PETROSAFE
Petroleum Safety & Environmental Services Co.
An Egyptian Oil Sector Company

ISO 9001 = ISO 14001
OHSAS 18001

بتروسيف
شركة الخدمات البترولية للسلامة والبيئة
إحدى شركات قطاع البترول

EGAS

The Egyptian Natural Gas Holding Company "EGAS"

Quantitative Risk *Assessment*
"QRA" Study
For
Tema Pressure Reduction Station

Prepared By
Petroleum Safety and Environmental Services Company
PETROSAFE

January 2016

Title	Quantitative Risk Assessment Study For Tema New Pressure Reduction and Odorant Station – Sohag Government – Upper Egypt
Customer	Egyptian Natural Gas Holding Company "EGAS"
Customer Reference	EGAS/QRA/02/2015-MG/MS
Confidentiality, Copyright and Reproduction	This document has been prepared by PETROSAFE in connection with a contract to supply services and is submitted only on the basis of strict confidentiality. The contents must not be disclosed to third parties other than in accordance with the terms of the contract.
Report Number	EGAS.HSE.QRA.Study.02/Tema/PRS.No.02/2015/QRA/MG/MS/DNV-PHAST.7.0-PETROSAFE-Final Report
Report Status	Revision 1

PETROSAFE
6w/4 Hassan Nassar St. - Takseem El-Laselky - New Maadi, Cairo, Egypt
Telephone: +(202) 2517 6935 / 2517 6936 / 2517 6937
Facsimile: +(202) 2517 6938 / 2517 6958
e-mail: mohamed.ghazaly@petrosafe.com.eg
mohamed.samy@petrosafe.com.eg

	Name	Signature		Date
Team Work	Chem. Waael Said Safety Auditing Section Head		PETROSAFE	28/01/2016
	Chem. Mohamad Samy Safety Studies Dept. Head		PETROSAFE	28/01/2016
	Geo. Mohamad Al-Ghazaly Safety Affairs Asst. Gen. Mgr.		PETROSAFE	28/01/2016
Reviewed by	Eng. Ahmad Farag Projects Asst. Gen. Mgr.		EGAS	/01/2016
Approved by	Asst. Chairman for Health, Safety		EGAS	/01/2016
	Eng. Gamal Hegazy Vice Chairman for Planning and Gas Projects		EGAS	/01/2016

Distribution

- Client – EGAS
- File – EGAS / PETROSAFE
- Library – EGAS / PETROSAFE

CONTENTS

Executive Summary

This report summarizes the Quantitative Risk Assessment (QRA) analysis study undertaken for the New Natural Gas Pressure Reduction & Metering Station "PRMS" with Odorant at Tema – Sohag Government – Upper Egypt – which owned by Egyptian Natural Gas Holding Company "EGAS" and operated by Regional Gas Company "REGAS" in order to identify and evaluate hazards generated from the new Tema PRMS.

The scope of work includes performing frequency assessment, consequence modeling analysis and Quantitative Risk Assessment of Tema PRS in order to assess their impacts on the surroundings.

The main objective of the Quantitative Risk Assessment (QRA) study is to demonstrate that Individual Risk "IR" for workers and Societal Risk "SR" for public fall within the ALARP region of Risk Acceptance Criteria, and the new Tema PRS doesn't lead to any unacceptable risks to the workers or the public.

QRA Study has been undertaken in accordance with the methodology outlined in the UKHSE as well as international regulations and standards.

QRA starts by Hazard Identification (HAZID) study, which determines the Major Accident Hazards (MAH) that requires consequence modelling, frequency analysis, and risk calculation.

In order to perform consequence modelling analysis of the potential hazardous scenarios resulting from loss of containment, some assumptions and design basis have been proposed. Three scenarios of the release have been proposed:

1. Gas Release from the inlet pipeline.
2. Gas Release from the outlet pipeline.
3. Leak from odorant tank.

The QRA has been performed using DNV Phast software (Ver. 7.0) for consequence modelling of different types of hazardous consequences.

Weather conditions have been selected based on wind speed and stability class for the area detailed weather statistics.

The worst case weather conditions has been selected represented by wind speed of 4.5 m/s and stability class "D" representing "Neutral" weather conditions, in order to obtain conservative results. The prevailing wind direction is North / North West (N/NW).

As per results from modeling the consequences of each scenario the following table summarize the study, and as follows:

Event	Scenario	Effects
Pin hole (1") gas release 0º 4" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects will be limited inside the PRS area.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation value (9.5 kW/m^2 and 12.5 kW/m^2) effects will be limited inside the PRS boundary.* *The heat radiation value (4 kW/m^2) effects will be near the security office from the SW side.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extend outside the PRS fence with a distances of about 45 m NW, 48 SW and 29 m SE reaching the security office and extending the road.* *The value of 0.137 bar and 0.206 bar will be limited inside from NE, SW and SE, but extended from 2 to 5 meters out from NW side.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the 0.020 bar will reach a distance of 32 m SE covering the security office, at NE fence covering the office building, 48 m NW and 40 SW.* *The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary from NE, SE and NW, with extending of about 2 m for 0.137 bar from NW side.*
Pin hole (1") gas release 45º 4" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects will be limited inside the PRS area.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation value (9.5 kW/m^2 & 12.5 kW/m^2) effects will be limited inside the PRS boundary.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extend outside the PRS fence with a distances of about 47 m NW, 38 SW and*

Event	Scenario	Effects
		30 m SE and reaching the security office and the road direction. *The value of 0.137 bar and 0.206 bar will be limited inside from NE and SE, but extended from 2 to 5 meters out from NW side.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	N/D
Half Rupture (2") gas release 0º 4" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects will be limited inside the PRS area.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation value of (9.5, 12.5, 25 & 37.5 kW/m^2) effects will extended the SE fence downwind, effecting the security office and the public road with different distances as per table (18).*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extend outside PRS fence with a distances of about 47 m NW, 29.5 m NE and 39.5 SE reaching the security office and the road.* *The value of 0.137 bar and 0.206 bar will be limited inside from NE, SW and SE, but extended from 4 & 2 meters outside from NW side.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extended the PRS NW fence to a distance of 15 m, SW fence 22 m and SE fence 40 m covering the security office the road.* *The value of 0.137 bar and 0.206 bar will be extended outside the PRS from the SE side to a distance of 10 & 12 m.*

Event	Scenario	Effects
Half Rupture (2") gas release 45º 4" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects will be limited inside the PRS boundary.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation of 9.5 kW/m^2 will effects the security office and extended the PRS SE fence with about 10 m reaching the road.* *The heat radiation of 12.5 kW/m^2 will be near the SW side of the security office and will extended the PRS SE fence with about 5 m.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extended outside the PRS fences with a distances of about 42 m NW, 38 SW and 29 m SE covering the security office and the road. This value will limited inside the PRS NE fence (at fence) and covering the office building.* *The value of 0.137 bar and 0.206 bar will be limited inside from NE, SW and SE, but extended from 5 & 2 meters outside from NW side.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extend outside the PRS fences with a distance of about 25 m SW, 24 NW and 29 m SE effecting the security office and the road. This value will reach the administration building at the NE side, but not extending the fence.* *The value of 0.137 bar and 0.206 bar will be limited inside PRS boundary and covering the off-take point.*
Full Rupture (4") gas release 4" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects (LFL and 50 % LFL) will extend outside the PRS boundary about 76.92 m.*
	Heat radiation / Jet fire	*The modeling show that the heat radiation values (9.5 & 12.5 kW/m^2) will cover the security office and administration building*

Event	Scenario	Effects
	9.5 kW/m^2 12.5 kW/m^2	*down & crosswind, and extended outside the PRS SE fence to the road.* *The heat radiation values of 25 & 37.5 kW/m^2 will cover security office, off-take surface point and extended the PRS SE fence to the road.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extend outside the PRS fences with a distance of about 42 m NW, 36 SW and 27 m SE covering the security office and reaching the road, and at NE fence covering the office building.* *The value of 0.137 bar and 0.206 bar will be limited inside PRS boundary from NE & SE, but extended from 5 & 2 meters out from NW side and 1 m SW effecting the off-take surface.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extended outside the PRS fence SE with a distance of 48 m effecting the security office and the road.* *The overpressure wave values of 0.137 bar and 0.206 bar will be outside the PRS boundary (SE fence) with a distance from 20 & 22 m downwind.*
	Heat radiation / Fireball 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation value of:* *9.5 kW/m^2 will be limited from NE & SE and extended 7 m SW & 10 m NW.* *12.5 kW/m^2 will be limited from NE & SE and extended 3 m SW & 9 m NW.* *25 kW/m^2 will be limited from NE, SE & SW and extended 1 m NW.* *37.5 kW/m^2 will be limited inside the PRS boundary.*
Pin hole (1") gas release 0^o 10" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects will be limited inside the PRS boundary.*

