25	82
		3	**950**	175	574
		1	**300**	325	1.066
	Liquid pool fire - up-wind	35	11.100	Not reached	Not reached
		10	**3.200**	Not reached	Not reached
		3	**950**	60	197
		1	**300**	205	673

[7] The effect distance at ground level is given from the side of the tank, the side of the pool and the edge of the trench for, respectively, the tank fire, the tank pit fire and the pipe trench fire.

4.3 Heavy fuel - pipe trench fire	Liquid pool fire - down-wind	35	11.100	Not reached	Not reached
		10	3.200	12	39
		3	950	73	240
		1	300	125	410
	Liquid pool fire - up-wind	35	11.100	Not reached	Not reached
		10	3.200	2	7
		3	950	16	52
		1	300	60	197
4.4 Heavy fuel - tank pit fire (pool size 10.000 m^2, i.e. 32.808 ft^2)	Liquid pool fire - down-wind	35	11.100	Not reached	Not reached
		10	3.200	20	66
		3	950	110	361
		1	300	192	630
	Liquid pool fire - up-wind	35	11.100	Not reached	Not reached
		10	3.200	2	7
		3	950	44	144
		1	300	124	407
4.5 Heavy fuel - tank pit fire (pool size 290 m x 290 m, i.e. 951ft x 951ft)	Liquid pool fire - down-wind	35	11.100	Not reached	Not reached
		10	3.200	25	82
		3	950	190	623
		1	300	345	1.132
	Liquid pool fire - up-wind	35	11.100	Not reached	Not reached
		10	3.200	2	7
		3	950	65	213
		1	300	220	722
4.6 Heavy fuel - tank pit fire (pool size 370 m x 370 m, i.e. 1.214 ft x 1.214 ft)	Liquid pool fire - down-wind	35	11.100	Not reached	Not reached
		10	3.200	25	82
		3	950	190	623
		1	300	345	1.132
	Liquid pool fire - up-wind	35	11.100	Not reached	Not reached
		10	3.200	2	7

		3	950	65	213
		1	300	220	722
4.7 Heavy fuel - tank pit fire (pool size 135 m x 135 m, i.e. 443 ft x 443 ft)	Liquid pool fire - down-wind	35	11.100	Not reached	Not reached
		10	**3.200**	20	66
		3	950	135	443
		1	300	240	787
	Liquid pool fire - up-wind	35	11.100	Not reached	Not reached
		10	**3.200**	Not reached	Not reached
		3	950	40	131
		1	300	145	476

Conclusions for Buckeye Bahamas Hub:

- In the case of a tank fire, i.e. scenario 4.1, there is a light impact (down-wind) on the residents. A light impact in this case means:
  - Dangerous radiation levels (> 3 kW/m^2) are not reached at ground level.
  - Within the 3 kW/m^2 (i.e. 950 $BTU/(h*ft^2)$) radiation contour, i.e. evacuation area/safe when protected, a few houses are located.
  - Within the 1 kW/m^2 (i.e. 300 $BTU/(h*ft^2)$) radiation contour, i.e. safe environment, a few more houses are located.
- In the case of a tank pit fire, i.e. scenarios 4.2, 4.4, 4.5, 4.6 and 4.7, there is impact (both up-wind and down-wind) on the residents. Impact in this case means:
  - Within the 10 kW/m^2 (i.e. 3.200 $BTU/(h*ft^2)$) radiation contour (down-wind) of scenario 4.2, i.e. unsafe area/1% exposed death/severe wounds/possible escalation or transfer to buildings and constructions, a few houses are located.
  - Within the 3 kW/m^2 (i.e. 950 $BTU/(h*ft^2)$) radiation contours, i.e. evacuation area/safe when protected, several houses are located. This holds for all the considered scenarios, for the down-wind results and for scenario 4.2; also for the up-wind results.
  - Within the 1 kW/m^2 (i.e. 300 $BTU/(h*ft^2)$) radiation contour, i.e. safe environment, even more houses are located. This holds for all the considered scenarios and for both the up-wind and down-wind results.
  - A low-hanging cloud of smoke (down-wind), in the case of insufficient thermal rise, will be an important threat to the residents.
- In case of a pipe trench fire, i.e. scenario 4.3, there is impact (mainly down-wind, but also up-wind) on the residents. Impact in this case means:
  - Within the 10 kW/m^2 (i.e. 3.200 $BTU/(h*ft^2)$) radiation contours (down-wind and up-wind), i.e. unsafe area/1% exposed death/ severe wounds/possible escalation or transfer to buildings and constructions, no houses are located.
  - Within the 3 kW/m^2 (i.e. 950 $BTU/(h*ft^2)$) radiation contour (down-wind), i.e. evacuation area/safe when protected, a few houses are located.
  - Within the 1 kW/m^2 (i.e. 300 $BTU/(h*ft^2)$) radiation contour (down-wind and up-wind), i.e. safe environment, a few more houses are located.

- A low-hanging cloud of smoke (down-wind), in the case of insufficient thermal rise, will be an important threat to the residents.

Note: The chance of a full surface pit fire is very small. Around the world there are only a few examples known of such fires. If a full surface pit fire occurs at Buckeye Bahamas Hub, at one of the tank pits near the boundary of the company and close to Pinder's Point and Lewis Yard, it will not develop rapidly. The reason for the slow development is the lack of oil which can rapidly develop into a full surface pit fire. In chapter 7 recommendations are made to enhance slow development by intervening in the fire quickly and adequately, and at the same time protecting the residents of Pinder's Point and Lewis Yard.

6 Conclusions

At the request of the Minister for Grand Bahama, Antea Group has carried out a safety assessment relating the potential threats of the industrial activities at the Freeport Industrial Park to the people living in Pinder's Point, Lewis Yard, Hunters and Hawksbill of Grand Bahama. Owing to the absence of applicable Bahamas legislation on external safety, the impact criteria used in risk evaluations of large incidents involving hazardous substances, executed in compliance with European legislation, were applied.

The assessment, which consisted of carrying out desk research (including analysis and modelling of the potential threats) and site visits, showed that impact of the identified incident scenarios from Freeport Industrial Park on Pinder's Point or Lewis Yard is possible. The focus is on the incident scenarios from Buckeye Bahamas Hub, since there is no additional threat to the residents of Pinder's Point or Lewis Yard caused by the other companies considered.

The relevant credible incident scenarios at Buckeye Bahamas Hub are heavy fuel fires in the tank pits near the south-side boundary to Pinder's Point and Lewis Yard and the pipe trench to the jetty. The hazard associated with these scenarios is heat radiation. The greatest danger for the residents is a full surface (tank) pit fire. Parts of Pinder's Point and Lewis Yard would be unsafe, in the case of an actual fire in one of the aforementioned locations. The effect distance (at ground level) of a tank fire with heavy fuel at Buckeye Bahamas Hub is mainly restricted to the area inside the boundary of the company and does not, therefore, heavily impact the residents of Pinder's Point or Lewis Yard.

Within the 10 kW/m^2 (i.e. 3.200 $BTU/(h*ft^2)$) radiation contour of fires, houses or other constructions do not provide reliable shelter. In such circumstances the presence of people in the area should be avoided. Additionally, the presence of people should also be avoided within the 3 kW/m^2 (i.e. 950 $BTU/(h*ft^2)$) radiation contour, under up-wind weather conditions. Because of the size and nature of the threat, people will flee or evacuate this area as well. (See also chapter 7.)

The effect distance (at ground level) of a full surface tank pit fire with heavy fuel at Buckeye Bahamas Hub reaches beyond the location of several houses. Within the 10 kW/m^2 (i.e. 3.200 $BTU/(h*ft^2)$) radiation contour there are a few houses located and within the 3 kW/m^2 (i.e. 950 $BTU/(h*ft^2)$) radiation contour (up-wind) are a few more houses. Currently, if a full surface tank pit fire occurs at Buckeye Bahamas Hub, there is a remote possibility of victims (fatalities or injuries) among the residents of Pinder's Point and Lewis Yard.

In the next chapter recommendations are provided for protecting the residents of Pinder's Point and Lewis Yard, i.e. no victims (fatalities or injuries), in the case of such an incident at Buckeye Bahamas Hub.

7 Recommendations

The conclusion of the safety assessment is that in the case of a full surface tank pit fire at Buckeye Bahamas Hub, parts of Pinder's Point and Lewis Yard are unsafe. In these parts, several houses are located. For these houses, there is a direct danger, in the sense that the houses do not offer sufficient protection to people. In addition, escalation or transfer of the fire to the houses is a real hazard, in the case of a full surface tank pit fire. This is also true in the case of a pipe trench fire in the down-wind situation, but on a smaller scale. Therefore, the aforementioned houses do not satisfy the minimal safety needs.

Minimal safety needs
The inhabited environment of the Freeport Industrial Park needs, at least, shelters to protect people from heat radiation of fires at the industry. Therefore, the houses need to be resistant to the remaining heat radiation from the fire. This is needed in order to provide shelter for fleeing or evacuated people and to prevent escalation or transfer of the fire to the houses.

Since the minimal safety needs are not satisfied, recommendations for protecting the residents of Pinder's Point and Lewis Yard are given in the following sections. Two types of recommendations are provided: The first type is a safety buffer zone and the second type is Lines of Defence (LODs; see also section 4.1). The LODs are recommended to control and combat incidents in order to prevent fatalities and possible injuries among the residents of Pinder's Point and Lewis Yard, while the safety buffer zone is meant as a direct measure to prevent fatalities and possible injuries.

7.1 Safety buffer zone

In order to (directly) prevent fatalities and possible injuries among the residents of Pinder's Point and Lewis Yard in the case of an incident at Buckeye Bahamas Hub, a safety buffer zone between the boundary of Buckeye Bahamas Hub and Pinder's Point and Lewis Yard is advised. The safety buffer zone is determined as stated in tenet 1 and tenet 2.

Tenet 1:
The radiation contour of 10 kW/m^2 (i.e. 3.200 $BTU/(h*ft^2)$), which is the maximum in the case of down-wind weather conditions, determines the boundary of the safety buffer zone around the industrial locations with a fire scenario. Houses do not offer a shelter, nor a safe haven, within this radiation contour.

Tenet 2:
The radiation contour of 3 kW/m^2 (i.e. 950 BTU/(h*ft^2)), under the up-wind weather conditions, also determines the boundary of the safety buffer zone around the industrial locations with a fire scenario.

People present are unprotected and not sufficiently safe within the 3 kW/m^2 (i.e. 950 BTU/(h*ft^2)) radiation contour in the case of a fire. Under up-wind weather conditions it is not expected that houses and constructions within this radiation contour, which could offer shelter, will actually function as shelters because of the size and nature of the threat. People will flee or evacuate such unsafe environments.

In other words: The safety buffer zone consists of the area in which the 10 kW/m^2 (i.e. 3.200 BTU/(h*ft^2)) can be reached (bounded by the dotted red lines) and the area in which the 3 kW/m^2 (i.e. 950 BTU/(h*ft^2)) can be reached in case of up-wind weather conditions (bounded by the solid orange lines). The safety buffer zone should not contain houses.

Antea Group advises the following, regarding the safety buffer zone:

Advise safety buffer zone
We advise creating a safety buffer zone starting from the edge of the tank pit or the edge of the pipe trench of Buckeye Bahamas Hub until the 3 kW/m^2 (i.e. 950 BTU/(h*ft^2)) radiation contour in the case of up-wind weather conditions (bounded by the solid orange lines).

For the residents of Pinder's Point and Lewis Yard, this means the following:
1. Existing houses and constructions (in which residents may be present) within the determined safety buffer zone should be removed (removal);
2. Prevent development of new buildings or constructions (in which residents may be present) within the determined safety buffer zone (stand still).

For the separate tank pits at Buckeye Bahamas Hub the safety buffer zone was determined. The complete safety buffer zone, existing of all the safety buffer zones united, is shown on a map in figure 7.1. In figure 7.2 the safety buffer zone border at the south-side of Buckeye Bahamas Hub is shown smoothed out. In attachment III the safety buffer zone of figure 7.2 is included in a zoomed-in version. In this version, the individual objects are more recognizable.

Note that outside of the determined safety buffer zone, between the 3 kW/m^2 (i.e. 950 BTU/(h*ft^2)) radiation contour, in the case of up-wind weather conditions (bounded by the solid orange lines) and the 1 kW/m^2 (i.e. 300 BTU/(h*ft^2)) radiation contour in the case of down-wind weather conditions (bounded by the dotted green lines), there is a potential unsafe environment. This area is potentially unsafe because the heat radiation can become higher than an unprotected person can bear. Escalation or transfer of the fire to the houses or constructions in this area is not a hazard.

Figure 7.1 Map with the determined safety buffer zone of Buckeye Bahamas Hub.

Figure 7.2 The safety buffer zone border at the south-side of Buckeye Bahamas Hub, smoothened.

7.2 Lines of Defence

The development of heavy fuel fires is fairly slow. Under the assumption that the tank pit fire is quickly detected and repressive measures are effectively taken (including timely alarm, complete evacuation and providing shelter to the residents of the residential areas nearby), there will be no victims (fatalities or injuries) among the residents.

Under the following conditions (Lines of Defence) there is sufficient time to protect the residents of Pinder's Point and Lewis Yard in the potential unsafe zone[8] (see also section 7.1):

- Rapid/early detection of a potential incident;
- After detection, fast and adequate notification of fire to the authorities;
- Presence of an adequate and practiced Emergency Response Plan (ERP) to deal with the following three incident scenarios: tank fire, tank pit fire and pipe trench fire. In addition, the resources available to combat the scenarios need to be part of the ERP and their use should be practiced.
- Fire protection on the tanks, at least on the south side near the boundary;
- Encourage slow development of fires by storing the heavy fuels under atmospheric conditions near the boundary of the south side of Buckeye Bahamas Hub, instead of storing lighter fuels in these tanks (which have larger radiation contours); in the future, avoid heating the tanks (this makes the temperature of the oil closer to the flash point).

[8] The zone between the 3 kW/m^2 (i.e. 950 $BTU/(h*ft^2)$) radiation contour in case of up-wind weather conditions (bounded by the solid orange lines) and the 1 kW/m^2 (i.e. 300 $BTU/(h*ft^2)$) radiation contour in case of down-wind weather conditions (bounded by the dotted green lines).

References

[1] M. Lumens, M.T.O. Jonker, 'Environmental Health Risk Assessment for Pinder's Point, Lewis Yard, and Surrounding Areas', final report, December 7, 2015.

[2] Handreiking Rampbestrijdingsplan Veiligheidsrapportplichtige Bedrijven, Ingenieurs/adviesbureau SAVE, januari 2002.

[3] Publicatiereeks gevaarlijke stoffen 6, http://www.publicatiereeksgevaarlijkestoffen.nl/publicaties/PGS6.html (visited on March 30, 2017).

[4] Publicatie Interventiewaarden, Rijksinstituut voor de Volksgezondheid en Milieu, december 2016. http://www.rivm.nl/rvs/ (visited on April 5, 2017).

[5] Fires in large atmospheric tanks and their effect on adjacent tanks, Loughborough University Institutional Repository, Doctoral thesis by Khalid Mansour, 2012.

[6] Brandveiligheid opslagtanks, The atmospheric storage tank, technical frame of reference (CIV02), Centrum Industriële Veiligheid.

7.2 Lines of Defence

The development of heavy fuel fires is fairly slow. Under the assumption that the tank pit fire is quickly detected and repressive measures are effectively taken (including timely alarm, complete evacuation and providing shelter to the residents of the residential areas nearby), there will be no victims (fatalities or injuries) among the residents.

Under the following conditions (Lines of Defence) there is sufficient time to protect the residents of Pinder's Point and Lewis Yard in the potential unsafe zone[8] (see also section 7.1):

- Rapid/early detection of a potential incident;
- After detection, fast and adequate notification of fire to the authorities;
- Presence of an adequate and practiced Emergency Response Plan (ERP) to deal with the following three incident scenarios: tank fire, tank pit fire and pipe trench fire. In addition, the resources available to combat the scenarios need to be part of the ERP and their use should be practiced.
- Fire protection on the tanks, at least on the south side near the boundary;
- Encourage slow development of fires by storing the heavy fuels under atmospheric conditions near the boundary of the south side of Buckeye Bahamas Hub, instead of storing lighter fuels in these tanks (which have larger radiation contours); in the future, avoid heating the tanks (this makes the temperature of the oil closer to the flash point).

[8] The zone between the 3 kW/m^2 (i.e. 950 $BTU/(h*ft^2)$) radiation contour in case of up-wind weather conditions (bounded by the solid orange lines) and the 1 kW/m^2 (i.e. 300 $BTU/(h*ft^2)$) radiation contour in case of down-wind weather conditions (bounded by the dotted green lines).

Appendix I – Impact of Bahama Rock

Introduction

One of the subjects of the safety assessment is the possible impact of the blasting activities of Bahama Rock on the Pinder's Point / Lewis Yard area.

In this appendix we treat this subject, discuss criteria for safe blasting levels and draw some conclusions. The results are based on desk research and a site visit at Bahama Rock.

Blasting process

The preparation for the controlled blasting process starts with the drilling of shot holes at a depth of 80 feet, which are fitted with a 4½ inch cardboard tube to maintain the integrity of the hole in the porous limestone. The cardboard cased holes are filled with solid oxidizer and liquid ammonium nitrate at approximately 14 feet below the surface. The packing of the tube continues by filling it with 0-1½ inch sized stones to stem and muffle the sound of the blast.

Ground vibration[9]

The energy released by the blast is sufficient to cause permanent changes to the rock mass. The area damaged by one blast hole is typically less than or equal to 35 times the hole diameter. For example, a 3-inch diameter hole would cause fracturing that extends to approximately 105 inches or almost 9 feet. Outside this area the energy is elastic, in other words the particles of the Earth are not permanently deformed or displaced. After the energy passes, the particles outside the area permanently damaged return to their original resting position.

As particles of the Earth are displaced, these particles impact other particles which impact other particles and, as this process continues, the energy is transmitted away from the blast site. This transmission of energy flows as a wave. An analogy would be the effect of dropping a stone into a pool of water. At the point of impact, the water is displaced sufficiently to produce individual droplets that separate. Past the impact point, the energy can be seen traveling away as waves. As the energy travels outward from the source, it diminishes or attenuates. With increasing distance, the affected area greatly increases and the energy becomes widely dispersed. In general, the amplitude of the vibration can be expected to decrease by approximately two-thirds for every doubling of the distance.