Event	Scenario	Effects
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation value (9.5 kW/m^2 & 12.5 kW/m^2) effects will be limited inside the PRS boundary.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extend outside the PRS boundary with a distances of about 8 m SE effecting the security office, 7 m SW and 22 m NW.* *The value of 0.137 bar and 0.206 bar will be limited inside PRS boundary.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	N/D
Pin hole (1") gas release 45º 10" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects will be limited inside the PRS area.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation value (9.5 kW/m^2 & 12.5 kW/m^2) effects will be limited inside the PRS boundary.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extend outside the PRS boundary with a distances of about 22 m NW, 8 m SW and 9 SE effecting the security office and reaching the road, also will be very close to the administration building from the NE side.* *The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	N/D
Half Rupture (5") gas release 0º 10" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud (UFL & LFL) will be limited inside the PRS boundary and the 50 % LFL may extended outside with about 3 m SE direction.*

Event	Scenario	Effects
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation value of 9.5, 12.5 kW/m^2 will effects the security and administration buildings down and crosswind (NE/SE).* *The values of 25 & 37.5 kW/m^2 effects the security office and extended outside the PRS SE fence to the road.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extended outside the PRS fences with a distance of about 21 m NW, 7 SW and 9 m SE effecting the security office and the road.* *The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extended the PRS fence from SE side with a distance of 14 m reaching the road, and limited inside the boundary from NE, NW & SW sides.* *The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary reaching the security office.*
Half Rupture (5") gas release 45º 10" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects will be limited inside the PRS area.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation value of 9.5 kW/m^2 & 12.5 kW/m^2 will extended outside the PRS fence from the SE side with a distance of 15 & 20 m covering the security office and reaching the road.* *The value of 9.5 kW/m^2 will be close to the administration building from the NE side.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extended outside the PRS fence with a distance of about 21 m NW, 8 m SW and 8 SE effecting the security office and reaching the road. This value will be close*

Event	Scenario	Effects
		to the administration building from the NE side. *The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will be limited inside the PRS fence from NE, SW and NW, but extended outside from the SE side covering the security office and reaching the road.* *The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary and may be close to the security office.*
Full Rupture (10") gas release 10" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects will be limited inside the PRS boundary for the (LFL & UFL) but may extended outside from SE side with a distance of about 6 m.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation of:* *9.5 kW/m^2 will extend to 40 m SE / 13 m NE / 5 m SW / at fence NW.* *12.5 kW/m^2 will extend to 38 m SE / 10 m NE / 1 m SW.* *25 kW/m^2 will extend to 30 m SE / 2 m NE.* *37.5 kW/m^2 will extend to 25 m SE.* *The heat radiations of 9.5, 12.5 and 25 kW/m^2 will affect the administration and security buildings, reaching the road.* *The heat radiation of 37.5 kW/m^2 will affect the security office and reaching the road, also close to the admin building.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extended outside the PRS boundary with a distances of about 21 m NW, 8 m SW and 8 SE covering the security office and reach the road. This value will be close to administration building from the NE side.* *The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary.*

Event	Scenario	Effects
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extended outside the PRS fence from SE side with a distance of 26 m covering the security office and reaching the road, and limited inside the boundary from NE, NW & SW sides.* *The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary covering the security office.*
	Heat radiation / Fireball 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation value (9.5 kW/m^2 and 12.5 kW/m^2) will be limited inside the PRS boundary.*
Odorant tank 1" leak		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects will be limited inside the PRS boundary but reaching the security office downwind (SE side).* *Consideration should be taken when deal with liquid, vapors and smokes according to the MSDS for the material.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation effects will be limited inside the PRS boundary from three sides (NE / SE / SW), but will extended beyond the NW fence with some of 5 & 10 meters (upwind).*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	N/D
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.137 bar and 0.206 bar will be extended the PRS SE fence affecting the security building and reaching the road at a distance of 12 and 10 m.* *The value of 0.020 bar will extend outside with a distances of about 5 m NE, 9 m SW, 41 m SE and 6 m NW.*

The previous table show that there are some potential hazards with heat radiation resulting from jet fire, and explosion overpressure waves in case of gas release and early or late ignited.

These hazards will affect the office and security buildings, also some scenarios will extend over the site boundary like heat radiation of 12.5 kW/m^2 and explosion overpressure waves reaching the outside road (Tall Ezzawaky - Tema Road) or other PRS sides.

These major hazards that extend over site boundary and/or effect on workers is used for Risk calculations.

Event Tree Analysis (ETA) is an analysis technique for identifying and evaluating the sequence of events in a potential accident scenario following the occurrence of an initiating event. ETA utilizes a visual logic tree structure known as an event tree (ET). ETA provides a Probabilistic Risk Assessment (PRA) of the risk associated with each potential outcome. ETA has been used for scenario development.

The following data and assumptions have been considered in the Event tree analysis (ETA):

- Failure frequency data (mainly E&P Forum/OGP),
- Risk reduction factors (if available),
- Ignition probabilities (both immediate and delayed),
- Vulnerability data.

Risks have been assessed for workers using International Risk Management Guidelines as a reference.

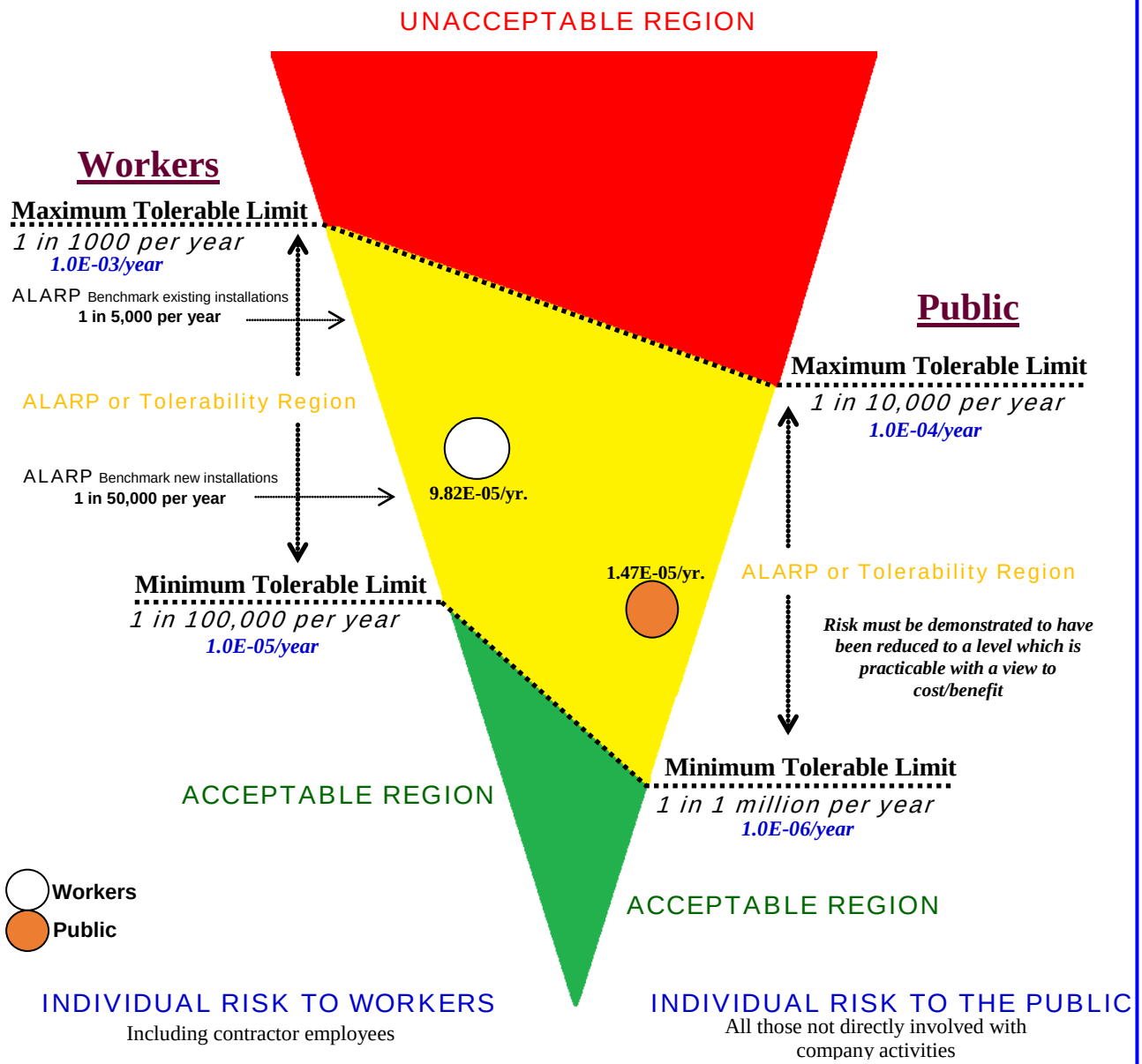
The resulting risks have been compared with International Risk Acceptance Criteria.

Risk evaluation for Individual Risk "IR" and Societal Risk "SR" for the major hazards are presented in the following tables:

No.	Scenario	Individual Risk "IR"	Acceptability Criteria
1	Gas Release from 2" / 4" Pipeline (Jet Fire/ Explosion)	***8.82E-05***	ALARP
	Gas Release from 5" / 10" Pipeline (Jet Fire/ Explosion)	***8.82E-06***	Acceptable (√)
2	Gas Release from 4" Pipeline Full Rupture (Jet Fire/ Explosion)	***4.65E-07***	Acceptable (√)
	Gas Release from 10" Pipeline Full Rupture (Jet Fire/ Explosion)	***4.65E-08***	Acceptable (√)
3	Odorant Tank 1" Leak (Jet Fire)	***7.2E-07***	Acceptable (√)
	TOTAL Risk for Workers	***9.82E-05***	**ALARP**

No.	Scenario	Societal Risk "SR"	Acceptability Criteria
1	Gas Release from 2" / 4" Pipeline (Jet Fire/Explosion)	***6.79E-06*** ***9.70E-07***	ALARP Acceptable (√)
2	Gas Release from 5" / 10" Pipeline (Jet Fire)	***6.79E-06***	ALARP
3	Gas Release from 4" Pipeline Full Rupture (Jet Fire)	***3.58E-08***	Acceptable (√)
	Gas Release from 10" Pipeline Full Rupture (Jet Fire)		
4	Odorant Tank 1" Leak (Jet Fire)	***7.92E-08***	Acceptable (√)
	TOTAL Risk for Public	***1.47E-05***	**ALARP**

The following figure show the Individual Risk "IR" as well as Societal Risk "SR" for Tema PRMS:



The level of Individual Risk to the most exposed worker at Tema PRS, based on the risk tolerability criterion used, is <u>ALARP</u>.

The level of Individual Risk to the exposed Public at Tema PRS area, based on the risk tolerability criterion used, is <u>ALARP</u>.

Introduction

The Egyptian Natural Gas Holding Company "EGAS" has engaged Petroleum Safety and Environmental Services Company "PETROSAFE" to identify and evaluate hazards generated from the "New Natural Gas Pressure Reduction and Odorant Station – PRS" at Tema – Sohag Government – Upper Egypt – which operated by Regional Gas Company "REGAS" in order to advice protective measures for minimizing risk up to acceptable level.

As part of this review a QRA study is conducted for the following objectives:

- Identify hazardous scenarios related to the most critical unexpected event(s).
- Determine the likelihood of the identified scenarios;
- Model the potential consequences of the identified scenarios;
- Determine the Potential risk of fatality resulting from the identified hazardous scenarios.

The proposed study should also identify existing arrangements for the prevention of major accidents and their mitigation. This would involve emergency plan and procedure for dealing with such events.

Petrosafe was selected to carry out this study, as it has the experience in conducting this type of work.

Petrosafe is also empowered by the Egyptian General Petroleum Corporation "EGPC" to identify and evaluate factors that relate to occupational health & safety and environmental protection.

Technical Definitions

ALARP	*Stands for "As Low As Reasonably Practicable", and is a term often used in the milieu of safety-critical and safety-involved systems. The ALARP principle is that the residual risk shall be as low as reasonably practicable.*
API	*American Petroleum Institute.*
Confinement	*A qualitative or quantitative measure of the enclosure or partial enclosure areas where vapors cloud may be contained.*
Congestion	*A qualitative or quantitative measure of the physical layout, spacing, and obstructions within a facility that promote development of a vapor cloud explosion.*
DNV PHAST	*Process Hazard Analysis Software Tool "PHAST" established by Det Norske Veritas "DNV". 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.*
E&P Forum	*Exploration and Production "E&P" Forum is the international association of oil companies and petroleum industry organizations formed in 1974. It was established to represent its members' interests at the specialist agencies of the United Nations, governmental and other international bodies concerned with regulating the exploration and production of oil and gas.*
EGAS	*The Egyptian Natural Gas Holding Company.*
EGPC	*The Egyptian General Petroleum Corporation.*
EX	*Explosion Proof Type Equipment.*
EERA	*Escape, Evacuation and Rescue Assessment.*
ESD	*Emergency Shut Down.*
Explosion	*Explosion is the delayed ignition of gas in a confined or congested area resulting in high overpressure waves.* *Once the explosion occurs it creates a blast wave that has a very steep pressure rise at the wave front and a blast wind that is a*

	transient flow behind the blast wave. The impact of the blast wave on structures near the explosion is known as blast loading. The two important aspects of the blast loading concern is the prediction of the magnitude of the blast and of the pressure loading onto the local structures. Pressure loading predications as a result of a blast; resemble a pulse of trapezoidal or triangular shape. They normally have duration of between approximately 40 msec and 400 msec. The time to maximum pressure is typically 20 msec. *Primary damage from an explosion may result from several events:* 1. *Overpressure - the pressure developed between the expanding gas and its surrounding atmosphere.* 2. *Pulse - the differential pressure across a plant as a pressure wave passes might cause collapse or movement, both positive and negative.* 3. *Missiles and Shrapnel - are whole or partial items that are thrown by the blast of expanding gases that might cause damage or event escalation. In general these "missiles" from atmospheric vapor cloud explosions cause minor impacts to process equipment since insufficient energy is available to lift heavy objects and cause major impacts. Small projectile objects are still a hazard to personnel and may cause injuries and fatalities. Impacts from rupture incidents may produce catastrophic results.*
(ETA) Event Tree Analysis	*Is a forward, bottom up, logical modeling technique for both success and failure that explores responses through a single initiating event and lays a path for assessing probabilities of the outcomes and overall system analysis. This analysis technique is used to analyze the effects of functioning or failed systems given that an event has occurred.*
Failure Rate	*Is the frequency with which an engineered system or component fails, expressed in failures per unit of time. It is highly used in reliability engineering.*
GASCO	*The Egyptian Natural Gas Company.*
Gas Cloud Dispersion	*Gas cloud air dilution naturally reduces the concentration to below the LEL or no longer considered ignitable (typically defined as 50 % of the LEL).*

HSE Policy	*Health, Safety and Environmental Policy.*
Hazard	*An inherent physical or chemical characteristic (flammability, toxicity, corrosively, stored chemical or mechanical energy) or set of conditions that has the potential for causing harm to people, property, or the environment.*
(HAZOP) Hazard And Operability Study	*Is a structured and systematic examination of a planned or existing process or operation in order to identify and evaluate problems that may represent risks to personnel or equipment, or prevent efficient operation. The HAZOP technique is qualitative, and aims to stimulate the imagination of participants to identify potential hazards and operability problems; structure and completeness are given by using guideword prompts.*
(HAZID) Hazard Identification Study	*Is a tool for hazard identification, used early in a project as soon as process flow diagrams, draft heat and mass balances, and plot layouts are available. Existing site infrastructure, weather, and geotechnical data are also required, these being a source of external hazards.*
(HAC) Hazardous Area Classification	*When electrical equipment is used in, around, or near an atmosphere that has flammable gases or vapors, flammable liquids, combustible dusts, ignitable fibers or flying's, there is always a possibility or risk that a fire or explosion might occur. Those areas where the possibility or risk of fire or explosion might occur due to an explosive atmosphere and/or mixture is often called a hazardous (or classified) location/area.*
(IR) Individual Risk	*The risk to a single person inside a particular building. Maximum individual risk is the risk to the most-exposed person and assumes that the person is exposed.*
Jet Fire	*A jet fire is a pressurized stream of combustible gas or atomized liquid (such as a high pressure release from a gas pipe or wellhead blowout event) that is burning. If such a release is ignited soon after it occurs, (i.e., within 2 - 3 minutes), the result is an intense jet flame. This jet fire stabilizes to a point that is close to the source of release, until the release is stopped. A jet fire is usually a very localized, but very destructive to anything close to it. This is partly because as well as producing thermal radiation, the jet fire causes considerable convective heating in the region*

	beyond the tip of the flame. The high velocity of the escaping gas entrains air into the gas "jet" causing more efficient combustion to occur than in pool fires. *Consequentially, a much higher heat transfer rate occurs to any object immersed in the flame, i.e., over 200 kw/sq. m (62,500 Btdsq. ft) for a jet fire than in a pool fire flame. Typically the first 10% of a jet fire length is conservatively considered un-ignited gas, as a result of the exit velocity causing the flame to lift off the gas point of release. This effect has been measured on hydrocarbon facility flares at 20% of the jet length, but a value of 10% is used to account for the extra turbulence around the edges of a real release point as compared to the smooth gas release from a flare tip. Jet flames have a relatively cool core near the source. The greatest heat flux usually occurs at impingement distances beyond 40% of the flame length, from its source. The greatest heat flux is not necessarily on the directly impinged side.*
kW/m^2	*Kilowatt per square meter – unit for measuring the heat radiation (or heat flux).*
LFL / LEL	*Lower Flammable Limit / Lower Explosive Limit - The lowest concentration (percentage) of a gas or a vapor in air capable of producing a flash of fire in presence of an ignition source.*
MSDS	*Material Safety Data Sheet.*
mm Hg	*A millimeter of mercury is a manometeric unit of pressure, formerly defined as the extra pressure generated by a column of mercury one millimeter high.*
MEL	*Maximum Exposure Limit.*
NFPA	*National Fire Protection Association.*
N	*North Direction.*
NE	*Northern East Direction.*
NW	*Northern West Direction.*
N/D	*Not Determined.*