Safe blasting levels – limits

Ground vibration limits are typically set to prevent property damage outside the blast area. There is not a standard limit. Limits are often rooted in research which is conducted over decades. By

[9] World of explosives; Society of Explosives Engineers, Inc; 2017

design, they are typically over-engineered to provide a safety factor. In some cases, limits are expressed as a single value, for example 25 mm/sec (i.e. 1.0 in/sec). However, it is more likely that the limits will vary based on frequency (see also figure A1.1 for an example).

A very common set of recommended limits is derived from research conducted by the United States Bureau of Mines (USBM). Part of this research has resulted in a report entitled *USBM RI 8507, "Structure Response and Damage Produced by Ground Vibration from Surface Mine Blasting"*. Based on this report the USBM recommended the frequency-based limiting criteria.

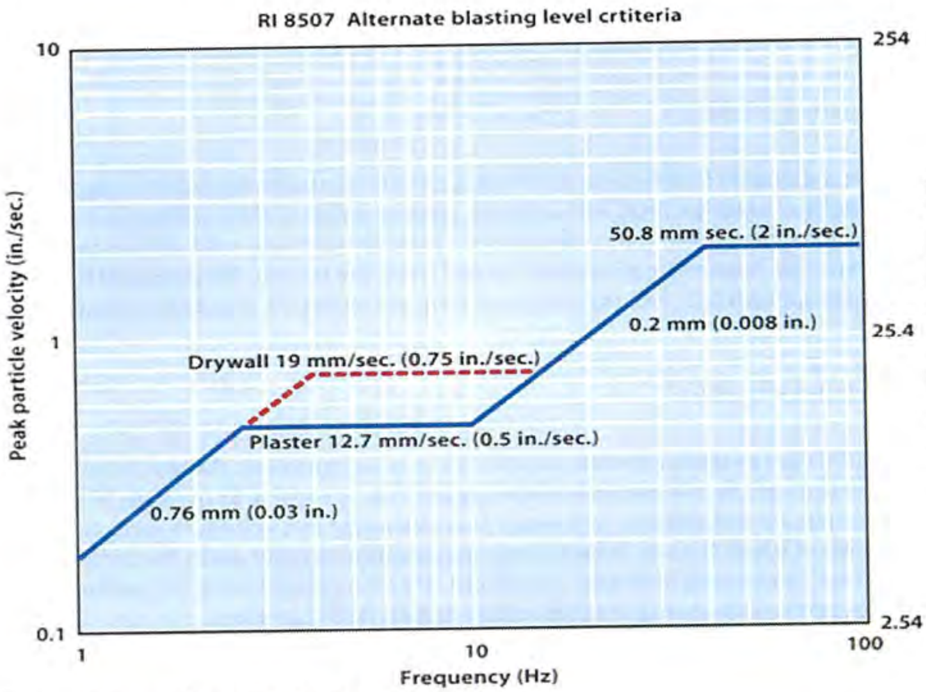


Figure A1.1 Alternate blasting level criteria.

Basis

The basis for the frequency-based limits is the concept of structure response. The recommended limits in the USBM report RI 8507 are thresholds in order to prevent cosmetic damage to the most susceptible materials such as plaster and sheetrock. Other materials, including masonry, concrete block and mass concrete, can withstand much higher levels of vibration without damage.

Human perception

Although people are sensitive to sounds and vibrations, it is difficult to quantify perceptions. Inside a structure, as an effect of the blast, people will feel the building shake and hear the objects around them (such as windows and ornaments) rattle. The human response to blasts is subjective as two people will react differently to the same vibration event depending on where they are in a structure, their frame of mind and their personality. Unfavorable perceptions to vibrations often result in complaints. For instance, when residents feel a blast, they may become concerned about damage to their home.

The threshold peak particle velocity of ground vibration perception is about 0.51 mm/s (i.e. 0.02 in/s) for most people. This is 1/100 of the limit of 50 mm/s (i.e. 2 in/s) commonly used for construction blasting, or, with reference to the graph above, under the charted boundaries.

Structure response

Residential structure response to blast vibration has been researched extensively (for example: USBM RI 8507 and RI 8896). Frequency is a very important component of ground vibration because it affects how structures respond. The general types of response within a structure caused by external vibrations are:

- Foundation Structure Response: The structure vibration below the ground level is equal to the incoming ground vibrations.
- Whole-Structure Response: The racking motions of the part of the building above ground, that respond to frequencies of 4 Hertz to 12 Hertz.
- Mid-Wall Response: Motions within individual panels or components of the part of the building above ground normally out of plane with walls, responsive to frequencies of 12 Hertz to 20 Hertz.

In the Whole Structure Response, the portion of the structure above ground is free-standing and moves more than the portion below ground because the foundation is fixed. Differential motions between the upper and lower corners cause racking responses. Mid-wall responses are typically responsible for window rattling, picture tilting, etc.

When the vibration frequency closely matches a natural or fundamental frequency of a structure or structural component, the structure or component will tend to respond more vigorously and the incoming ground vibrations will be amplified in the upper portion of the structure. Alternatively, if the ground vibration frequency does not match the natural frequency, very little seismic energy transfers into the structure, and there will be little, if any, response.

Response of foundations

The foundation is the strongest part of a house or other structure (e.g. oil tank). Vibration standards are designed to protect the weakest parts of the house, such as plaster and drywall. Ground vibrations strong enough to crack foundations consisting of concrete and masonry would far exceed the limits set by typical standards including USBM RI 8507 (Z-curve).

Limits valid for and used by Bahama Rock

In the permit of The Port Authority Bahama Rock it is stated that Bahama Rock is limited to a Peak Particle Velocity (PPV) of 1.5 inch/sec for all frequencies (red line in figure A1.2). This is above the limits of the Z-curve of USBM RI 8507 (less strict) for most frequencies.
Bahama Rock uses an internal limit if 0.5 inch/sec. for all frequencies (orange line in diagram). This is stricter than the USBM Z-curve.

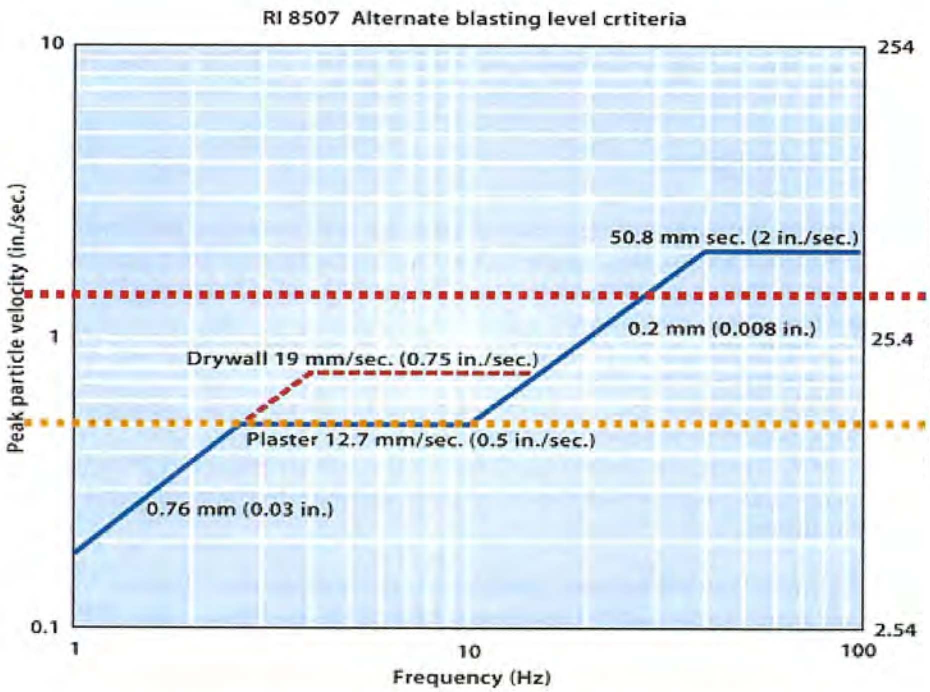


Figure A1.2 Alternate blasting level criteria including limits of Bahama Rock (red line: permitted limit, orange: internal limit of Bahama Rock).

Actual vibration levels

The Bahama Rock blasting operations are overseen by a third-party consultant (GeoSonics, FL). A blasting seismograph is set up prior to a blast. The seismographs are placed at five different locations, including the residential area of Hawksbill. These are continuous monitoring stations. A seismograph is normally also placed at the residential structure closest to a blast. Continuous monitoring stations might be used at quarries, mines and long-term projects.

The information recorded by the seismograph is used by blasting specialists to evaluate blast design performance and ensure regulatory compliance. Most importantly, the recordings verify that the vibrations are within standards and are set to not damage houses and other structures.

Blasting seismographs start recording at threshold levels of vibrations, which is referred to as the trigger level. This level is set low enough to detect the blast vibrations, but high enough that it will not accidentally record non-blast vibrations (such as nearby human activity). Once triggered, the data is recorded, stored in the seismograph and cannot be altered.

The International Society of Explosives Engineers (ISEE) Field Practice Guidelines for Blasting Seismographs is the industry standard for the correct monitoring of blast vibrations. All recordings made by the seismograph are retrieved and evaluated to ensure that the vibrations fall within appropriate limits. From these evaluations, it follows that the output of the recordings are relative to the standards limits (Z-curve). This is valid for the longitudinal, the transverse and the vertical components of the vibrations.

Conclusion

The operations of Bahama Rock do not harm the buildings of the Pinder's Point / Lewis Yard areas and do not harm the foundations of the oil tanks of Buckeye Bahamas Hub.

Appendix II – Results Buckeye Bahamas Hub

This appendix contains the effect distances on the map for scenario's 4.1 to 4.7 of Buckeye Bahamas Hub. Please see the Technical Background Document (TBD) of this Safety Assessment, Appendix IV sections 4.1 till 4.7, as well.

Figure A3.1: Effect distance of scenario 4.1 'Heavy fuel - tank fire'.

Figure A3.2 Effect distance of scenario 4.2 'Heavy fuel - tank pit (pool size 42.000 m^2) fire'.

Figure A3.3 Effect distance of scenario 4.3 'Heavy fuel - pipe trench fire'.

Figure A3.4 Effect distance of scenario 4.4 'Heavy fuel – tank pit (pool size 10.000 m²) fire'.

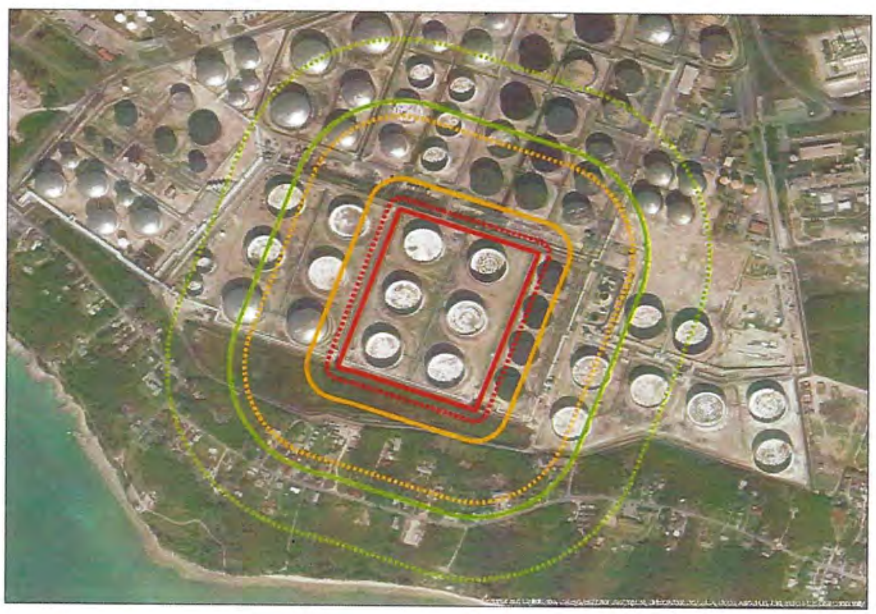


Figure A3.5 Effect distance of scenario 4.5 'Heavy fuel – tank pit (pool size 290 m x 290 m) fire'.

Figure A3.6 Effect distance of scenario 4.6 'Heavy fuel – tank pit (pool size 370 m x 370 m) fire'.

Figure A3.7 Effect distance of scenario 4.7 'Heavy fuel – tank pit (pool size 135 m x 135 m) fire'.

Appendix III – Safety buffer zone zoomed-in

In this attachment the safety buffer zone, as presented in figure 7.2 (see also figure A4.1), is zoomed-in such that the individual objects are more recognizable. Figures A4.2 till A4. 6 show the safety buffer zone, zoomed-in, from East to West.

Figure A4.1 The safety buffer zone border at the south-side of Buckeye Bahamas Hub, smoothened.

Figure A4.2 The safety buffer zone border at the south-side of Buckeye Bahamas Hub, zoomed in part 1 of 5, East side.

Figure A4.3 The safety buffer zone border at the south-side of Buckeye Bahamas Hub, zoomed in part 2 of 5.

Figure A4.4 The safety buffer zone border at the south-side of Buckeye Bahamas Hub, zoomed in part 3 of 5.

Figure A4.5 The safety buffer zone border at the south-side of Buckeye Bahamas Hub, zoomed in part 4 of 5.

Figure A4.6 The safety buffer zone border at the south-side of Buckeye Bahamas Hub, zoomed in part 5 of 5, West.

Figure A4.6 The safety buffer zone border at the south-side of Buckeye Bahamas Hub, zoomed in part 5 of 5, West.

Appendix IV – Technical Background Document

This attachment consists of the Technical Background Document of this Safety Assessment. It contains the technical background information, i.e. the technical modelling details and results.

Technical Background Document

for the Safety Assessment Grand Bahama

project number 0415183.00
final
November 8, 2017

Understanding today.
Improving tomorrow.

Technical Background Document

for the Safety Assessment Grand Bahama

Project number 0415183.00
final
November 8, 2017

Authors
M.T.J. Pronk MSc
ir. J.B.R. Van der Schaaf
ir. F. Veldman - de Roo

Client
Ministry for Grand Bahama
The Hon. Dr. Michael Darville
Harold DeGregory Complex 4th
Freeport Grand Bahama

Date release	Description revision	For approval	Release
Nov. 8, 2017	Final	J. Van der Schaaf	M. Pronk

Table of Contents

Introduction

At the request of the Minister for Grand Bahama, Antea Group has carried out a safety assessment relating the potential threats of the industrial activities at the Freeport Industrial Park to the people living in Pinder's Point and Lewis Yard. To do so, the potential threats of the industrial activities have been modelled and analyzed. This document contains the technical background information, i.e. the technical modelling details and results, of the safety assessment. For the safety assessment, we refer to the document "Safety Assessment Grand Bahama, Risk Assessment for Pinder's Point, Lewis Yard and surrounding areas, Antea Group, final, revision 2.0, November 8, 2017".

By executing a standardized sub selection method, we were able to analyze which scenario of a loss of containment (LOC) situation can cause damage outside the boundary of the company under consideration. Note that only these scenario', i.e. the scenario's which can cause a damage outside the boundary of the company under consideration, are modelled. In this assessment three types of hazards are considered, namely fire radiation (kW/m^2), explosion overpressure (barg) and exposure or toxic substances (concentration in mg/m^3). For each of these hazard types, the scenario with the largest effect has been modelled in Phast (version 6.7).

In the safety assessment the following companies at the Freeport Industrial Park, which are presented in figure 1, are involved:

A. Polymers International;
B. PharmaChem;
C. Grand Bahama Power Company;
D. Bahama Rock;
E. Freeport Container port;
F. Bahamian Brewery & Beverage Co.;
G. Bradfort Bahamas;
H. Grand Bahama Shipyard;
I. FOCOL;
J. Buckeye Bahamas Hub.

Figure 1: Locations of the companies involved.

1 Polymers International

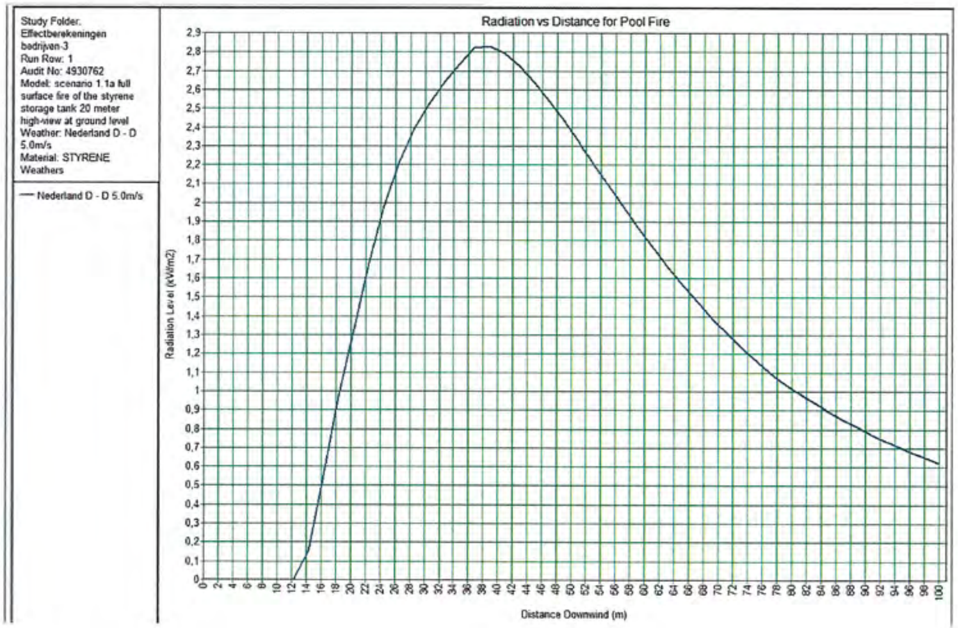
1.1 Styrene - tank fire

Polymers International Limited			# 1.1
Scenario description			
Company ***Polymers International Limited***	Installation: ***Styrene storage***	Type of activity: *Storage*	
Type of containment: *Insulated Atmospheric Tank, chilled (60-70 deg F)*		System volume: *5.000 m³* Tank diameter: *26 m.*	
LOC (Loss of Containment) type: *Roof failure*		LOC location: *(New) Styrene monomer storage tank*	
Scenario (elaboration)			
Due to an incident, the tank roof has lost its integrity, the styrene in the tank has ignited resulting in a ***full surface fire of the styrene storage tank***			
Release			
Product name: *Styrene*	Temp [deg C]: *20*	Pressure [barg]: *Atmospheric.*	Phase [S/L/G/2 phase]: *L*
Hole size: [diam mm]: *does not apply*	Release duration: [sec]: *does not apply*	Tank height [m]: *20* Pool diameter [m] *26* Pool size [m^2] *2123*	Leak rate [kg/s]: *does not apply*
Physical effect			
Nature of effect: *Liquid Pool Fire*	Effect distance at ground level: - Lethal [100%] [m]: n.r.[1] - Lethal [1%] [m]: n.r. - Wounded [m]: 26 - Safe [m]: 68	Effect criterion: Threshold limits - Lethal [100%]: 35 kW/m^2 - Lethal [1%]: 10 kW/m^2 - Wounded : 3 kW/m^2 - Safe: 1 kW/m^2	