OGP	*Oil and Gas Producers.*
ppm	*Part Per Million.*
PRS	*Pressure Reduction Station.*
P&ID's	*Piping and Instrumentation Diagrams.*
PETROSAFE	*Petroleum Safety and Environmental Services Company.*
QRA	*Quantitative Risk Assessment Study is a formal and systematic approach to estimating the likelihood and consequences of hazardous events, and expressing the results quantitatively as risk to people, the environment or your business.*
ReGas	*Regional Gas Company.*
Risk	*Relates to the probability of exposure to a hazard, which could result in harm to personnel, the environment or general public. Risk is a measure of potential for human injury or economic loss in terms of both the incident likelihood and the magnitude of the injury / loss.*
Risk Assessment	*The identification and analysis, either qualitative or quantitative, of the likelihood and outcome of specific events or scenarios with judgments of probability and consequences.*
scm/hr	*Standard Cubic Meter Per Hour.*
SCBA	*Self-Contained Breathing Apparatus.*
SE	*Southern East Direction.*
SW	*Southern West Direction.*
TWA	*Time Weighted Averages.*
UFL/UEL	*Upper flammable limit, the flammability limit describing the richest flammable mixture of a combustible gas.*
V	*Volume.*
Vapor Cloud Explosion (VCE)	*An explosion in air of a flammable material cloud.*

Objectives

The objectives of this QRA for the unit facilities are:

- Identify hazardous scenarios related to the facilities based on historical data recorded.
- Determine the likelihood (frequencies) of the identified scenarios;
- Model the potential consequences of the identified scenarios;
- Determine the Potential risk of fatality resulting from the identified hazardous scenarios;
- Evaluate the risk against the acceptable risk level to ensure that it is within *As Low As Reasonably Practicable "ALARP"*, otherwise additional control measures and recommendations will be provided at this study to reduce the Risk, *(ALARP)*.

Quantitative Risk Assessment Study Scope

The scope of work of this QRA study is limited to the following:

- Identification of the Most Critical Event(s) or scenarios that may lead to fetal accidents as well as to ensure that the expected risk will not exceed the Acceptable Risk Level as per national and international standards.
- Normal operation of the facilities (e.g. Construction and specific maintenance activities are excluded from this analysis);
- The study determines Frequencies, Consequences (Including Associated Effect Contours) and Potential Risk of Fatality for the identified hazardous scenarios.

Quantitative Risk Assessment "QRA" Studies

Method of Assessment

1.0- General Method Used

Attention was mainly focussed on those accidents where a gross failure of containment could result in the generation of a large vapour cloud of flammable or toxic material. The approach adopted has involved the following stages:

- Identification of hazardous materials,
- Establishment of maximum total inventories and location.

During the site visit by the study team, the overall functioning of the site was discussed in some detail and the Companies were asked to provide a complete list of holdings of hazardous materials. A preliminary survey notes was issued by the team, as a private communication to the company concerned, and this formed the basis for subsequent more discussion and analysis.

From the PRS design model provided by the client, it was impractical to examine in depth all possible failure modes for all parts within the time allowed for this study. Instead, only those potential failures which might contribute, either directly or indirectly, to off-site risks were examined.

2.0- Risk Assessment

As the PRS is under design so it was therefore necessary for the study team to identify and analyse the hazards potential from first principles the routes by which a single or multiple accident could affect the community or neighbouring.

The terms of reference required the team to investigate and determine the overall risk to health and safety both from individual installations and then foreseeable interactions.

The assessment of risk in a complex situation is difficult. No method is perfect as all have advantages and limitations.

It was agreed that the quantitative approach was the most meaningful way of comparing and evaluating different risks. The risk assessment framework shown in Figure (1) was used for this study.

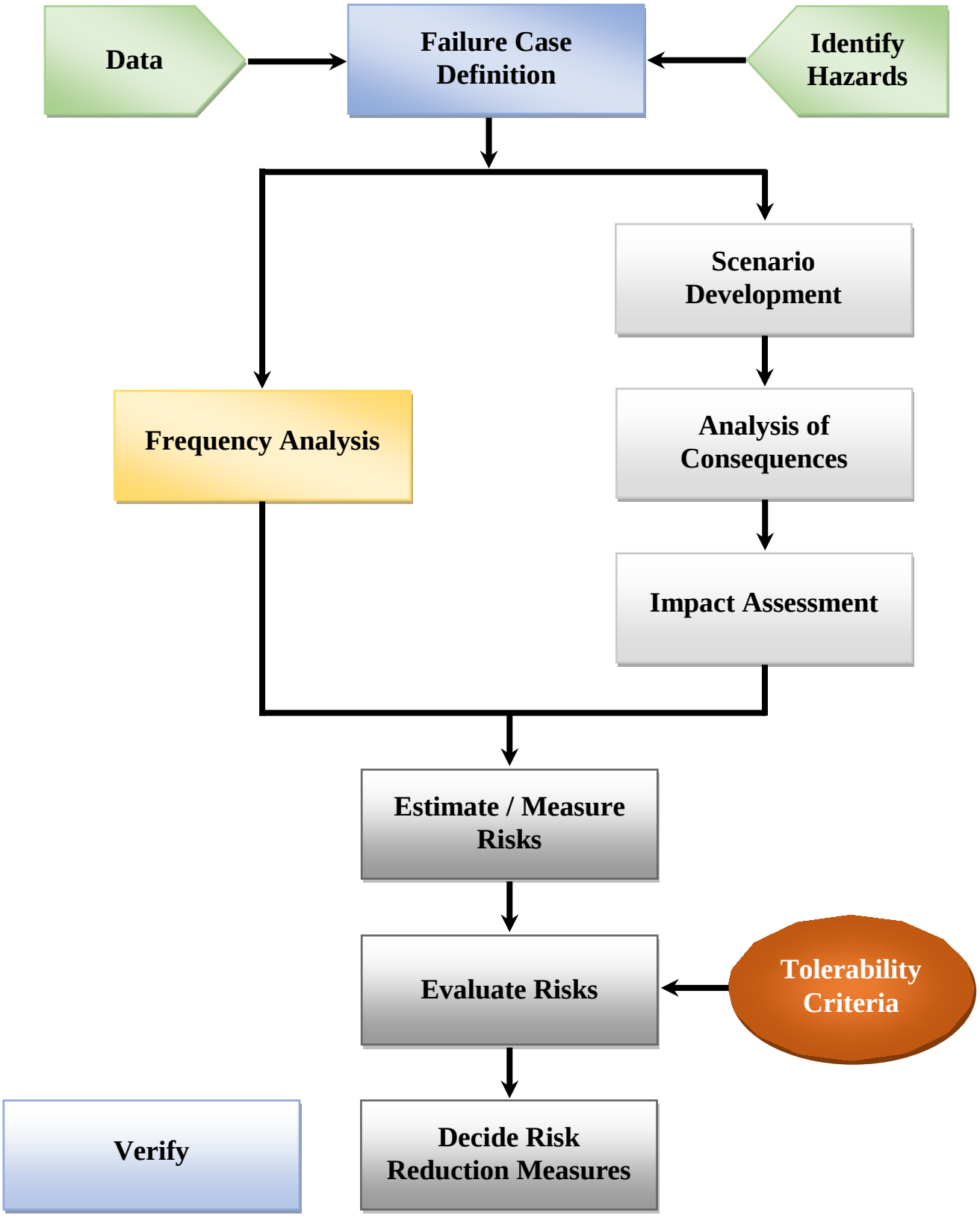


Figure (1) Risk Assessment Framework

Modeling the Consequences

Modeling of the consequences is one of the key steps in Quantitative Risk Assessment "QRA", as it provides the link between hazard identification (in this study Potential Loss of Containment Incidents) and the determination of possible impact of those incidents on People (Worker / Public), Asset and the Environment.

In this study, Natural Gas (Mainly Methane CH_4) was considered. There are several types of consequences to be considered for modelling, these include: Gas Dispersion (UFL - LFL - 50 % LFL) / Heat Radiation / Explosion Overpressure modeling, also each of these scenarios described in the following table:

Table (1) Description of Modeling of the Different Scenario

Discharge Modeling	*Modeling of the mass release rate and its variation overtime.*
Radiation Modeling	*Modeling of the Thermal radiation from fires.*
Dispersion Modeling	*Modeling of the Gas and two-phase releases.*
Overpressure	*Associated with explosions or pressure burst.*

Toxic hazards are considered as a result of releases / loss of containment for which discharge modeling and gas dispersion modeling are required. The hazard ranges are dependent upon the condition of the release pressure and rate of release.

There are a number of commercial software for modeling gas dispersion, fire, explosion and toxic releases. PETROSAFE select the *DNV PHAST Ver. 7.0 Software package* in modeling scenarios.

The software developed by DNV in order to provide a standard and validated set of consequence models that can be used to predict the effects of a release of hydrocarbon or chemical liquid or vapour. (Results of the modeling are shown in the study pages from 53 to 108)

Criterion for Risk Tolerability

The main function of this phase of the work was to assess the effectiveness of the proposed arrangement for managing risks against performance standards.

In order to do this, we need firstly to define a performance standard and secondly, to be able to analyse the effectiveness of the arrangements in a manner which permits a direct comparison with these standards.

The defining of performance standards is undertaken at the following three levels:

- Policy-based
- System
- Technical

Where the present work is mainly concerned with the assessment against the standards associated with the first two levels.

The policy-based performance standard relates to this objective to provide a working environment, where the risk to the individual is reduced to a level, which is ALARP.

This performance standard is, therefore, expressed in the form of individual risk and the arrangements for managing this risk should result in a level of 'Individual Risk', based on a proposed Tolerability Criteria, Figure (2).

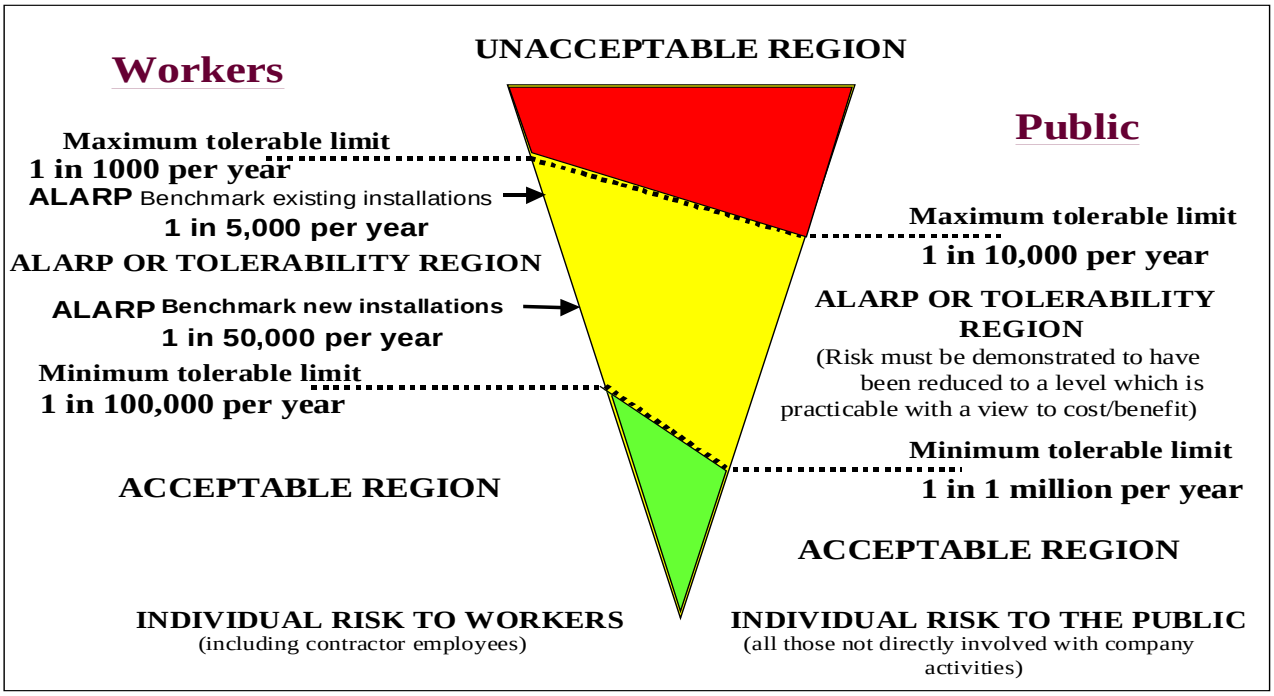


Figure (2) Criteria for Individual Risk Tolerability

The criterion for IR tolerability for workers and to the public is outlined in Table (2) and Figure (3).

It should be noted that this criteria is proposed only as a guideline. Risk assessment is no substitute to professional judgement.

Table (2) Proposed Individual Risk (IR) Criteria (per person/year)

Risk Level	Workers	Public
Intolerable	*> 10^{-3} per person/yr.*	*> 10^{-4} per person/yr.*
Negligible	*> 10^{-5} per person/yr.*	*> 10^{-6} per person/yr.*

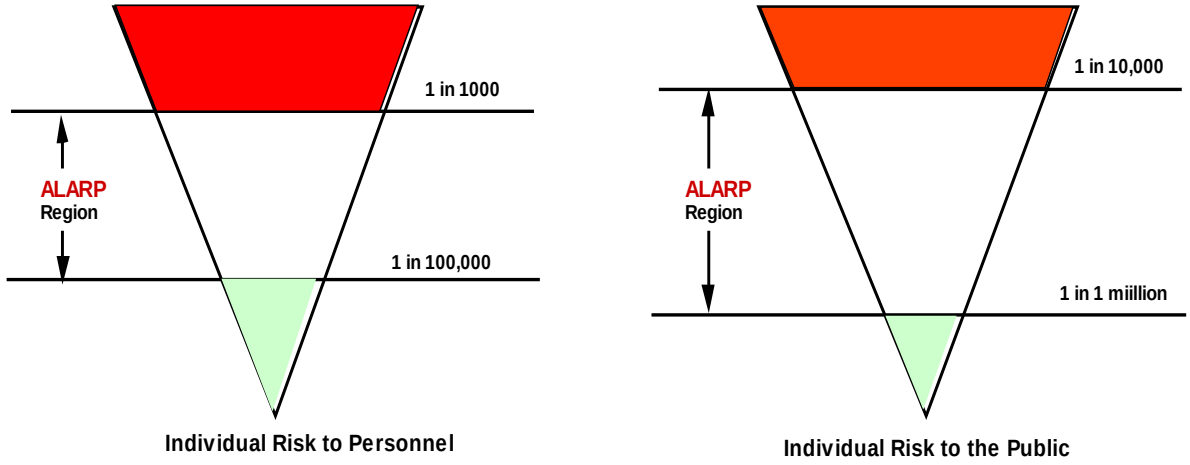


Figure (3) Proposed Individual Risk Criteria

Workers would include the Company employees and contractors. The public includes the general public, visitors, and any third party who is not directly involved in the Company work activities.

On this basis we have chosen to set our level of intolerability at Individual Risk for workers of 1 in 1,000 per year, and we define an individual risk of 1 in 100,000 per year as broadly acceptable. Consequently, our ALARP region is between 1 in 1,000 and 1 in 100,000 per person/year.

It is important to ensure that conflict between these subordinate standards and those stemming from international codes and standards are avoided and that any subordinate standards introduced are at least on a par with or augment those standards which are associated with compliance with these international

requirements. These system level performance standards are included as part of the summaries from the QRA. These are used as the basis for assessing the suitability and sufficiency of ReGas Site arrangements for both protecting personnel on site and members of the public from major hazards and securing effective response in an emergency. Failure to meet acceptance criteria at this level results in the identification of remedial measures for assessment both qualitatively and quantitatively.

The analytical work uses a system analysis approach and is divided into a number of distinct phases:

- Data collection, including results from site-based qualitative assessments.
- Definition of arrangements.
- Qualitative evaluation of arrangements against a catalogue of fire and explosion hazards from other major accident hazards.
- Preparation of event tree analyses models.
- Consolidation of list of design events.
- Analysis of the effect of design events on fire, explosion and toxic hazard management and emergency response arrangements.
- Quantification of that impact in terms of individual risk.