[1] n.r.: level not reached

Scenario data

Radiation vs distance at ground level (side-view)



Appendix

Plan

Plan

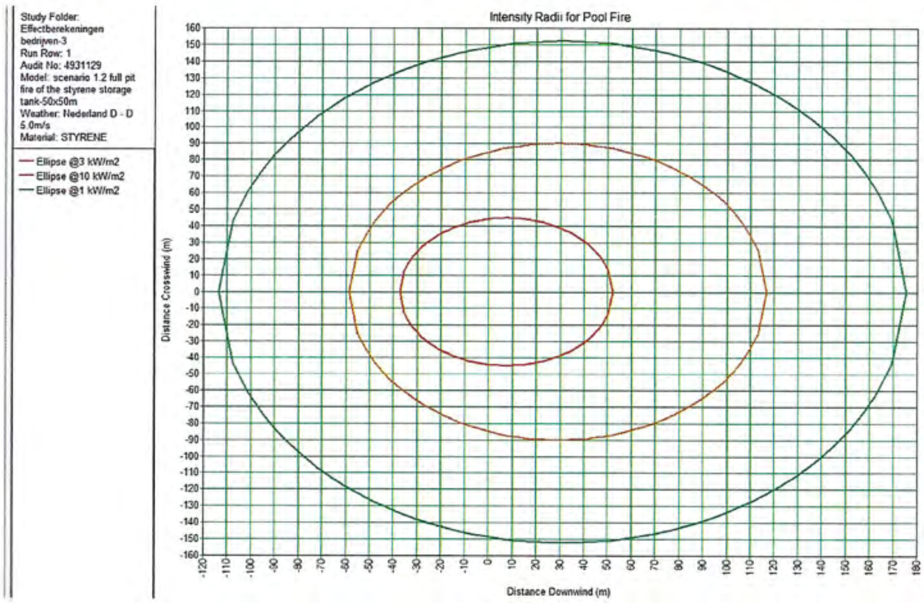
1.2 Styrene - pit fire

Polymers International Limited Scenario description			# 1.2
Company: *Polymers International Limited*	Installation: *Styrene storage*	Type of activity: *Storage*	
Type of containment: *Insulated Atmospheric Tank, chilled (60-70 F)*		System volume: *5.000 m³* Tank diameter: *26 m.* Pit: *65 x 65 m.*	
LOC (Loss of Containment) type: *Tank failure*		LOC location: *(New) Monomer storage tank*	
Scenario (elaboration)			
Due to an incident, the tank has lost its integrity, the tank pit is full of styrene; the styrene has ignited resulting in a full surface tank pit fire of styrene			
Release:			
Product name: *Styrene*	Temp [deg C]: *20*	Pressure [barg]: *Atmospheric*	Phase [S/L/G/2 phase]: *L*
Hole size: [diam mm]: *does not apply for this scenario*	Release duration: [sec]: *does not apply*	Pool size [m²] *4225*	Leak rate [kg/s]: *does not apply*
Physical effect:			
Nature of effect: *Liquid Pool Fire*	Effect distance: from edge bund (ground level) - Lethal [100%] [m]: n.r.[2] - Lethal [1%] [m]: 20 - Wounded [m]: 80 - Safe [m]: 140	Effect criterion: Threshold limits - Lethal [100%]: 35 kW/m² - Lethal [1%]: 10 kW/m² - Wounded : 3 kW/m² - Safe 1 kW/m²	

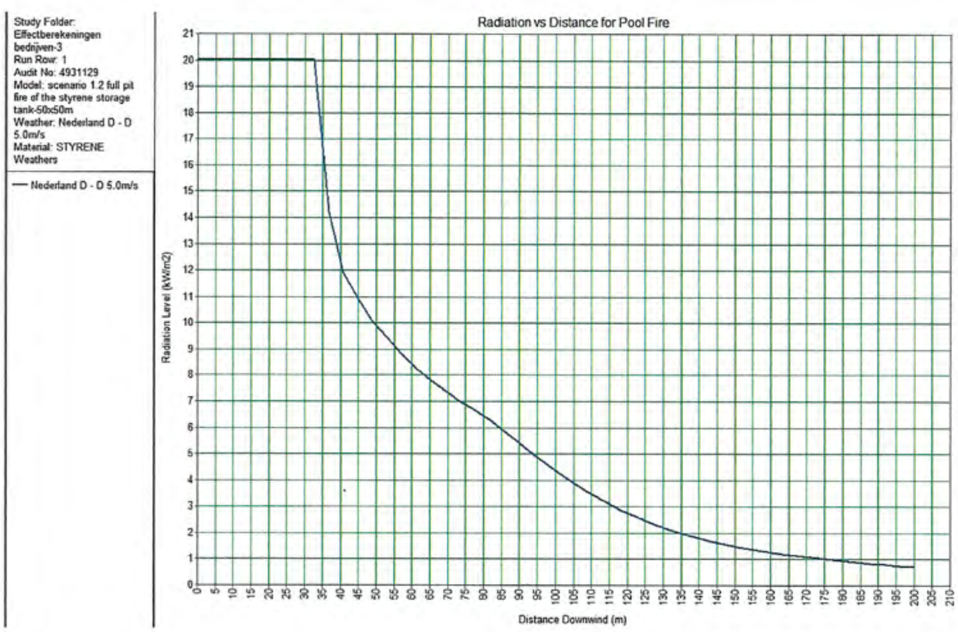
[2] n.r. level not reached

Scenario data

Radiation at ground level

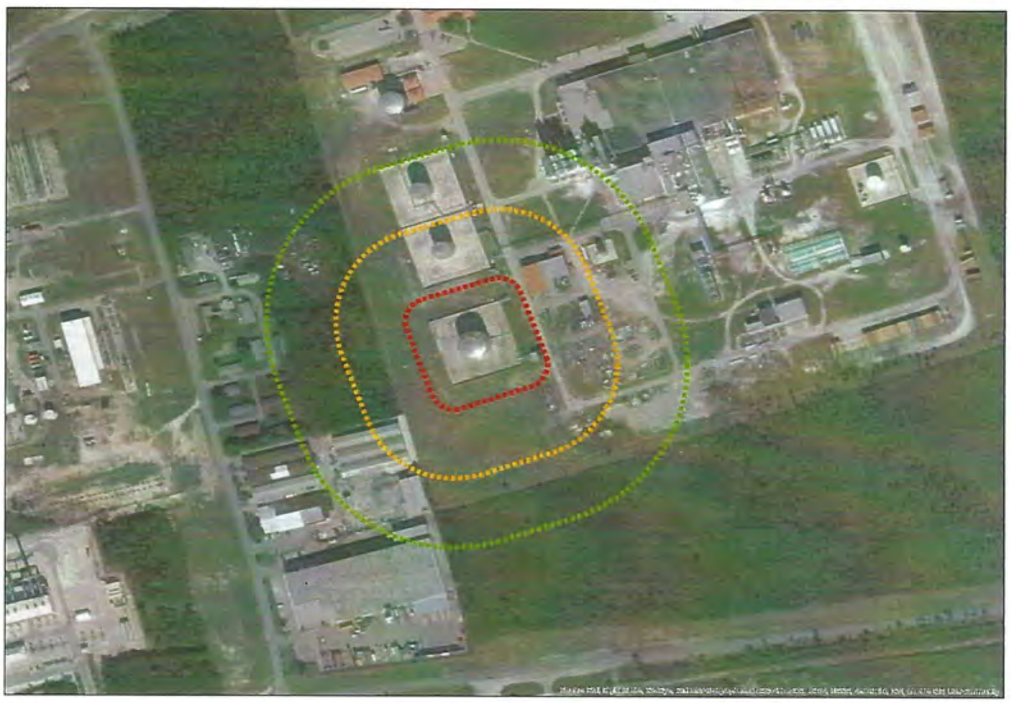


Radiation vs distance at ground level (side view)



Appendix

Plan

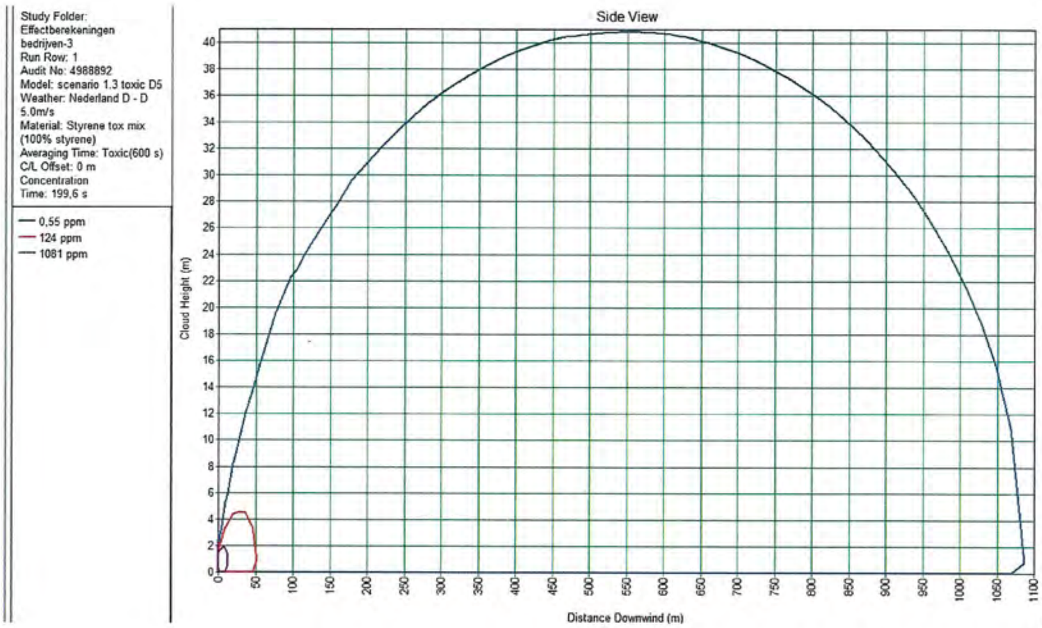


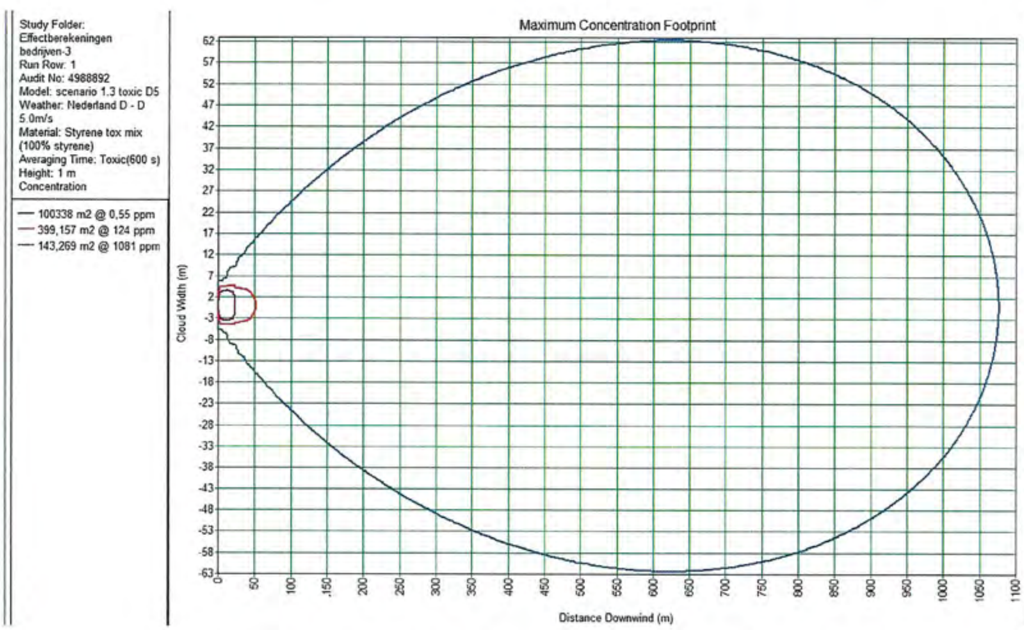
1.3 Styrene - toxic exposure from pit

Polymers International Limited Scenario description			# 1.3
Company *Polymers International Limited*	Installation: *Styrene storage*	Type of activity: *Storage*	
Type of containment: *Insulated Atmospheric Tank, chilled (60-70 F)*		System volume: *5.000 m^3* Tank diameter: *26 m.* Pit: *65 x 65 m.*	
LOC (Loss of Containment) type: *Tank failure*		LOC location: *(New) Styrene monomer storage tank*	
Scenario (elaboration)			
Due to an incident, the tank has lost its integrity, the tank pit is full of styrene; the styrene has not ignited resulting in a toxic plume of styrene that evaporates			
Release:			
Product name: *Styrene*	Temp [deg C]: *20*	Pressure [barg]: *Atmospheric.*	Phase [S/L/G/2 phase]: *L*
Hole size: [diam mm]: *does not apply for scenario*	Release duration: [sec]: *does not apply*	Pool size [m^2] *4225*	Leak rate [kg/s]: *not relevant for scenario*
Physical effect:			
Nature of effect: *Toxic plume*	Effect distance: - LTV distance [m]: 20 - ALV distance [m]: 50 *(F1.5: 125)* - AV distance [m]: 1080 *(F1.5: > 3000)*		Effect criterion: Threshold limits (concentration) - LTV[3] = 1081 ppm - ALV[4] = 124 ppm - AV[5] = 0.55 ppm

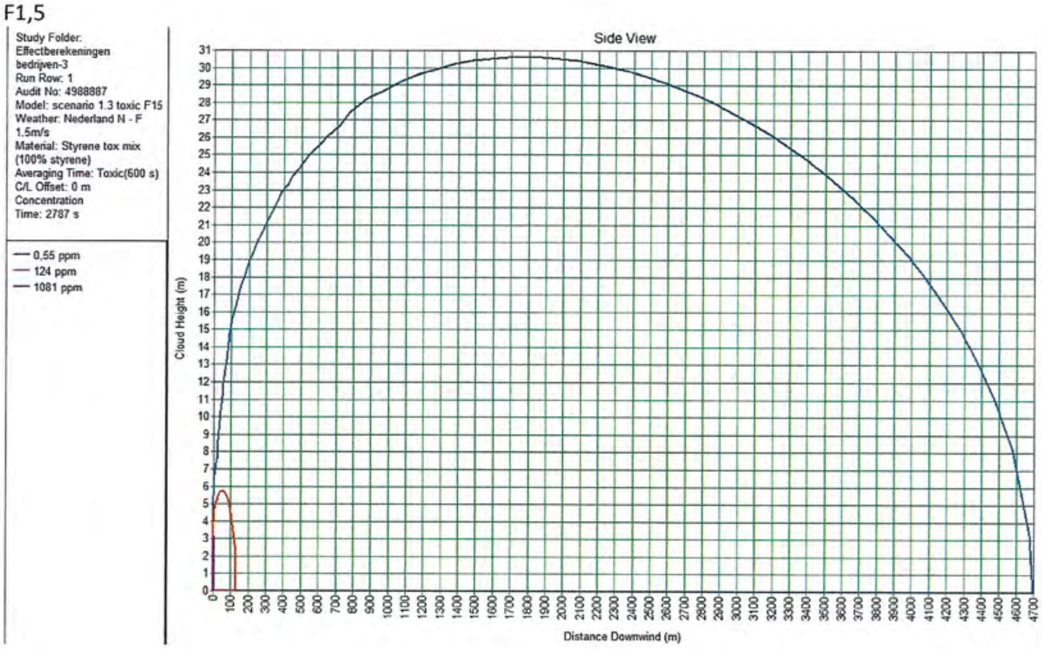
[3] : LTV: Life-Threatening Value
[4] : ALV: Alarming Limit Value
[5] : ATV: Awareness Value

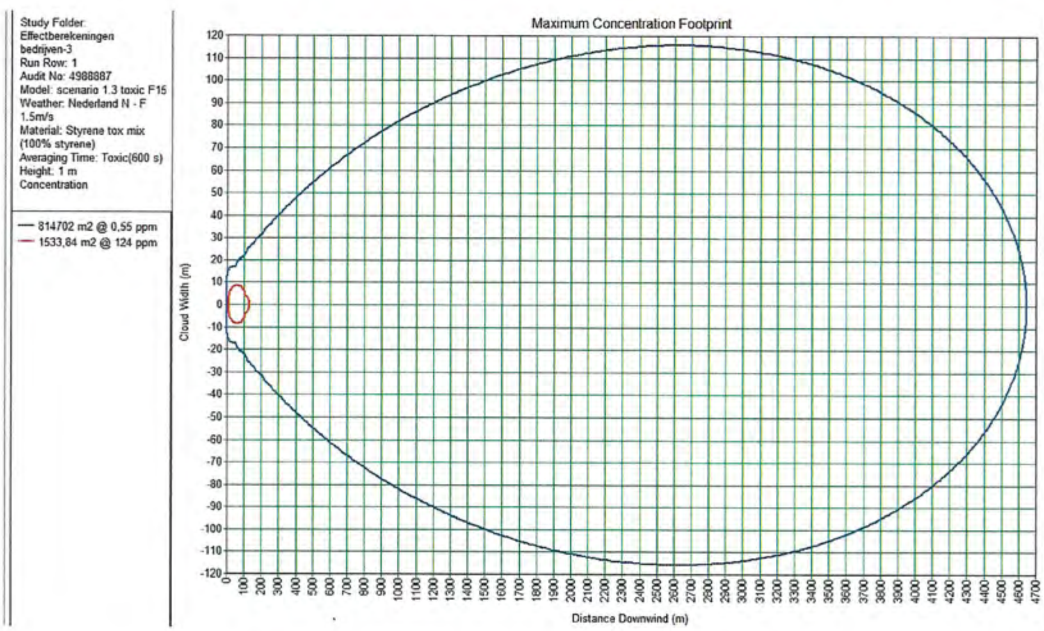
D5


Study Folder:
Effectberekeningen
bedrijven-3
Run Row: 1
Audit No: 4988892
Model: scenario 1.3 toxic D5
Weather: Nederland D - D
5.0m/s
Material: Styrene tox mix
(100% styrene)
Averaging Time: Toxic(600 s)
C/L Offset: 0 m
Concentration
Time: 199,6 s
0,55 ppm
124 ppm
1081 ppm
Side View
Cloud Height (m)
Distance Downwind (m)


Study Folder:
Effectberekeningen
bedrijven-3
Run Row: 1
Audit No: 4988892
Model: scenario 1.3 toxic D5
Weather: Nederland D - D
5.0m/s
Material: Styrene tox mix
(100% styrene)
Averaging Time: Toxic(600 s)
Height: 1 m
Concentration
100338 m2 @ 0,55 ppm
399,157 m2 @ 124 ppm
143,269 m2 @ 1081 ppm
Maximum Concentration Footprint
Cloud Width (m)
Distance Downwind (m)

F1,5


Study Folder: Effectberekeningen bedrijven-3
Run Row: 1
Audit No: 4988887
Model: scenario 1.3 toxic F15
Weather: Nederland N - F 1.5m/s
Material: Styrene tox mix (100% styrene)
Averaging Time: Toxic(600 s)
C/L Offset: 0 m
Concentration
Time: 2787 s
0,55 ppm
124 ppm
1081 ppm
Side View
Cloud Height (m)
Distance Downwind (m)


Study Folder: Effectberekeningen bedrijven-3
Run Row: 1
Audit No: 4988887
Model: scenario 1.3 toxic F15
Weather: Nederland N - F 1.5m/s
Material: Styrene tox mix (100% styrene)
Averaging Time: Toxic(600 s)
Height: 1 m
Concentration
814702 m2 @ 0,55 ppm
1533,84 m2 @ 124 ppm
Maximum Concentration Footprint
Cloud Width (m)
Distance Downwind (m)

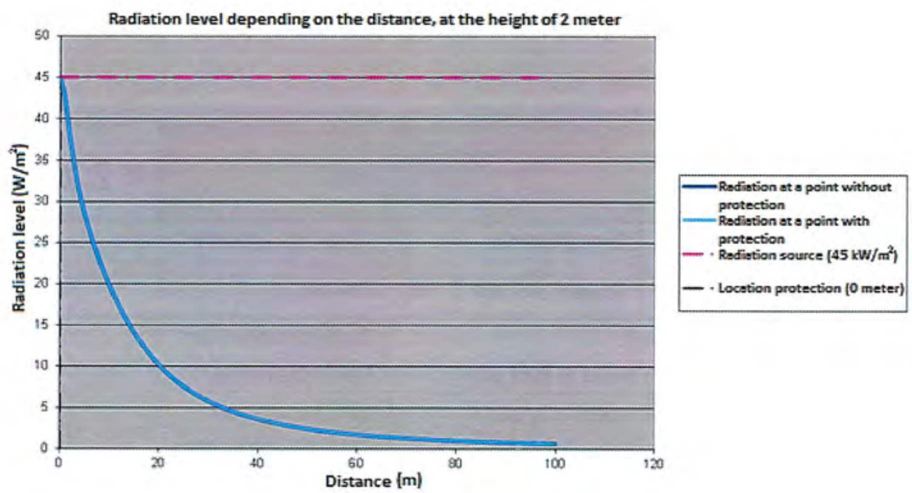
Appendix

Plan

2 PharmaChem Technologies

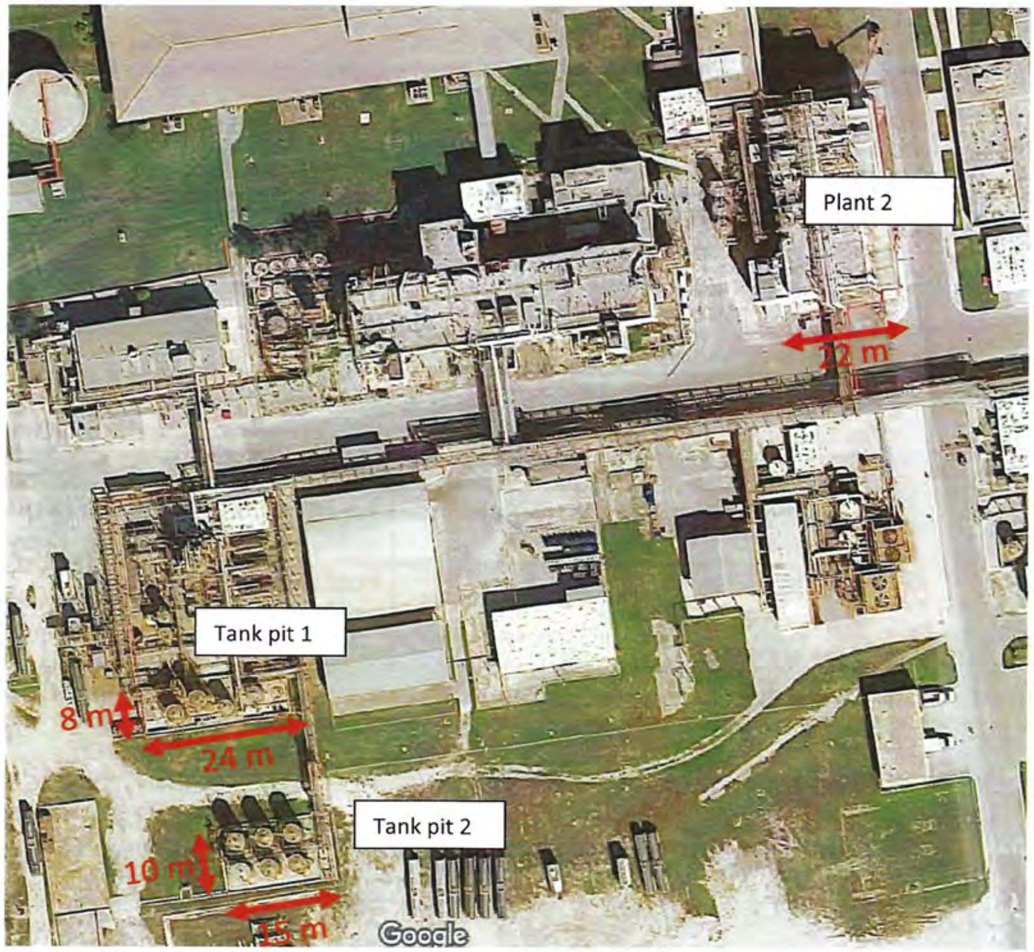
2.1 Solvent - tank pit 1 fire

PharmaChem Technologies Scenario description			# 2.1
Company: *PharmaChem Technologies*	Installation: *Solvent storage* 1	Type of activity: *Storage*	
Type of containment: *Cylindrical atmospheric tanks in tank pit*		System volume: Tank diameter:	
LOC (Loss of Containment) type: *Tank failure*		LOC location: *Tank pit 1 (see map)*	
Scenario (elaboration)			
Due to an incident, a storage tank has lost its integrity, the tank pit is full of solvent; the solvent has ignited resulting in a full surface fire of solvent (e.g. iso-propyl acetate, propanol)			
Release:			
Product name: *Styrene*	Temp [deg C]: *20*	Pressure [barg]: *Atmospheric*	Phase [S/L/G/2 phase]: *L*
Hole size: [diam mm]: *does not apply for this scenario*	Release duration: [sec]: *does not apply*	Pool size [m^2] *192*	Leak rate [kg/s]: *does not apply*
Physical effect:			
Nature of effect: *Liquid Pool Fire*	Effect distance at ground level: - Lethal [100%] [m]: 3 - Lethal [1%] [m]: 20 - Wounded [m]: 45 - Safe [m]: 80	Effect criterion: Threshold limits - Lethal [100%]: 35 kW/m^2 - Lethal [1%]: 10 kW/m^2 - Wounded : 3 kW/m^2 - Safe 1 kW/m2	


Radiation level depending on the distance, at the height of 2 meter
Radiation level (W/m²)
Distance (m)
0
5
10
15
20
25
30
35
40
45
50
0
20
40
60
80
100
120
Radiation at a point without protection
Radiation at a point with protection
Radiation source (45 kW/m²)
Location protection (0 meter)

Appendix

Plan

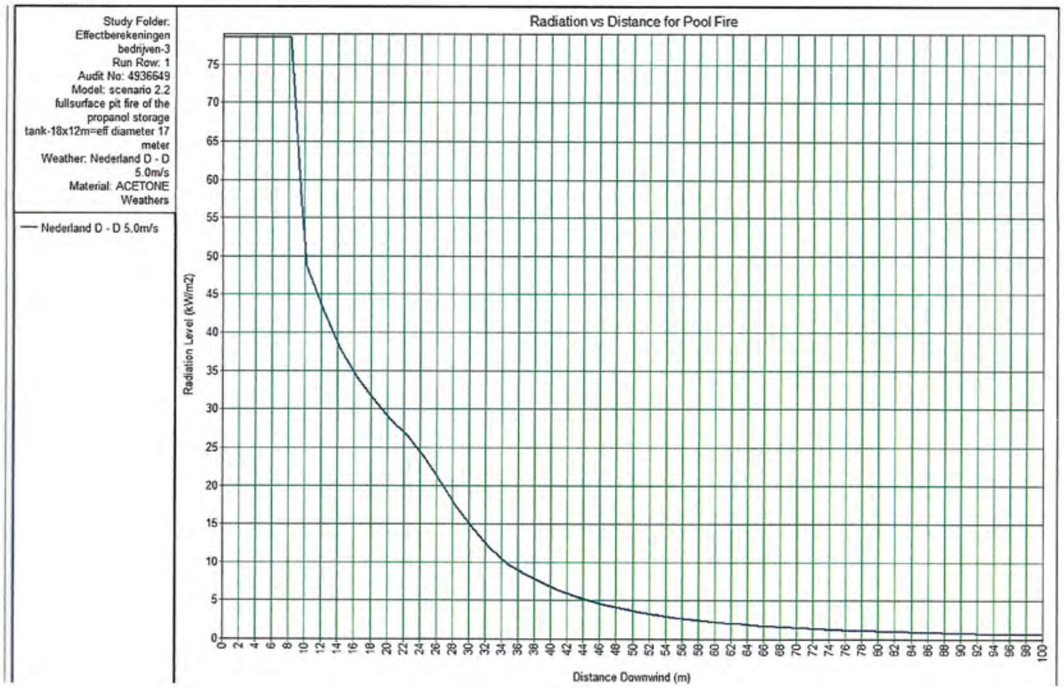


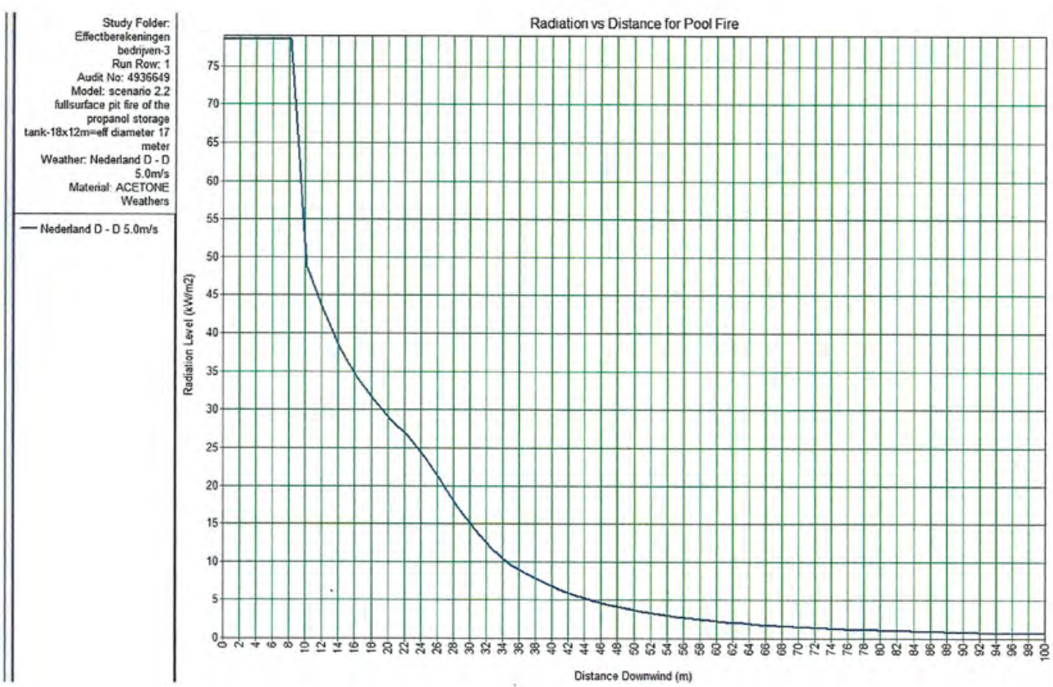
2.2 Solvent - tank pit 2 fire

PharmaChem Technologies Scenario description			# 2.2
Company: *PharmaChem Technologies*	Installation: *Solvent storage 2*	Type of activity: *Storage*	
Type of containment: *Cylindrical atmospheric tanks in tank pit*		System volume: Tank diameter:	
LOC (Loss of Containment) type: *Tank failure*		LOC location: *Tank pit 1 (see map)*	
Scenario (elaboration)			
Due to an incident, a storage tank has lost its integrity, the tank pit is full of solvent; the solvent has ignited resulting in a full surface fire of solvent (e.g. acetone, iso-propyl ether, DMF)			
Release:			
Product name: *Acetone*	Temp [deg C]: *20*	Pressure [barg]: *Atmospheric*	Phase [S/L/G/2 phase]: *L*
Hole size: [diam mm]: *does not apply for this scenario*	Release duration: [sec]: *does not apply*	Pool size [m^2] *18 m x 12 m: 216 m^2*	Leak rate [kg/s]: *does not apply*
Physical effect:			
Nature of effect: *Liquid Pool Fire*	Effect distance at ground level: - Lethal [100%] [m]: 7 - Lethal [1%] [m]: 25 - Wounded [m]: 45 - Safe [m]: 75		Effect criterion: Threshold limits - Lethal [100%]: 35 kW/m^2 - Lethal [1%]: 10 kW/m^2 - Wounded : 3 kW/m^2 - Safe: 1 kW/m2

2.2 Solvent - tank pit 2 fire

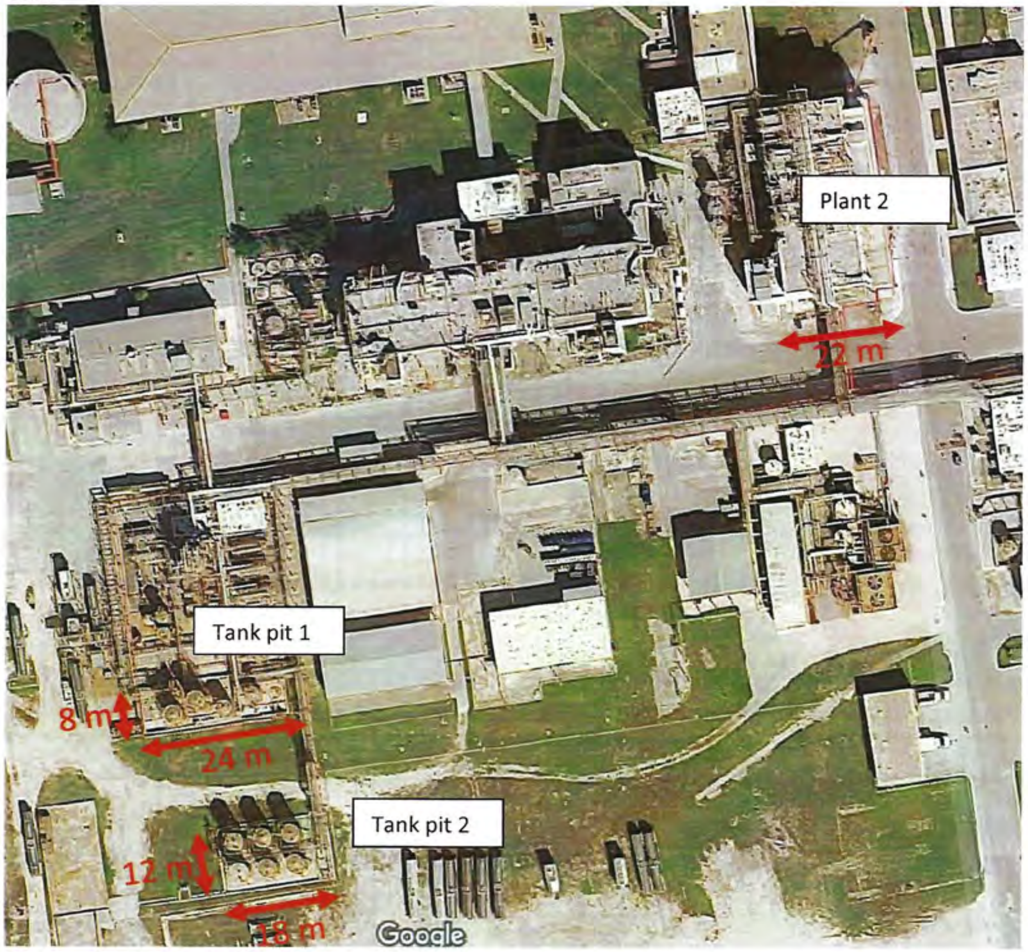
PharmaChem Technologies Scenario description			# 2.2
Company: *PharmaChem Technologies*	Installation: *Solvent storage 2*	Type of activity: *Storage*	
Type of containment: *Cylindrical atmospheric tanks in tank pit*		System volume: Tank diameter:	
LOC (Loss of Containment) type: *Tank failure*		LOC location: *Tank pit 1 (see map)*	
Scenario (elaboration)			
Due to an incident, a storage tank has lost its integrity, the tank pit is full of solvent; the solvent has ignited resulting in a full surface fire of solvent (e.g. acetone, iso-propyl ether, DMF)			
Release:			
Product name: *Acetone*	Temp [deg C]: *20*	Pressure [barg]: *Atmospheric*	Phase [S/L/G/2 phase]: *L*
Hole size: [diam mm]: *does not apply for this scenario*	Release duration: [sec]: *does not apply*	Pool size [m^2] *18 m x 12 m: 216 m^2*	Leak rate [kg/s]: *does not apply*
Physical effect:			
Nature of effect: *Liquid Pool Fire*	Effect distance at ground level: - Lethal [100%] [m]: 7 - Lethal [1%] [m]: 25 - Wounded [m]: 45 - Safe [m]: 75	Effect criterion: Threshold limits - Lethal [100%]: 35 kW/m^2 - Lethal [1%]: 10 kW/m^2 - Wounded : 3 kW/m^2 - Safe: 1 kW/m2	


Study Folder: Effectberekeningen bedrijven-3
Run Row: 1
Audit No: 4936649
Model: scenario 2.2 fullsurface pit fire of the propanol storage tank-18x12m=eff diameter 17 meter
Weather: Nederland D - D 5.0m/s
Material: ACETONE Weathers
Nederland D - D 5.0m/s
Radiation vs Distance for Pool Fire
Radiation Level (kW/m2)
Distance Downwind (m)