The main model is based on a systems approach, and it takes the following form:

- Estimates of incremental individual risk (IIR) per person/yr.
- Is caused-consequences based.
- Uses event tree analysis to calculate the frequency of occurrence.
- Estimates incremental individual risk utilizing event tree analysis, based on modeling the emergency response arrangements from detection through to recovery to a place of safety.

Personnel Vulnerability and Structural Damage

A criterion was used in the QRA study for the calculation of personnel vulnerability and structural / asset damage as a result of fire, explosion and toxic release is shown in Table (3).

The criteria shown below provide some assumptions for the impairment effects of hydrocarbon releases on personnel and structures, which are based on Health and Safety Executive: Methods of approximation and determination of human vulnerability for offshore major accident hazard assessment)

Table (3) Criteria for Personnel Vulnerability and Structural Damage

Event Type	Threshold of Fatality	Asset/Structural Damage
Jet and Diffusive Fire Impingement	6.3 kW/ m^2 (1) 12.5 kW/m^2 (2)	- Flame impingement 10 minutes. - 300- 500 kW/m^2 Structural Failure within 20 minutes.
Pool Fire Impingement	6.3 kW/ m^2 (1) 12.5 kW/m^2 (2)	- Flame impingement 20 minutes - 100 - 150 kW/m^2 Structural Failure within 30 minutes.
Smoke	2.3% v/v (3) 15% v/v (4)	
Explosion Overpressure	300 mbar	100 mbar

(1) Fatality within 1- 2 minutes
(2) Fatal < 1 minute
(3) Above 2.3%, escape possible but difficult
(4) No escape possible, fatal in a few seconds

The effects of exposure to fire are expressed in terms of heat radiation (kW/m^2) and overpressure waves are shown in Tables (4), (5) and (6).

Table (4) Fire Heat Radiation Effects on Structures (World Bank)

Radiation Level kW/m^2	Observed Effect
37.5	Sufficient to cause damage to process equipment
25	Minimum energy to ignite wood at indefinitely long exposure (non-piloted)
12.5	Minimum energy required to ignite wood, melting of plastic tubing

Table (5) Heat Radiation Effects on People

Radiation Level kw/m^2	Effects on People
1.2	Equivalent to heat from sun at midday summer
1.6	Minimum level at which pain can be sensed
4 - 6	Pain caused in 15 - 20 seconds, Second Degree burns after 30 seconds
12	20 % chance of fatality for 60 seconds exposure
25	100 % chance of fatality for continuous exposure 50 % chance of fatality for 30 seconds exposure
40	30 % chance of fatality for 15 seconds exposure
50	100 % chance of fatality for 20 seconds exposure

Table (6) Effects of Overpressure

Pressure		Effects / Damage
bar	psig	
0.002	0.03	Occasional breakage of glass windows
0.006	0.1	Breakage of some small windows
0.021	0.3	Probability of serious damage beyond this point = 0.05 10 % glass broken
0.027	0.4	Minor structural damage of buildings
0.068	1.0	Partial collapse of walls and roofs, possible injuries
0.137	2.0	Some severe injuries, death unlikely
0.206	3.0	Steel frame buildings distorted / pulled from foundation
0.275	4.0	Oil storage tanks ruptured
0.344	5.0	Wooden utilities poles snapped / Fatalities
0.41	6.0	Nearly complete destruction of building
0.48	7.0	Loaded wagon train overturned
0.689	10.0	Total destruction of buildings

Quantification of the Frequency of Occurrence

The probability of a sequence of events leading to a major hazard is dependent on the probability of each event in a sequence occurring; usually these probabilities may be multiplied together to obtain the end event probability or frequency.

The technique of Quantified Risk Assessment 'QRA' requires data in the form of probability or frequency to be estimated for each input event.

Ideally, data relating to hardware failures and human error that are specific to each plant should be obtained from the company's maintenance and historical records.

Unfortunately, records available were not in the form that allows data relevant to this study to be obtained. Therefore, other sources of data were used as a basis for failure/error scenarios. The sources of information and data are shown in the References section of this report.

Identification of Scenarios Leading to Selected Failures

For each selected failure scenario, the potential contributory factors were examined, taking into account any protective features available. Typically, the factors examined included:

- Operator error
- Metallurgical fatigue or ageing of materials
- Internal or external Corrosion
- Loss of process control, e.g. pressure, temperature or flow, etc.
- Overfilling of vessels
- Introduction of impurities
- Fire and/or explosion
- Missiles
- Flooding

Account was taken at this stage of those limited releases, which although in themselves did not constitute a significant off-site hazard could, under some circumstances, initiate a sequence leading to a larger release, as a knock-on effect.

It was noted that the proposed criterion for risk tolerability was used in Egypt by the following organizations - British Gas / British Petroleum / Shell / Total.

Relevant Weather Data for the Study

- **Weather Data**

The Weather Data relevant to this study consists of a list of weather conditions in the form of different combinations of wind-speed/direction, temperature, humidity and atmospheric stability. Table (7)

The weather conditions are an important input into the dispersion calculations and results for a single set of conditions could give a misleading picture of the hazard potential.

Met-oceanographic data gathered from Weather Spark "International Weather Data" for the Middle of Upper Egypt Area over a period of 3 years.

These data included wind speed and direction; air temperature and humidity, as well as current speed, direction and wave height.

Table (7) Annual Average Temperature, Relative Humidity and Wind Speed / Direction

• **Air Temperature ^{o}C**		
	Min. Recorded	**3** ^{o}C
	Max. Recorded	**43** ^{o}C
	Annual Average	***30 ^{o}C***
• **Relative Humidity %**		
	Average Daily Min.	**22 %**
	Average Daily Max.	**78 %**
	Annual Average	***45 %***
• **Wind Speed**		
	Annual Average	***4.5 m / sec.***
• **Wind Direction**		
	Annual Average	***North / North West (N/NW)***

Figures (4, 5 & 6) show the monthly variations of the wind direction from one month to another and the directions.

The general climatic conditions at Middle of Upper Egypt Area are summarized in Tables No. (8, 9, 10, 11 & 12) Below.

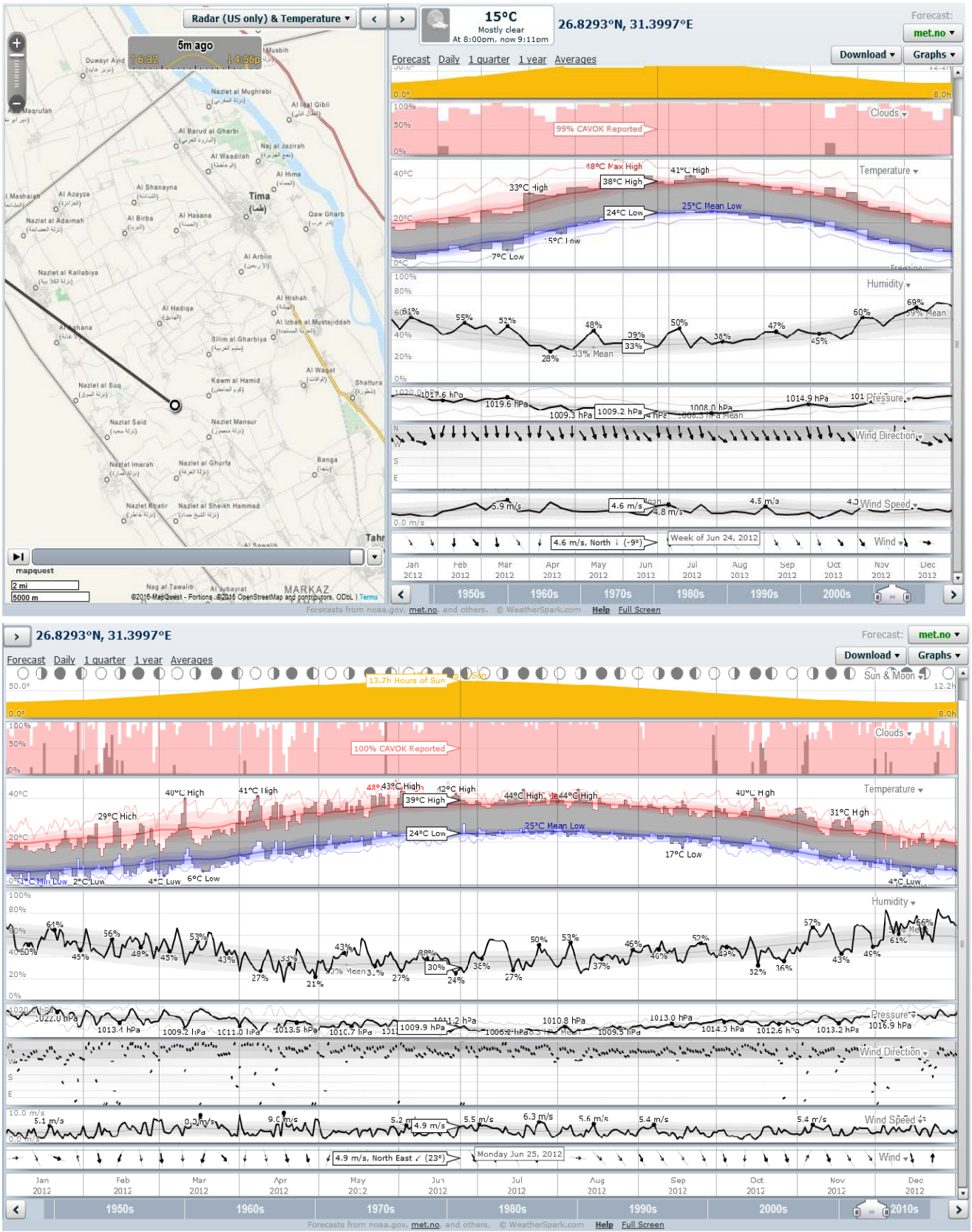


Figure (4) 2012 - Weather Data from Weather Spark "International Weather Data"