Study Folder: Effectberekeningen bedrijven-3
Run Row: 1
Audit No: 4936649
Model: scenario 2.2 fullsurface pit fire of the propanol storage tank-18x12m=eff diameter 17 meter
Weather: Nederland D - D 5.0m/s
Material: ACETONE Weathers
Nederland D - D 5.0m/s
Radiation vs Distance for Pool Fire
Radiation Level (kW/m2)
Distance Downwind (m)

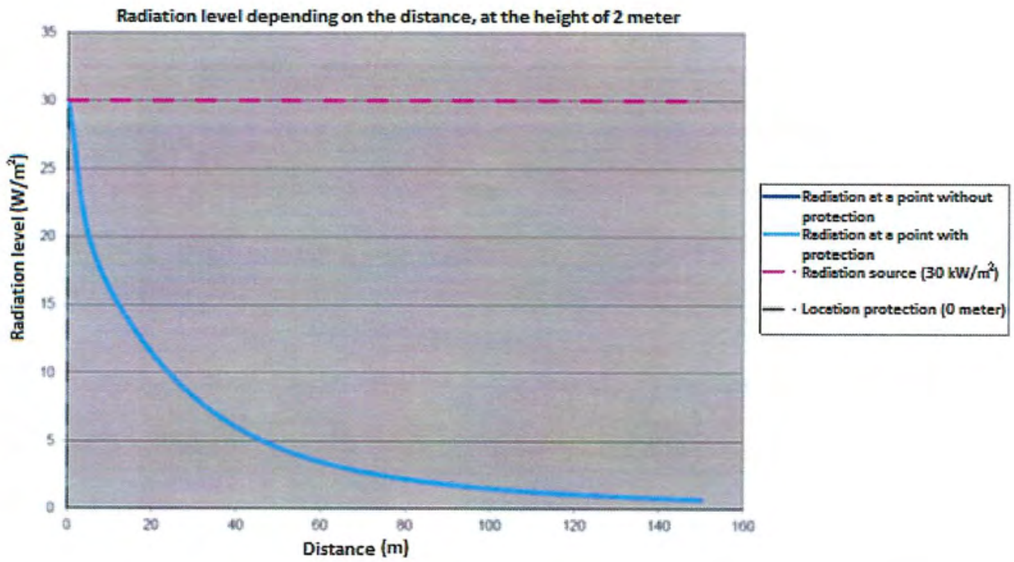
Appendix

Plan



2.3 Solvent - fire in new building

PharmaChem Technologies Scenario description			# 2.3
Company: *PharmaChem Technologies*	Installation: *New production building*	Type of activity: *API production*	
Type of containment: *Building*		Length: 80 m Height: 22 m	
LOC (Loss of Containment) type: *Building in fire*		LOC location: *New building (see map)*	
Scenario (elaboration)			
Due to an incident, a reactor with solvent has lost its integrity, the floor of the building is full of solvent; the solvent has ignited resulting in a full surface fire of solvent. The wall of the building has completely disappeared and the radiation of the fire comes from a surface of 80 x 22 m. (very pessimistic approach, worst case if possible at all). 50% of the wall is 'transparent'			
Release:			
Product name: *Acetone*	Temp [deg C]: *20*	Pressure [barg]: *Atmospheric*	Phase [S/L/G/2 phase]: *L*
Hole size: [diam mm]: *does not apply for this scenario*	Release duration: [sec]: *does not apply*	Pool size [m²] *1000*	Leak rate [kg/s]: *does not apply*
Physical effect:			
Nature of effect: *Liquid Pool Fire*	Effect distance at ground level: - Lethal [100%] [m]: 3 - Lethal [1%] [m]: 24 - Wounded [m]: 65 - Safe [m]: 120	Effect criterion: Threshold limits - Lethal [100%]: 35 kW/m² - Lethal [1%]: 10 kW/m² - Wounded : 3 kW/m² - Safe 1 kW/m2	


Radiation level depending on the distance, at the height of 2 meter
Radiation level (W/m²)
Distance (m)
0
5
10
15
20
25
30
35
0
20
40
60
80
100
120
140
160
Radiation at a point without protection
Radiation at a point with protection
Radiation source (30 kW/m²)
Location protection (0 meter)

Appendix

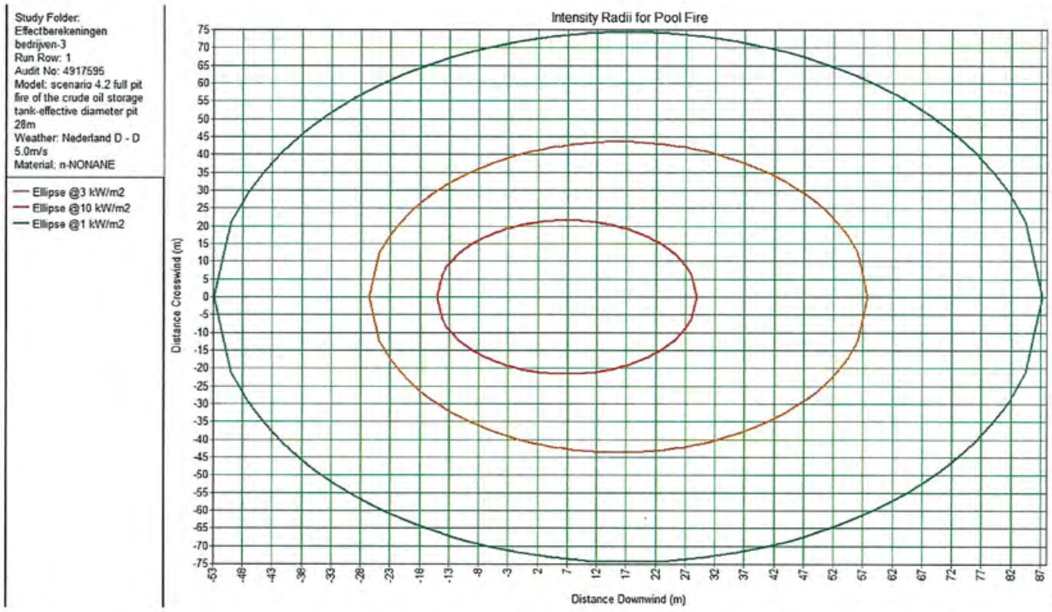
Plan

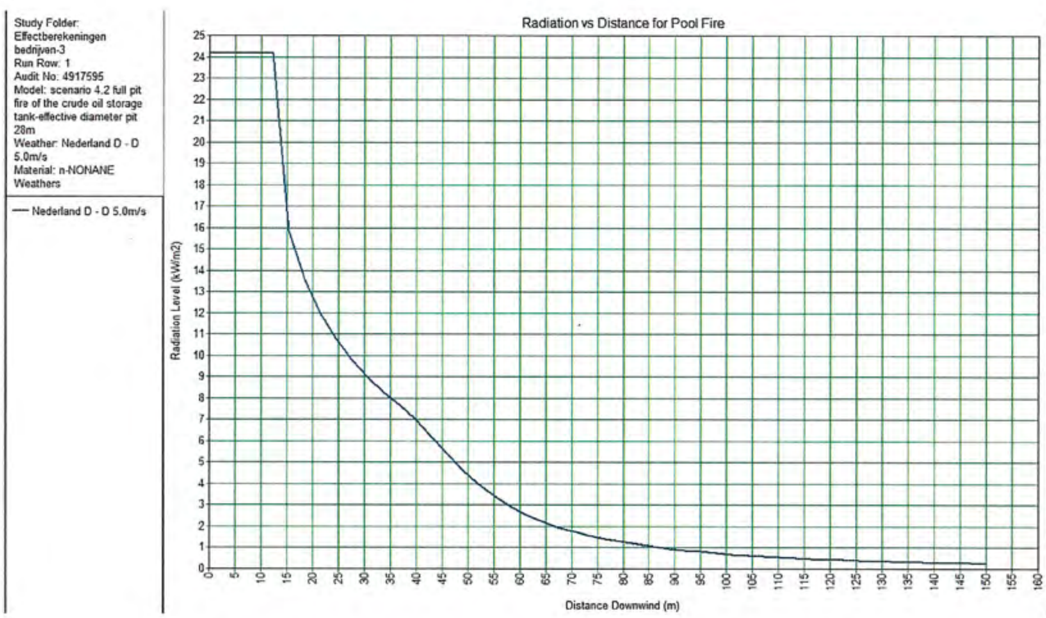
3 Grand Bahama Power Company

3.1 Heavy fuel - tank pit 1 fire

<table>
<tr><td colspan="3">Grand Bahama Power Company Limited
Scenario description</td><td># 3.1</td></tr>
<tr><td>Company:
Grand Bahama Power Company Limited</td><td>Installation:
Diesel storage</td><td colspan="2">Type of activity:
Storage</td></tr>
<tr><td colspan="2">Type of containment:
Cylindrical atmospheric tanks in tank pit</td><td colspan="2">System volume: *10.000 m^3* (largest tank)
Tank diameter: *23* m</td></tr>
<tr><td colspan="2">LOC (Loss of Containment) type:
Tank failure</td><td colspan="2">LOC location:
Tank pit 1 (see map)</td></tr>
<tr><td colspan="4">Scenario (elaboration)</td></tr>
<tr><td colspan="4">*Due to an incident, a storage tank has lost its integrity, the tank pit is full of fuel (heavy fuel)*</td></tr>
<tr><td colspan="4">Release:</td></tr>
<tr><td>Product name:
Diesel</td><td>Temp [deg C]:
20</td><td>Pressure [barg]:
Atmospheric</td><td>Phase [S/L/G/2 phase]: *L*</td></tr>
<tr><td>Hole size: [diam mm]: *does not apply for this scenario*</td><td>Release duration: [sec]: *does not apply*</td><td>Pool size [m^2]
2750 (25 m x 110 m (net))</td><td>Leak rate [kg/s]: *does not apply*</td></tr>
<tr><td colspan="4">Physical effect:</td></tr>
<tr><td>Nature of effect:
Liquid Pool Fire</td><td colspan="2">Effect distance at ground level:
- Lethal [100%] [m]: n.r[6]
- Lethal [1%] [m]: 24
- Wounded [m]: 58
- Safe [m]: 88</td><td>Effect criterion:
Threshold limits
- Lethal [100%]: 35 kW/m^2
- Lethal [1%]: 10 kW/m^2
- Wounded : 3 kW/m^2
- Safe 1 kW/m^2</td></tr>
</table>

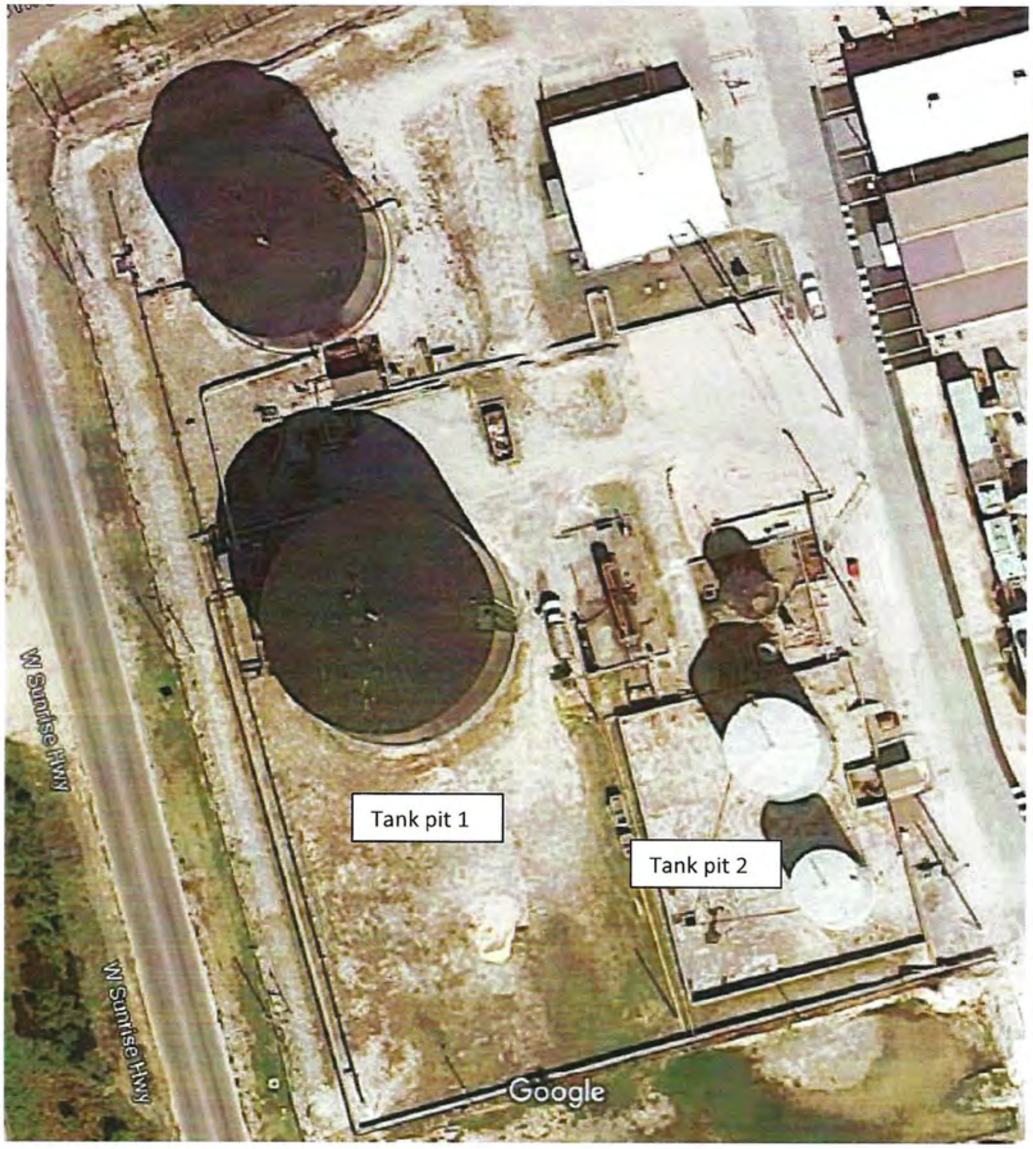
[6] n.r.: not reached

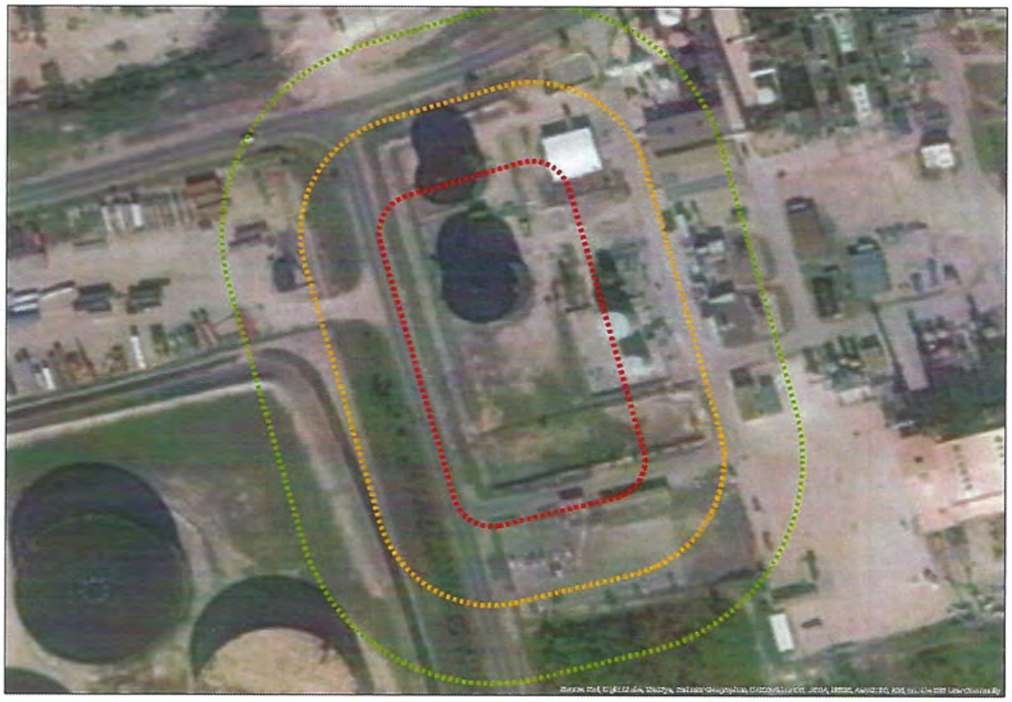

Study Folder: Effectberekeningen bedrijven-3
Run Row: 1
Audit No: 4917595
Model: scenario 4.2 full pit fire of the crude oil storage tank-effective diameter pit 28m
Weather: Nederland D - D 5.0m/s
Material: n-NONANE
Ellipse @3 kW/m2
Ellipse @10 kW/m2
Ellipse @1 kW/m2
Intensity Radii for Pool Fire
Distance Crosswind (m)
Distance Downwind (m)


Study Folder: Effectberekeningen bedrijven-3
Run Row: 1
Audit No: 4917595
Model: scenario 4.2 full pit fire of the crude oil storage tank-effective diameter pit 28m
Weather: Nederland D - D 5.0m/s
Material: n-NONANE
Weathers
Nederland D - D 5.0m/s
Radiation vs Distance for Pool Fire
Radiation Level (kW/m2)
Distance Downwind (m)

Appendix

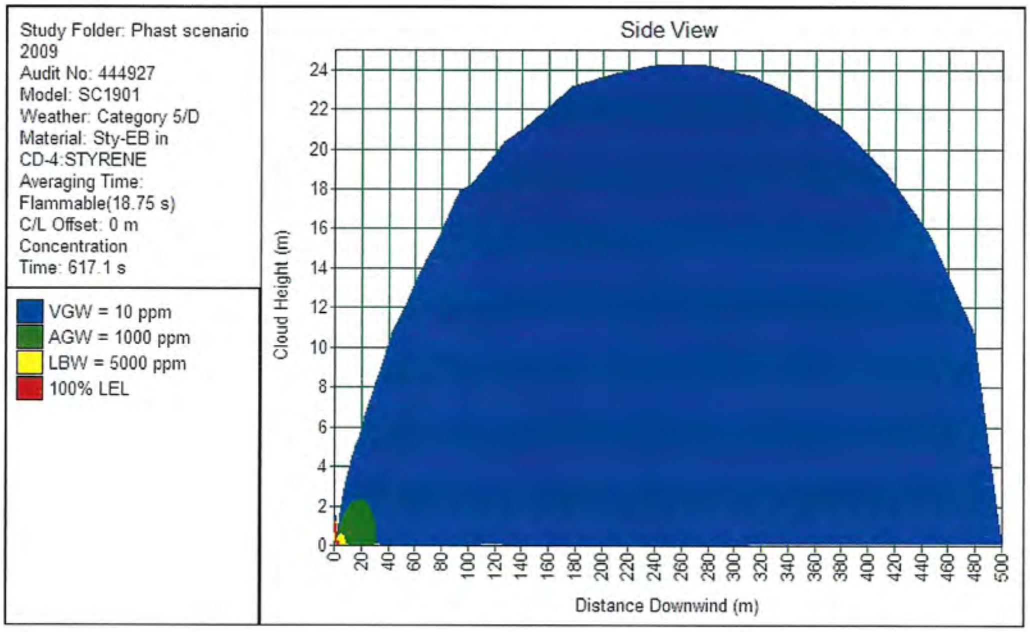
Plan



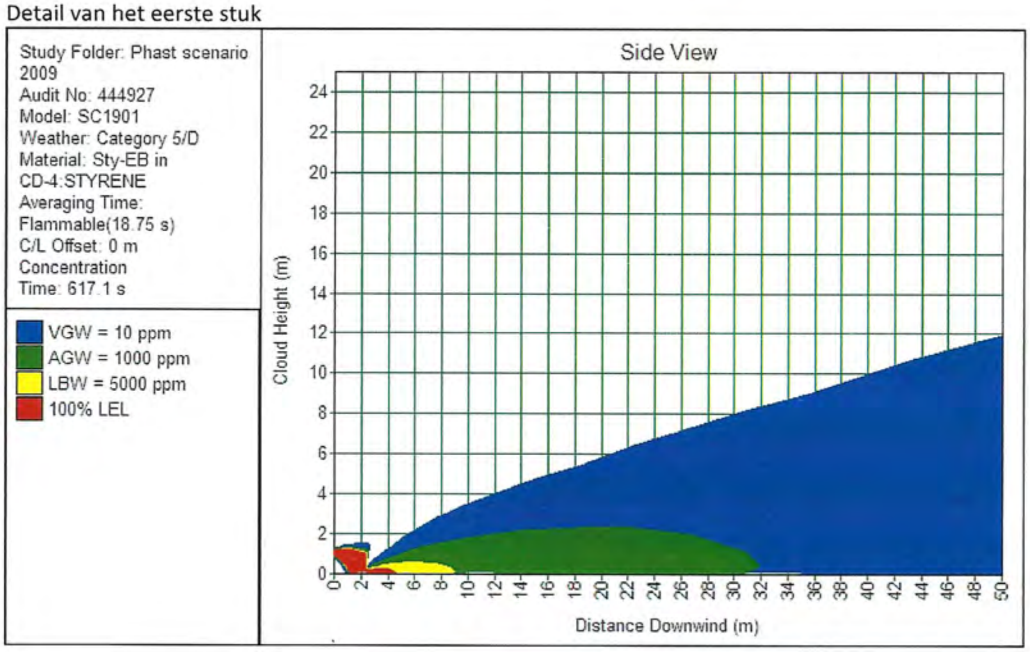


3.2 Heavy fule - tank pit 2 fire

Grand Bahama Power Company Limited			# 3.2
Scenario description			
Company: *Grand Bahama Power Company Limited*	Installation: *Diesel storage*	Type of activity: *Storage*	
Type of containment: *Cylindrical atmospheric tanks in tank pit*		System volume: *1.426 m^3* (largest tank) Tank diameter: *12* m	
LOC (Loss of Containment) type: *Tank failure*		LOC location: *Tank pit 2 (see map)*	
Scenario (elaboration)			
Due to an incident, a storage tank has lost its integrity, the tank pit is full of fuel (heavy fuel)			
Release:			
Product name: *Diesel*	Temp [deg C]: *20*	Pressure [barg]: *Atmospheric*	Phase [S/L/G/2 phase]: *L*
Hole size: [diam mm]: *does not apply for this scenario*	Release duration: [sec]: *does not apply*	Pool size [m^2] *690 (23 m x 30 m)*	Leak rate [kg/s]: *does not apply*
Physical effect:			
Nature of effect: *Liquid Pool Fire*	Effect distance: - Lethal [100%] [m]: n.v.t. - Lethal [1%] [m]: 10 - Wounded [m]: 38 - Safe [m]: 38		Effect criterion: Threshold limits - Lethal [100%]: 35 kW/m^2 - Lethal [1%]: 10 kW/m^2 - Wounded : 3 kW/m^2 - Safe: 1 kW/m2

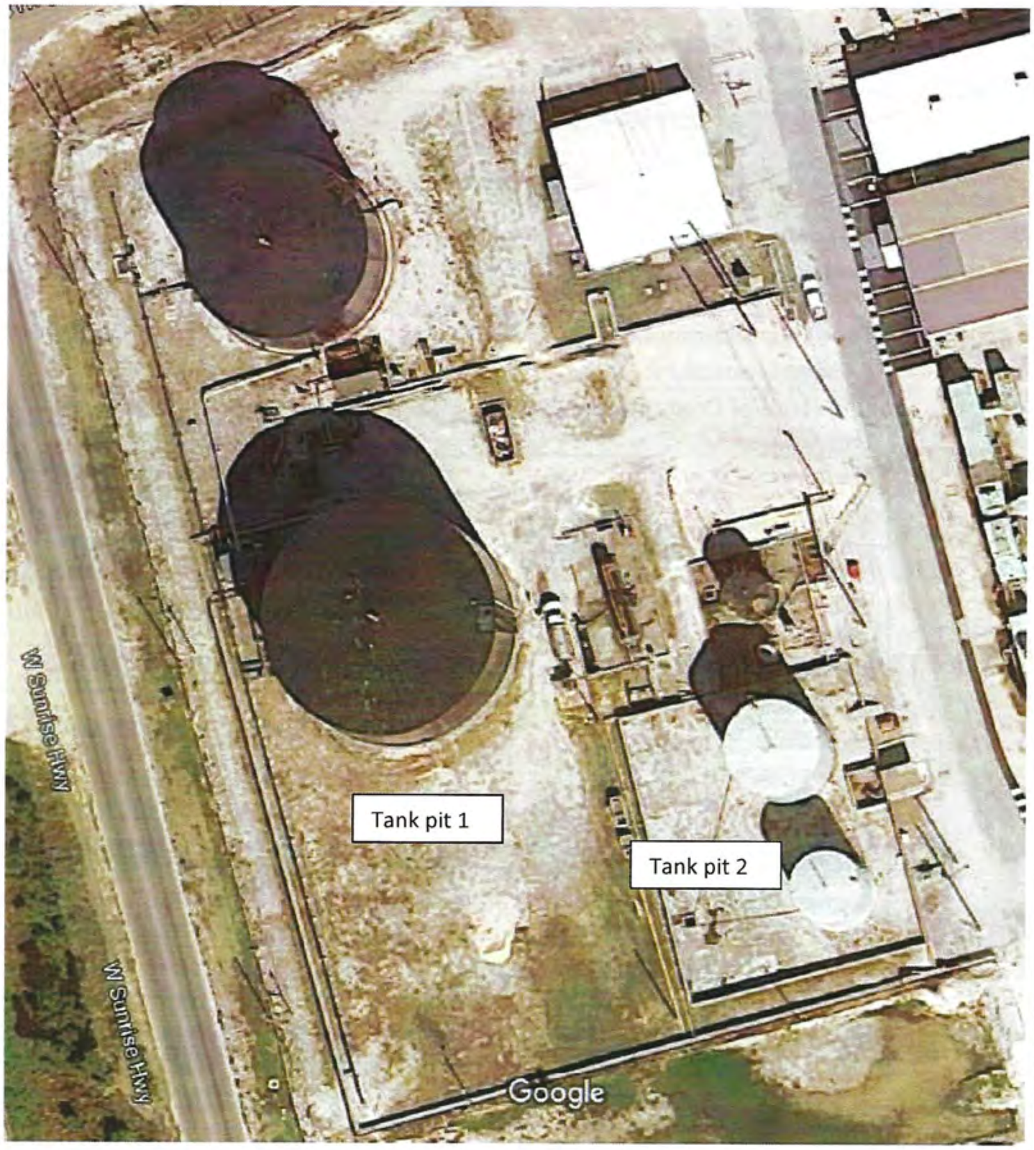


Detail van het eerste stuk



Appendix

Plan



4 Buckeye Bahamas Hub

4.1 Heavy fuel - tank fire

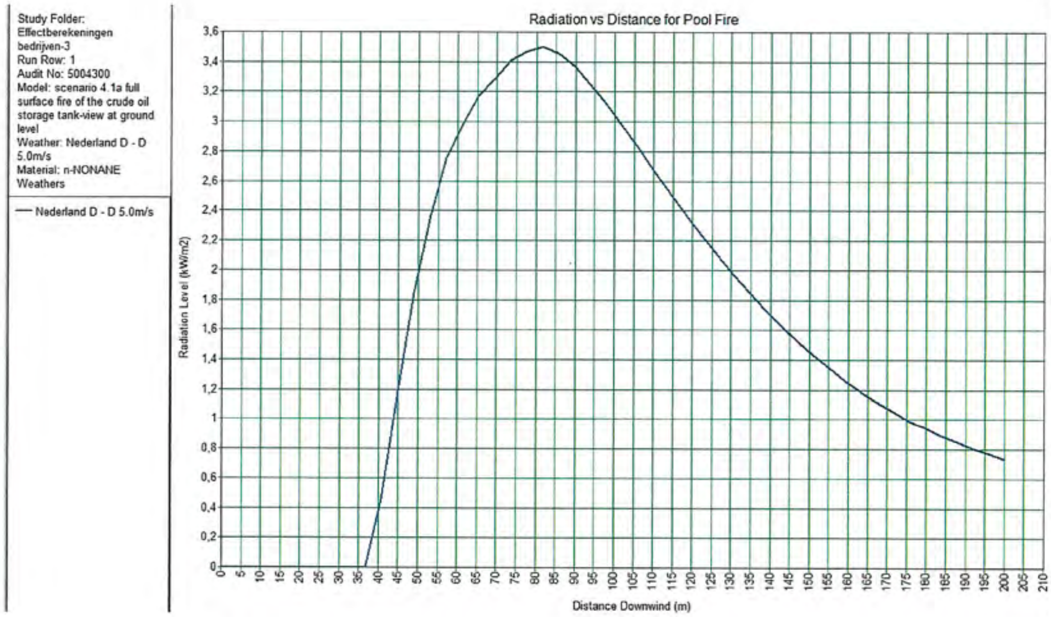
Buckeye Bahamas Hub; BORCO			# 4.1
Scenario description			
Company: *Buckeye Bahamas Hub; BORCO*	Installation: *Oil storage*	Type of activity: *Storage*	
Type of containment: *Cylindrical atmospheric tanks in tank pit*		System volume: largest tank Pool size: *75 m diameter*	
LOC (Loss of Containment) type: *Tank failure*		LOC location: *Tank pit (see map)*	
Scenario (elaboration)			
Due to an incident, a storage tank has lost its integrity, the full surface of tank (heavy fuel)			
Release:			
Product name: *n-Nonane*	Temp [deg C]: *20*	Pressure [barg]: *Atmospheric*	Phase [S/L/G/2 phase]: *L*
Hole size: [diam mm]: *does not apply for this scenario*	Release duration: [sec]: *does not apply*	Pool size [m²] *2463 (net))*	Leak rate [kg/s]: *does not apply*
Physical effect:			
Nature of effect: *Liquid Pool Fire*	Effect distance at ground level **(Downwind):** - Lethal [100%] [m]: *n.r*[7] - Lethal [1%] [m]: *n.r* - Wounded [m]: *65 from side of tank* - Safe [m]: *138 from side of tank*		Effect criterion: Threshold limits - Lethal [100%]: 35 kW/m^2 - Lethal [1%]: 10 kW/m^2 - Wounded : 3 kW/m^2 - Safe: 1 kW/m^2
Nature of effect:	Effect distance at ground level **(Upwind):**		Effect criterion: Threshold limits

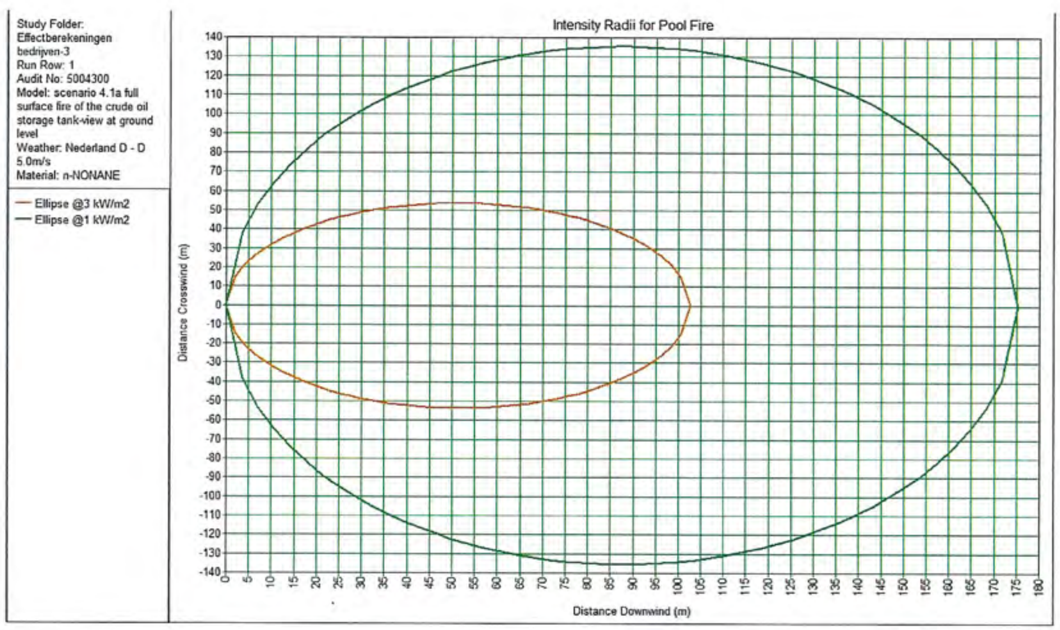
[7] n.r.: not reached

Liquid Pool Fire	- Lethal [100%] [m]: *n.r*[8] - Lethal [1%] [m]: *n.r.* - Wounded [m]: *n.r* - Safe [m]: *n.r*	- Lethal [100%]: 35 kW/m^2 - Lethal [1%]: 10 kW/m^2 - Wounded : 3 kW/m^2 - Safe: 1 kW/m^2

[8] n.r.: not reached

n-Nonane


Study Folder: Effectberekeningen bedrijven-3
Run Row: 1
Audit No: 5004300
Model: scenario 4.1a full surface fire of the crude oil storage tank-view at ground level
Weather: Nederland D - D 5.0m/s
Material: n-NONANE
Weathers
Nederland D - D 5.0m/s
Radiation vs Distance for Pool Fire
Radiation Level (kW/m2)
Distance Downwind (m)


Study Folder: Effectberekeningen bedrijven-3
Run Row: 1
Audit No: 5004300
Model: scenario 4.1a full surface fire of the crude oil storage tank-view at ground level
Weather: Nederland D - D 5.0m/s
Material: n-NONANE
Ellipse @3 kW/m2
Ellipse @1 kW/m2
Intensity Radii for Pool Fire
Distance Crosswind (m)
Distance Downwind (m)

Appendix

Plan

4.2 Heavy fuel - tank pit (pool size 42.000 m²) fire

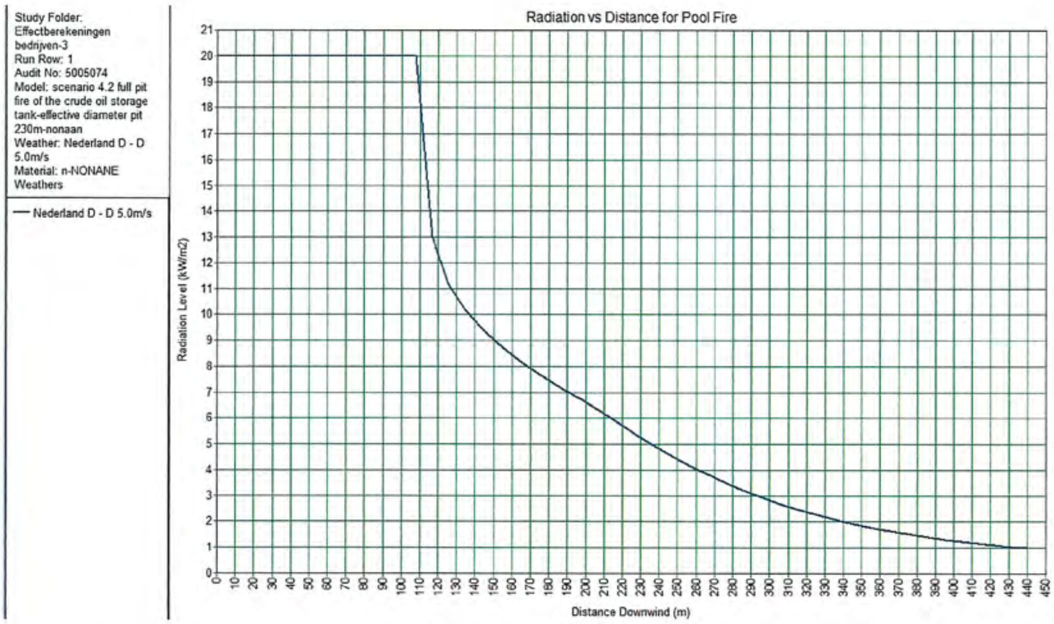
Buckeye Bahamas Hub; BORCO Scenario description			# 4.2
Company: *Buckeye Bahamas Hub; BORCO*	Installation: *Oil storage*	Type of activity: *Storage*	
Type of containment: *Cylindrical atmospheric tanks in tank pit*		System volume: largest tank Pool size: *42.000 m². Eff diam: 230 m*	
LOC (Loss of Containment) type: *Tank failure*		LOC location: *Tank pit (see map)*	
Scenario (elaboration)			
Due to an incident, a storage tank has lost its integrity, the tank pit is full of fuel (heavy fuel)			
Release:			
Product name: *N-nonane*	Temp [deg C]: *20*	Pressure [barg]: *Atmospheric*	Phase [S/L/G/2 phase]: *L*
Hole size: [diam mm]: *does not apply for this scenario*	Release duration: [sec]: *does not apply*	Pool size [m²] *28900 (net))*	Leak rate [kg/s]: *does not apply*
Physical effect:			
Nature of effect: *Liquid Pool Fire*	Effect distance at ground level **(Downwind):** - Lethal [100%] [m]: *n.r*[9] - Lethal [1%] [m]: *25 from side pool* - Wounded [m]: *175 from side of pool* - Safe [m]: *325 from side of pool*		Effect criterion: Threshold limits - Lethal [100%]: 35 kW/m² - Lethal [1%]: 10 kW/m² - Wounded : 3 kW/m² - Safe: 1 kW/m²
Nature of effect:	Effect distance at ground level **(Upwind):**		Effect criterion: Threshold limits