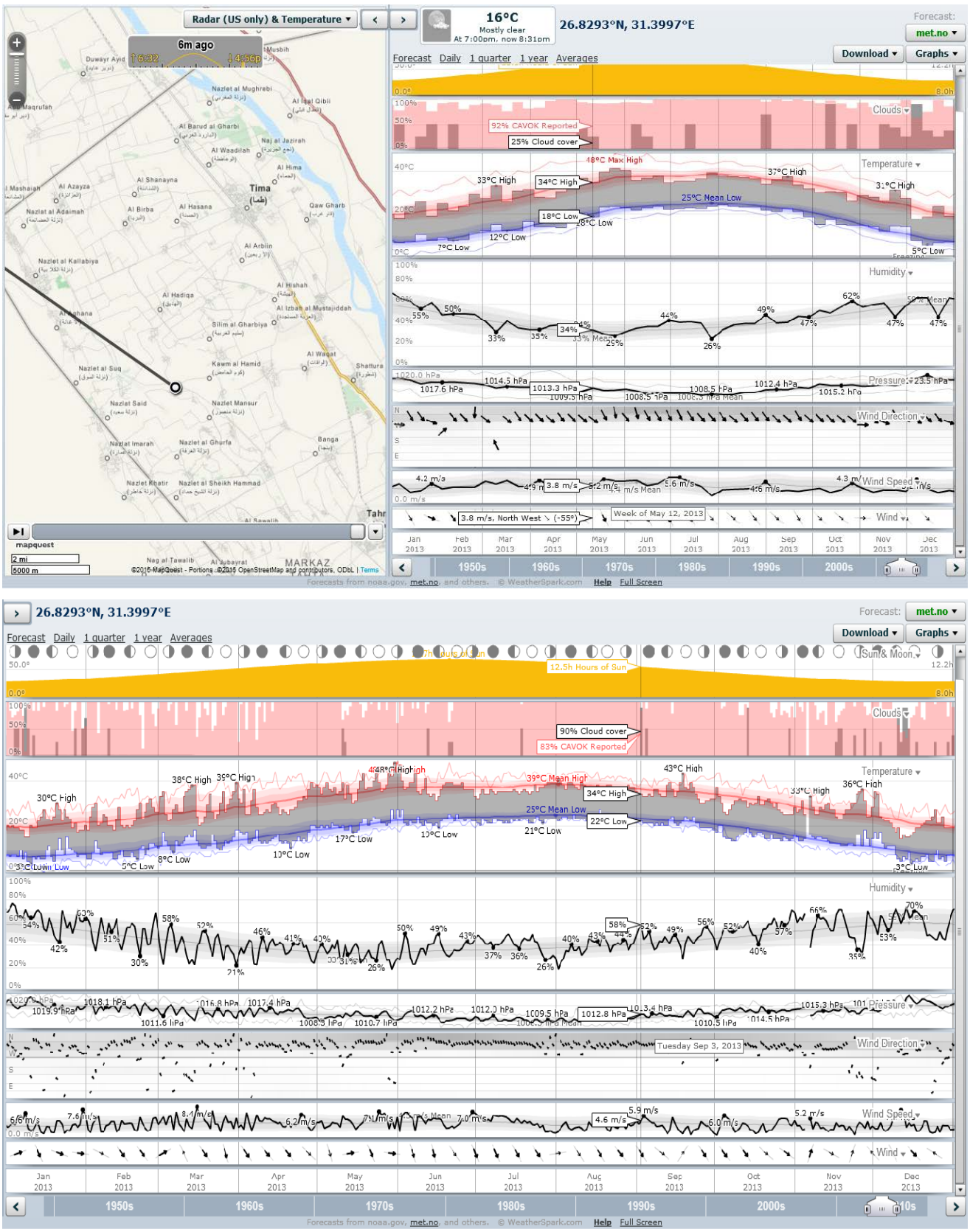


Figure (5) 2013 - Weather Data from Weather Spark "International Weather Data"

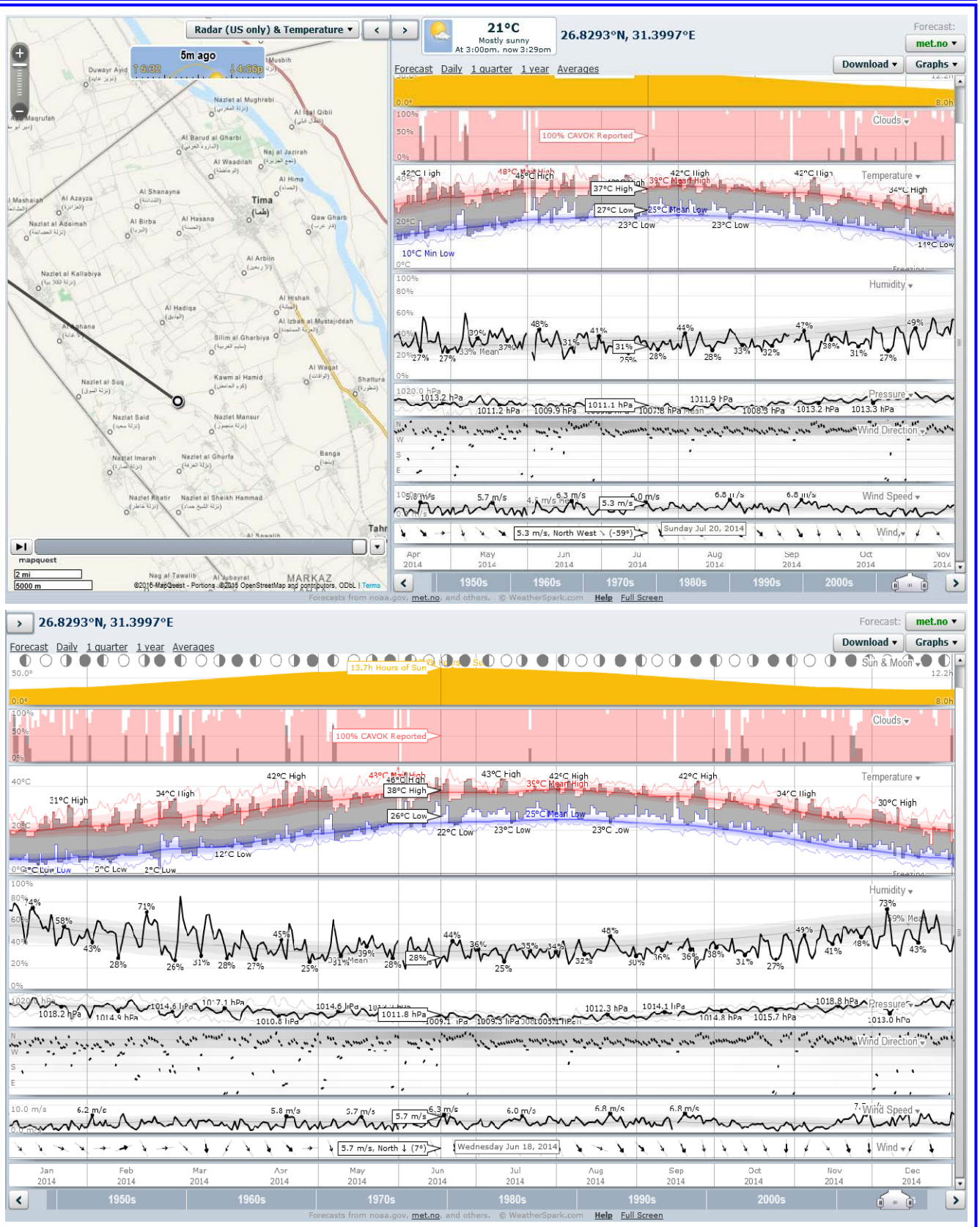


Figure (6) 2014 - Weather Data from Weather Spark "International Weather Data"