[9] n.r.: not reached

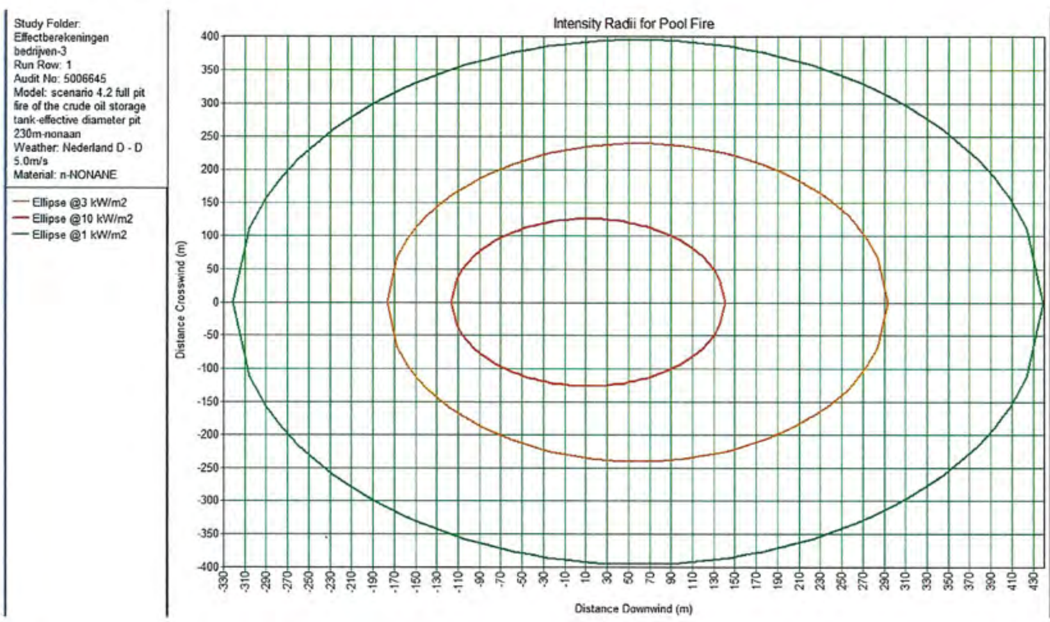
Liquid Pool Fire	- Lethal [100%] [m]: *n.r*[10] - Lethal [1%] [m]: *n.r.* - Wounded [m]: 60 *from side of pool* - Safe [m]: *205 from side of pool*	- Lethal [100%]: 35 kW/m^2 - Lethal [1%]: 10 kW/m^2 - Wounded : 3 kW/m^2 - Safe: 1 kW/m^2

[10] n.r.: not reached

n-Nonane (Downwind)



n-Nonane (Topview)



Appendix

Plan

4.3 Heavy fuel - pipe trench fire

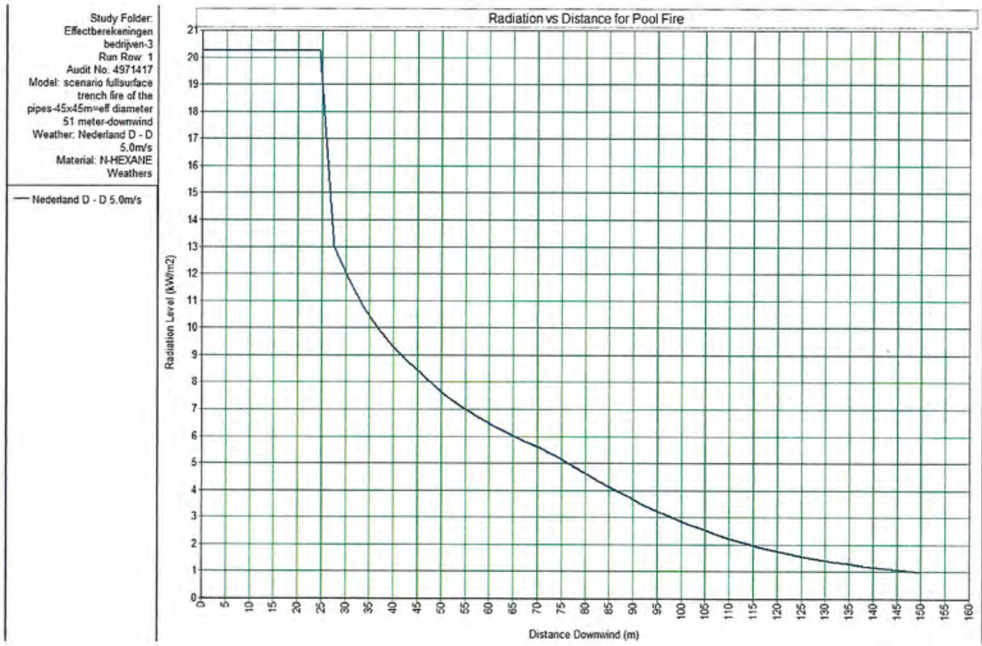
Buckeye Bahamas Hub; BORCO Scenario description			# 4.3
Company: *Buckeye Bahamas Hub; BORCO*	Installation: *Oil storage*	Type of activity: *Storage*	
Type of containment: *Pipelines in trench form terminal to jetties*		System volume: Pool size: *45 m. wide*	
LOC (Loss of Containment) type: *Pipe failure*		LOC location: *Trench (see map)*	
Scenario (elaboration)			
Due to an incident, a pipe in the trench has lost its integrity, the trench is full of fuel (heavy fuel)			
Release:			
Product name: *n-Hexane*	Temp [deg C]: *20*	Pressure [barg]: *Atmospheric*	Phase [S/L/G/2 phase]: *L*
Hole size: [diam mm]: *does not apply for this scenario*	Release duration: [sec]: *does not apply*	Pool size [m^2] *2025 m^2 (net))*	Leak rate [kg/s]: *does not apply*
Physical effect:			
Nature of effect: *Liquid Pool Fire*	Effect distance at ground level **(Downwind):** - Lethal [100%] [m]: *n.r*[11] - Lethal [1%] [m]: *12 from edge trench* - Wounded [m]: *73 from edge trench* - Safe [m]: *125 from edge trench*		Effect criterion: Threshold limits - Lethal [100%]: 35 kW/m^2 - Lethal [1%]: 10 kW/m^2 - Wounded : 3 kW/m^2 - Safe: 1 kW/m^2
Nature of effect:	Effect distance at ground level **(Upwind):** - Lethal [100%] [m]: *n.r*[12]		Effect criterion: Threshold limits

[11] n.r.: not reached

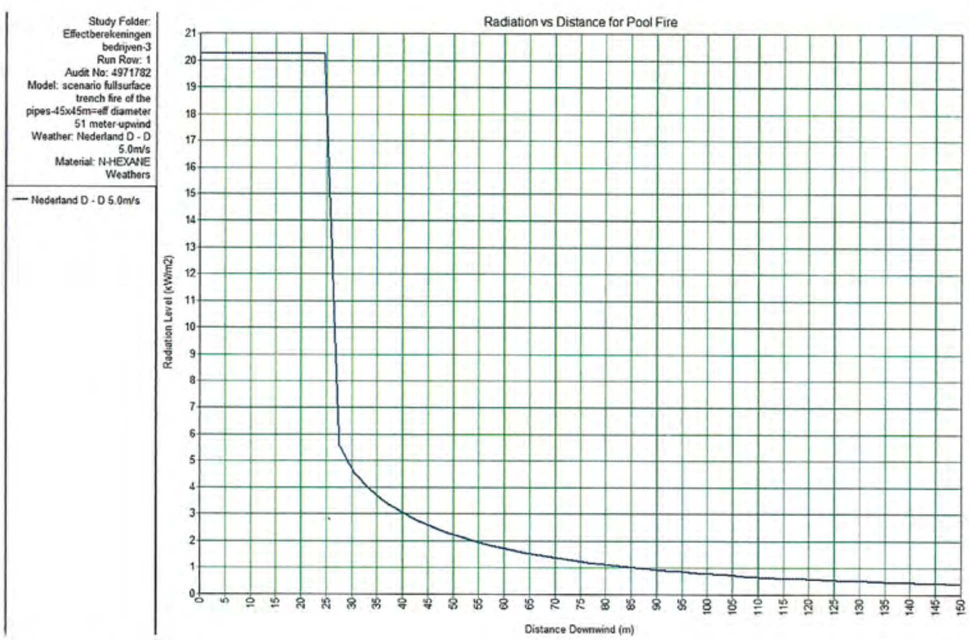
[12] n.r.: not reached

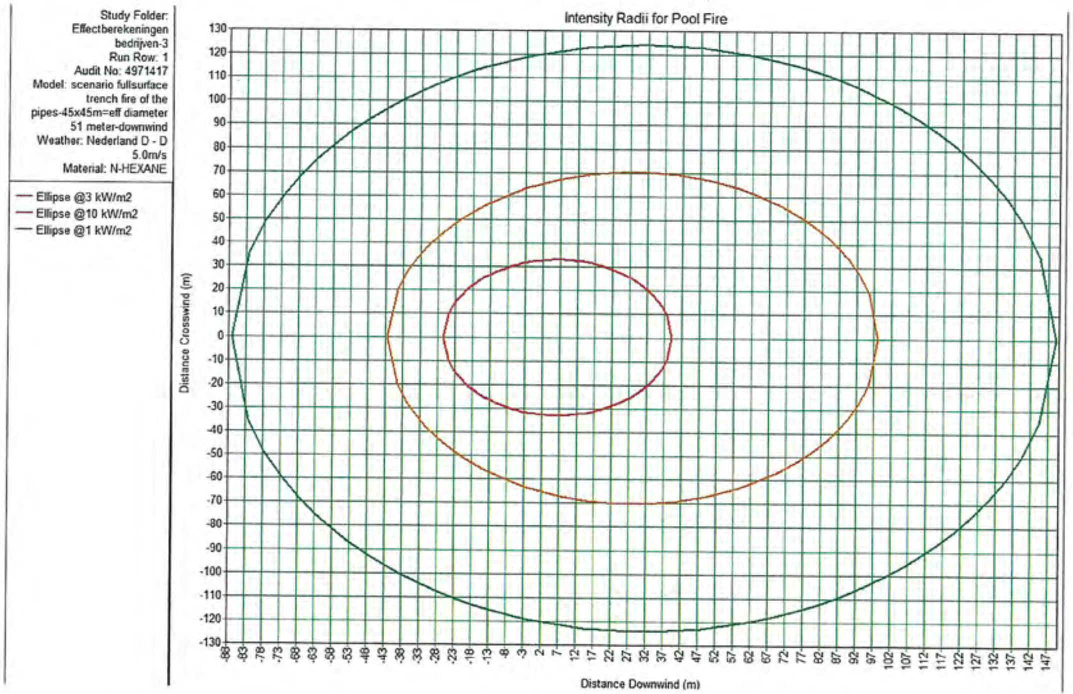
Liquid Pool Fire	- Lethal [1%] [m]: *2 from edge of trench* - Wounded [m]: 16 *from edge trench* - Safe [m]: *60 from edge trench*	- Lethal [100%]: 35 kW/m^2 - Lethal [1%]: 10 kW/m^2 - Wounded : 3 kW/m^2 - Safe 1 kW/m^2

n-Hexane (Downwind)



n-Hexane (180 degr.: Upwind)




Study Folder: Effectberekeningen bedrijven-3
Run Row: 1
Audit No: 4971417
Model: scenario fullsurface trench fire of the pipes-45x45m=eff diameter 51 meter-downwind
Weather: Nederland D - D 5.0m/s
Material: N-HEXANE
Ellipse @3 kW/m2
Ellipse @10 kW/m2
Ellipse @1 kW/m2
Intensity Radii for Pool Fire
Distance Crosswind (m)
Distance Downwind (m)

Appendix

Plan

4.4 Heavy fuel - tank pit (pool size 10.000 m²) fire

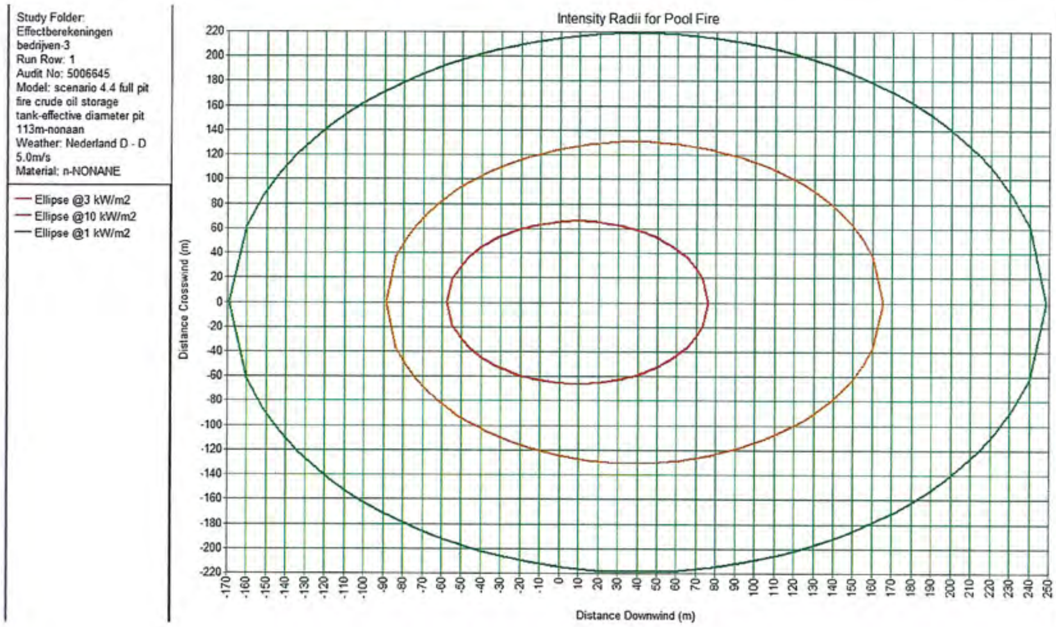
Buckeye Bahamas Hub; BORCO Scenario description			**# 4.4**
Company: *Buckeye Bahamas Hub; BORCO*	Installation: *Oil storage*	Type of activity: *Storage*	
Type of containment: *Cylindrical atmospheric tanks in tank pit*		System volume: largest tank Pool size: *10.000 m². Eff diam: 113 m*	
LOC (Loss of Containment) type: *Tank failure*		LOC location: *Tank pit (see map)*	
Scenario (elaboration)			
Due to an incident, a storage tank has lost its integrity, the tank pit is full of fuel (heavy fuel)			
Release:			
Product name: *N-nonane*	Temp [deg C]: *20*	Pressure [barg]: *Atmospheric*	Phase [S/L/G/2 phase]: *L*
Hole size: [diam mm]: *does not apply for this scenario*	Release duration: [sec]: *does not apply*	Pool size [m²] *10.000 (net))*	Leak rate [kg/s]: *does not apply*
Physical effect:			
Nature of effect: *Liquid Pool Fire*	Effect distance at ground level **(Downwind):** - Lethal [100%] [m]: *n.r*[13] - Lethal [1%] [m]: *20 from side pool* - Wounded [m]: *110 from side of pool* - Safe [m]: *192 from side of pool*	Effect criterion: Threshold limits - Lethal [100%]: 35 kW/m² - Lethal [1%]: 10 kW/m² - Wounded : 3 kW/m² - Safe: 1 kW/m²	
Nature of effect: *Liquid Pool Fire*	Effect distance at ground level **(Upwind):** - Lethal [100%] [m]: *n.r*[14] - Lethal [1%] [m]: *2 from side of pool*	Effect criterion: Threshold limits - Lethal [100%]: 35 kW/m²	

[13] n.r.: not reached

[14] n.r.: not reached

	- Wounded *pool* - Safe *pool*	[m]: 44 *from side of* [m]: *124 from side of*	- Lethal [1%]: 10 kW/m^2 - Wounded : 3 kW/m^2 - Safe 1 kW/m^2

n-Nonane (Topview)



Appendix

Plan

4.5 Heavy fuel - tank pit (pool size 290 m x 290 m) fire

Buckeye Bahamas Hub; BORCO Scenario description			# 4.5
Company: *Buckeye Bahamas Hub; BORCO*	Installation: *Oil storage*	Type of activity: *Storage*	
Type of containment: *Cylindrical atmospheric tanks in tank pit*		System volume: largest tank Pool size: *290 x 290 m Eff diam: 327 m*	
LOC (Loss of Containment) type: *Tank failure*		LOC location: *Tank pit (see map)*	
Scenario (elaboration)			
Due to an incident, a storage tank has lost its integrity, the tank pit is full of fuel (heavy fuel)			
Release:			
Product name: *N-nonane*	Temp [deg C]: *20*	Pressure [barg]: *Atmospheric*	Phase [S/L/G/2 phase]: *L*
Hole size: [diam mm]: *does not apply for this scenario*	Release duration: [sec]: *does not apply*	Pool size [m^2] *84.100 (net))*	Leak rate [kg/s]: *does not apply*
Physical effect:			
Nature of effect: *Liquid Pool Fire*	Effect distance at ground level **(Downwind):** - Lethal [100%] [m]: *n.r*[15] - Lethal [1%] [m]: *25 from side pool* - Wounded [m]: *190 from side of pool* - Safe [m]: *345 from side of pool*		Effect criterion: Threshold limits - Lethal [100%]: 35 kW/m^2 - Lethal [1%]: 10 kW/m^2 - Wounded : 3 kW/m^2 - Safe: 1 kW/m^2
Nature of effect: *Liquid Pool Fire*	Effect distance at ground level **(Upwind):** - Lethal [100%] [m]: *n.r*[16] - Lethal [1%] [m]: *2 from side of pool*		Effect criterion: Threshold limits - Lethal [100%]: 35 kW/m^2

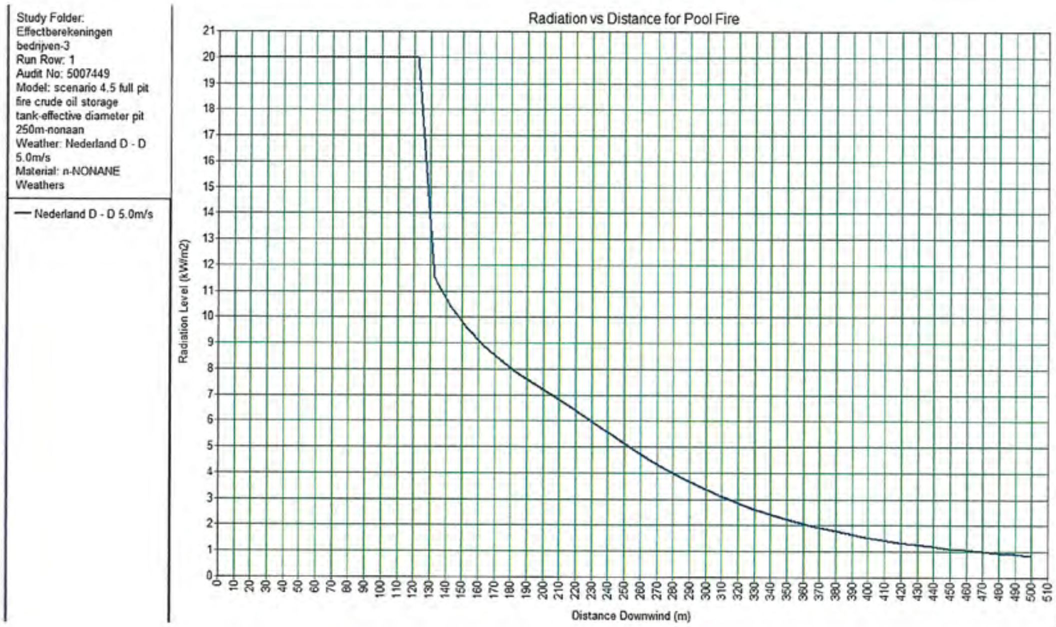
[15] n.r.: not reached

[16] n.r.: not reached

	- Wounded *pool* - Safe *pool*	[m]: 65 *from side of* [m]: *220 from side of*	- Lethal [1%]: 10 kW/m^2 - Wounded : 3 kW/m^2 - Safe 1 kW/m^2

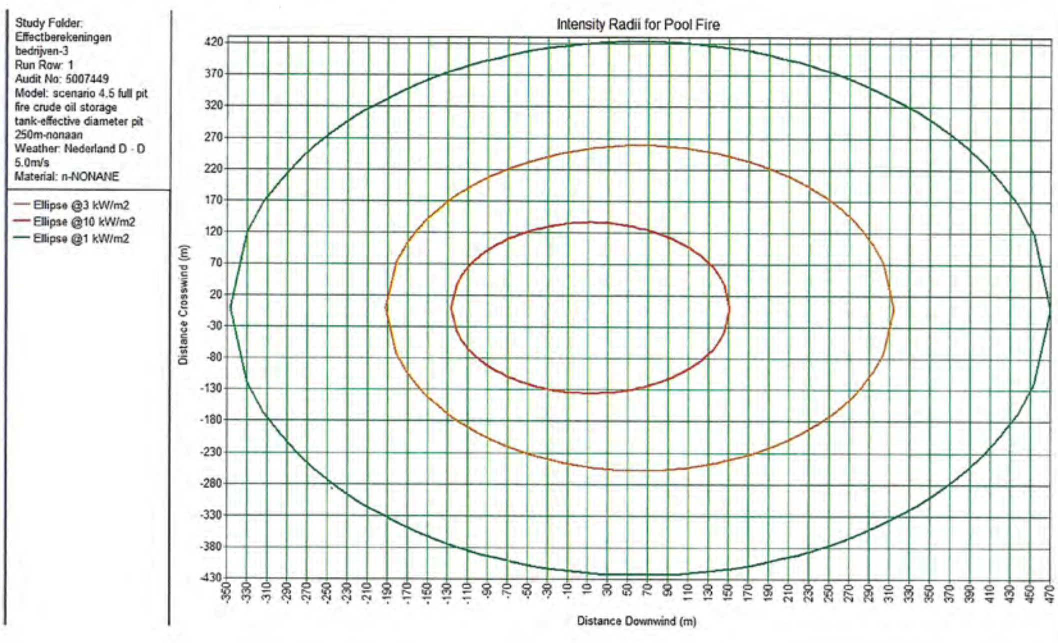
n-Nonane (Downwind)

diam. of 250 m is max. for calculations / effects.



n-Nonane (Topview)

diam. of 250 m is max. for calculations / effects.



Appendix

Plan

4.6 Heavy fuel - tank pit (pool size 370 m x 370 m) fire

Buckeye Bahamas Hub; BORCO Scenario description			# 4.6
Company: *Buckeye Bahamas Hub; BORCO*	Installation: *Oil storage*	Type of activity: *Storage*	
Type of containment: *Cylindrical atmospheric tanks in tank pit*		System volume: largest tank Pool size: *370 x 370 m Eff diam: 417 m*	
LOC (Loss of Containment) type: *Tank failure*		LOC location: *Tank pit (see map)*	
Scenario (elaboration)			
Due to an incident, a storage tank has lost its integrity, the tank pit is full of fuel (heavy fuel)			
Release:			
Product name: *N-nonane*	Temp [deg C]: *20*	Pressure [barg]: *Atmospheric*	Phase [S/L/G/2 phase]: *L*
Hole size: [diam mm]: *does not apply for this scenario*	Release duration: [sec]: *does not apply*	Pool size [m²] *136.900 (net))*	Leak rate [kg/s]: *does not apply*
Physical effect:			
Nature of effect: *Liquid Pool Fire*	Effect distance at ground level **(Downwind):** - Lethal [100%] [m]: *n.r*[17] - Lethal [1%] [m]: *25 from side pool* - Wounded [m]: *190 from side of pool* - Safe [m]: *345 from side of pool*		Effect criterion: Threshold limits - Lethal [100%]: 35 kW/m² - Lethal [1%]: 10 kW/m² - Wounded : 3 kW/m² - Safe: 1 kW/m²
Nature of effect:	Effect distance at ground level **(Upwind):**		Effect criterion: Threshold limits

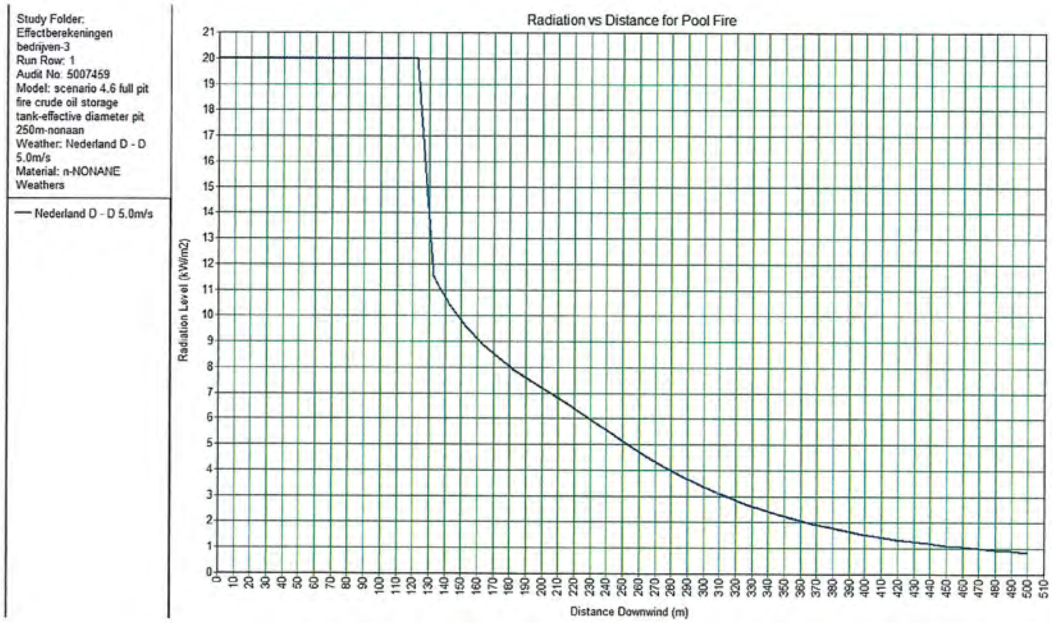
[17] n.r.: not reached

Liquid Pool Fire	- Lethal [100%] [m]: *n.r*[18] - Lethal [1%] [m]: *2 from side of pool* - Wounded [m]: 65 *from side of pool* - Safe [m]: *220 from side of pool*	- Lethal [100%]: 35 kW/m^2 - Lethal [1%]: 10 kW/m^2 - Wounded : 3 kW/m^2 - Safe 1 kW/m^2

[18] n.r.: not reached

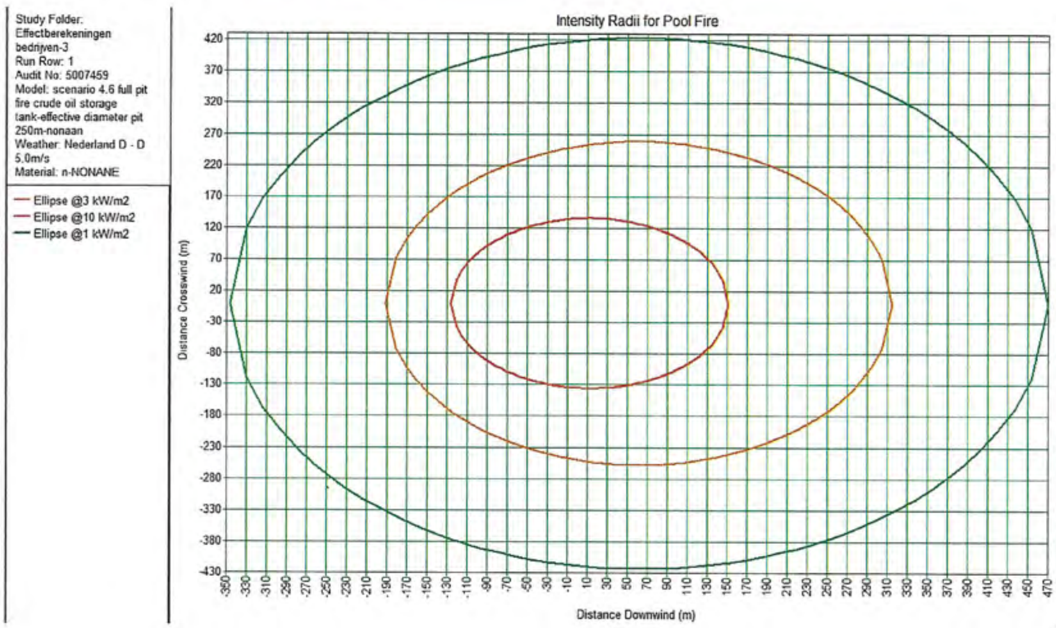
n-Nonane (Downwind)

diam. of 250 m is max. for calculations / effects.



n-Nonane (Topview)

diam. of 250 m is max. for calculations / effects.



Appendix

Plan

4.7 Heavy fuel - tank pit (pool size 135 m x 135 m) fire

<table>
<tr><td colspan="3">Buckeye Bahamas Hub; BORCO
Scenario description</td><td colspan="2"># 4.7</td></tr>
<tr><td>Company:
Buckeye Bahamas Hub; BORCO</td><td>Installation:
Oil storage</td><td colspan="3">Type of activity:
Storage</td></tr>
<tr><td colspan="2">Type of containment:
Cylindrical atmospheric tanks in tank pit</td><td colspan="3">System volume: largest tank
Pool size: 135 x 135 m Eff diam: 152 m</td></tr>
<tr><td colspan="2">LOC (Loss of Containment) type:
Tank failure</td><td colspan="3">LOC location:
Tank pit (see map)</td></tr>
<tr><td colspan="5">Scenario (elaboration)</td></tr>
<tr><td colspan="5">Due to an incident, a storage tank has lost its integrity, the tank pit is full of fuel (heavy fuel)</td></tr>
<tr><td colspan="5">Release:</td></tr>
<tr><td>Product name:
N-nonane</td><td>Temp [deg C]:
20</td><td>Pressure [barg]:
Atmospheric</td><td colspan="2">Phase [S/L/G/2 phase]: L</td></tr>
<tr><td>Hole size:
[diam mm]:
does not apply for this scenario</td><td>Release duration: [sec]:
does not apply</td><td>Pool size [m²]
18.225 (net))</td><td colspan="2">Leak rate [kg/s]:
does not apply</td></tr>
<tr><td colspan="5">Physical effect:</td></tr>
<tr><td>Nature of effect:

Liquid Pool Fire</td><td colspan="2">Effect distance at ground level (Downwind):

- Lethal [100%] [m]: n.r[19]
- Lethal [1%] [m]: 20 from side pool
- Wounded [m]: 135 from side of pool
- Safe [m]: 240 from side of pool</td><td colspan="2">Effect criterion:

Threshold limits
- Lethal [100%]: 35 kW/m²
- Lethal [1%]: 10 kW/m²
- Wounded : 3 kW/m²
- Safe: 1 kW/m²</td></tr>
<tr><td>Nature of effect:

Liquid Pool Fire</td><td colspan="2">Effect distance at ground level (Upwind):

- Lethal [100%] [m]: n.r[20]
- Lethal [1%] [m]: n.r.</td><td colspan="2">Effect criterion:

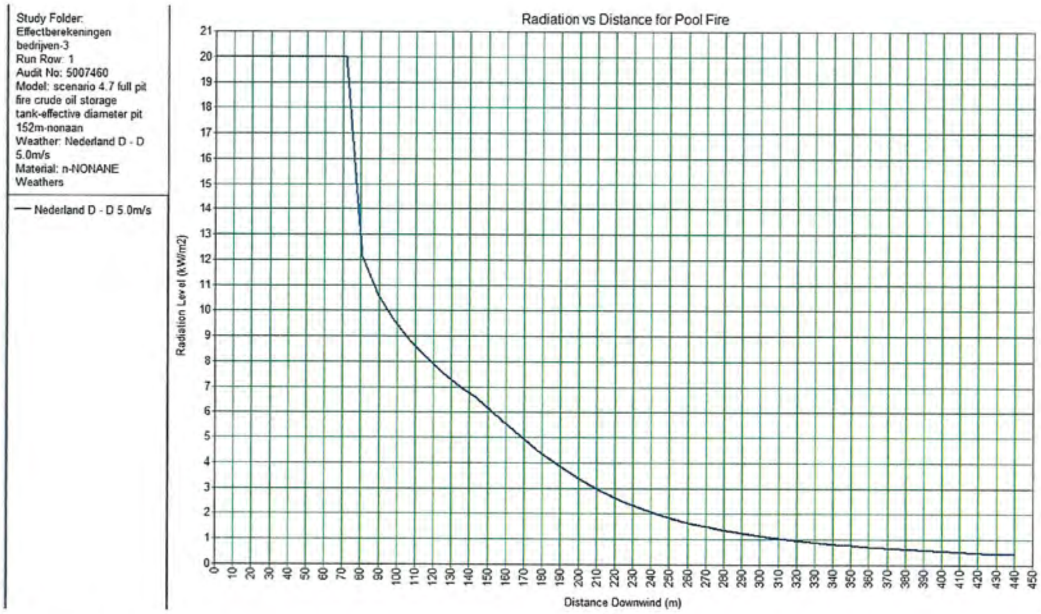
Threshold limits
- Lethal [100%]: 35 kW/m²</td></tr>
</table>

[19] n.r.: not reached

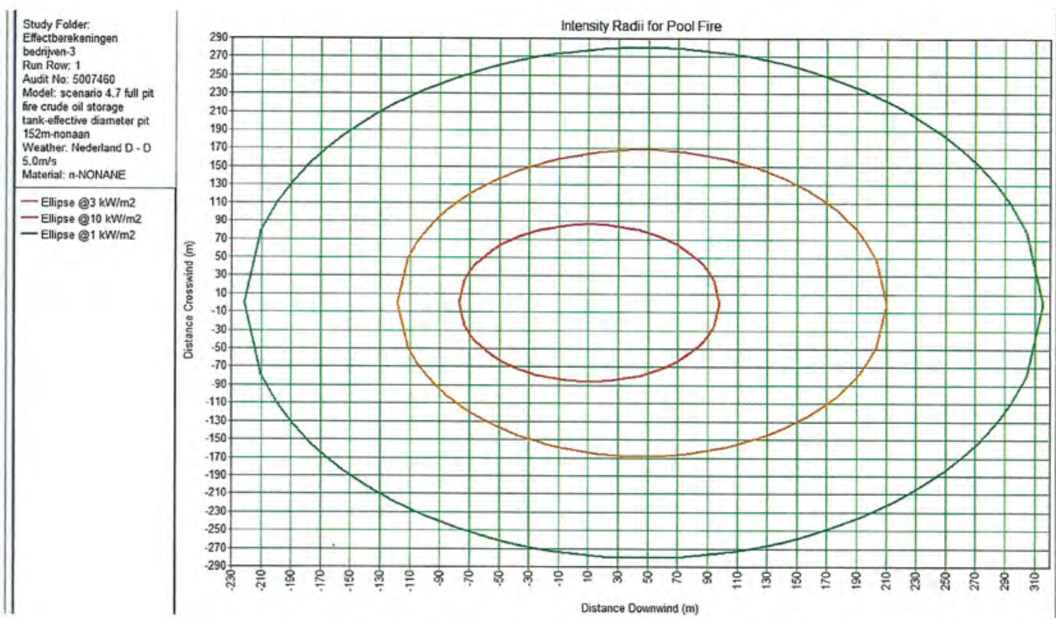
[20] n.r.: not reached

	- Wounded *pool* - Safe *pool*	[m]: 40 *from side of* [m]: *145 from side of*	- Lethal [1%]: 10 kW/m^2 - Wounded : 3 kW/m^2 - Safe 1 kW/m^2

n-Nonane (Downwind)



n-Nonane (Topview)



Appendix

Plan

About Antea Group

From city to countryside, from air to water: Antea Group's engineers and consultants have been contributing to our living environment in the Netherlands for years now. We design bridges and roadways, and create residential neighborhoods and water structures. But we are also involved in areas such as the environment, safety, asset management and energy. Under the name Oranjewoud, we expanded into an all-round, independent partner for companies and government bodies. As the Antea Group, we also apply this knowledge at a global level. By combining valuable knowledge, including on technical matters, with a pragmatic approach, we make solutions attainable and workable. Goal-oriented, with an eye for sustainability. In this way, we anticipate today's questions and tomorrow's answers. Just as we have been for over 60 years now.

Contact information

29, Monitorweg
1322 BK ALMERE
P.O. Box 10044
1301 AA ALMERE

machiel.pronk@anteagroup.com

www.anteagroup.nl

A member of INOGEN®