Table (8) Mean of Monthly Air Temperature (°C)

Months		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp. (c°)	H	15	26	19	38	33	41	38	35	32	36	23	18
	L	3	14	8	20	20	25	25	23	19	21	12	9
	H	22	20	20	25	37	31	34	35	36	29	24	16
	L	9	9	11	13	20	21	22	25	24	17	12	6
	H	20	22	31	30	32	43	36	39	33	28	25	21
	L	6	9	17	18	18	31	23	31	25	21	18	13

Table (9) Mean of Monthly Wind Speed (m/sec) and Direction

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind Speed (m/sec) & Direction	4.3 NW	4.7 NE	5.4 N	5.5 SW	4.0 NW	3.5 NW	4.8 N	5.6 N	3.1 NW	4.6 N	5.3 NW	5.7 N
	3.6 NW	4.6 NW	6.2 NW	4.1 NW	5.9 NW	5.0 NW	4.4 NW	4.2 NW	5.5 NW	3.0 NW	4.0 NW	6.6 W
	4.3 NW	5.3 W	4.8 SW	5.3 NW	5.7 NW	5.7 N	4.7 NW	5.5 N	4.6 NW	3.5 N	4.8 N	6.9 N

Table (10) Mean of Monthly Relative Humidity (%)

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Relative Humidity (%)	56	39	47	25	48	37	38	43	45	45	43	78
	65	35	22	33	23	41	39	38	49	58	66	70
	68	60	31	60	47	24	41	32	41	39	50	55

Table (11) Mean of Cloud Cover on the Scale 0 – 8

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cloud Cover (0-8)	0	6	0	0	0	0	0	0	0	0	4	0
	0	0	0	0	0	0	0	0	0	0	3	7
	0	0	4	0	0	0	0	0	0	4	0	0

Table (12) Mean of Monthly Sunshine Hours

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sunshine Hours	10.5	11.1	11.9	12.7	13.4	13.7	13.5	13	12.1	11.3	10.7	10.3
	10.5	11.1	11.9	12.7	13.4	13.7	13.5	13	12.1	11.3	10.7	10.3
	10.5	11.1	11.9	12.7	13.4	13.7	13.5	13	12.1	11.3	10.7	10.3

- **Stability Categories**

The two most significant variables, which would affect the dispersion calculations, are: Wind-speed and atmospheric stability. The stability class is a measure of the atmospheric turbulence caused by thermal gradients. Pasqual Stability identifies six main categories, which are shown in the Tables (13 & 14) and summarized in Table (15).

Table (13) Pasqual Stability Categories

A	B	C	D	E	F
Very Unstable	Unstable	Moderately Unstable	Neutral	Moderately Stable	Stable

Neutral conditions correspond to a vertical temperature gradient of about 1^{o} C per 100 m.

Table (14) Relationship between Wind Speed and Stability

Wind speed		**Day-time Solar Radiation**		**Night-time Cloud Cover**		
(m/s)	Strong	Medium	Slight	Thin <3/8	Medium >3/8	Overcast >4/5
<2	A	A-B	B	-	-	D
2-3	A-B	B	C	E	F	D
3-5	B	B-C	C	D	E	D
5-6	C	C-D	D	D	D	D
>6	C	D	D	D	D	D

Table (15) Sets of Weather Conditions Initially Selected for this Study

Set for Wind Speed and Stability	
Wind speed	Stability
4.5 m/sec.	D

Tema Pressure Reduction Station Description

Background

Tema Pressure Reduction Station is owned by Regions Gas Company "ReGas". It is located about 13 km South / West direction from Tema City – Sohag Government – Upper Egypt. The station will provide natural gas to public housing.

The station natural gas feeding will be from the National Gas Pipeline owned by GASCO with pressure from 45 to 70 bar, then reduce the gas pressure to 7 bar and adding odorant, then connected to the Tema City internal distribution network to public housing.

PRMS Location Coordinates (Regions Gas Company Data)

Point	Vertical (X)	Horizontal (Y)
1	*2968833.191*	*341305.946*
2	*2968857.843*	*341360.647*
3	*2968827.757*	*341374.266*
4	*2968803.105*	*341319.505*

PRMS Description (Regions Gas Company Data)

The PRMS surrounded by 3 m height fence and will mainly consist of the followings: (Ref. Figure 7, 8 and 9)

- Inlet module: which contains 4" # 600 manual isolation valve.
- Filter module: two identical streams, each contain inlet and outlet isolation valves.
- Heating system module: two identical.
- Metering module: two identical.
- Regulating module: two identical regulating lines.
- Outlet module: it contains manual outlet isolation valve.
- Odorant module: 50 lit. capacity container
- Off-take will be an underground room including the isolation valves with GASCO underground pipeline 32".
- Security Building (one floor)
- Administration Building (one floor)

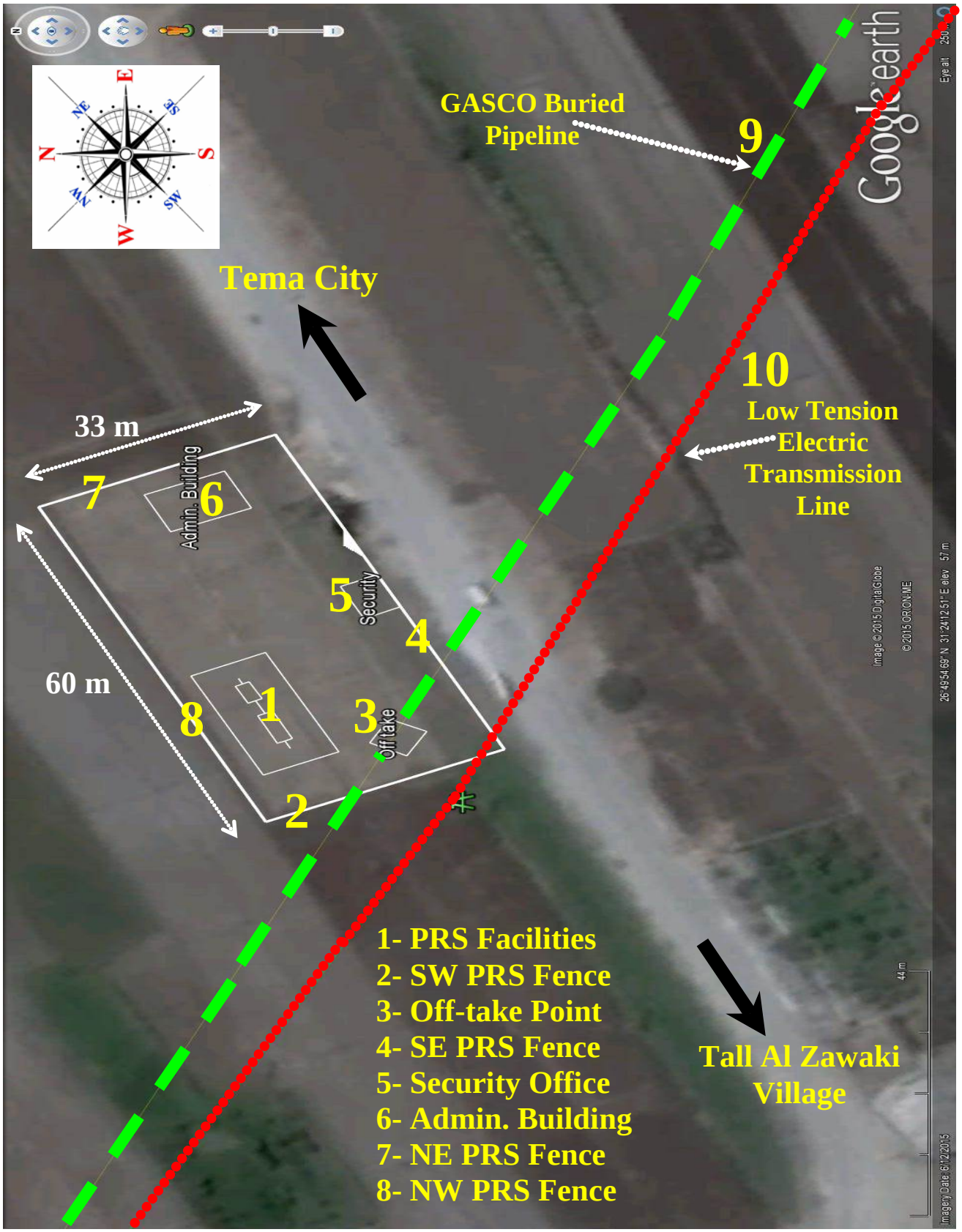


Figure (7) Tema Pressure Reduction Station Plotted on Google Earth Photo

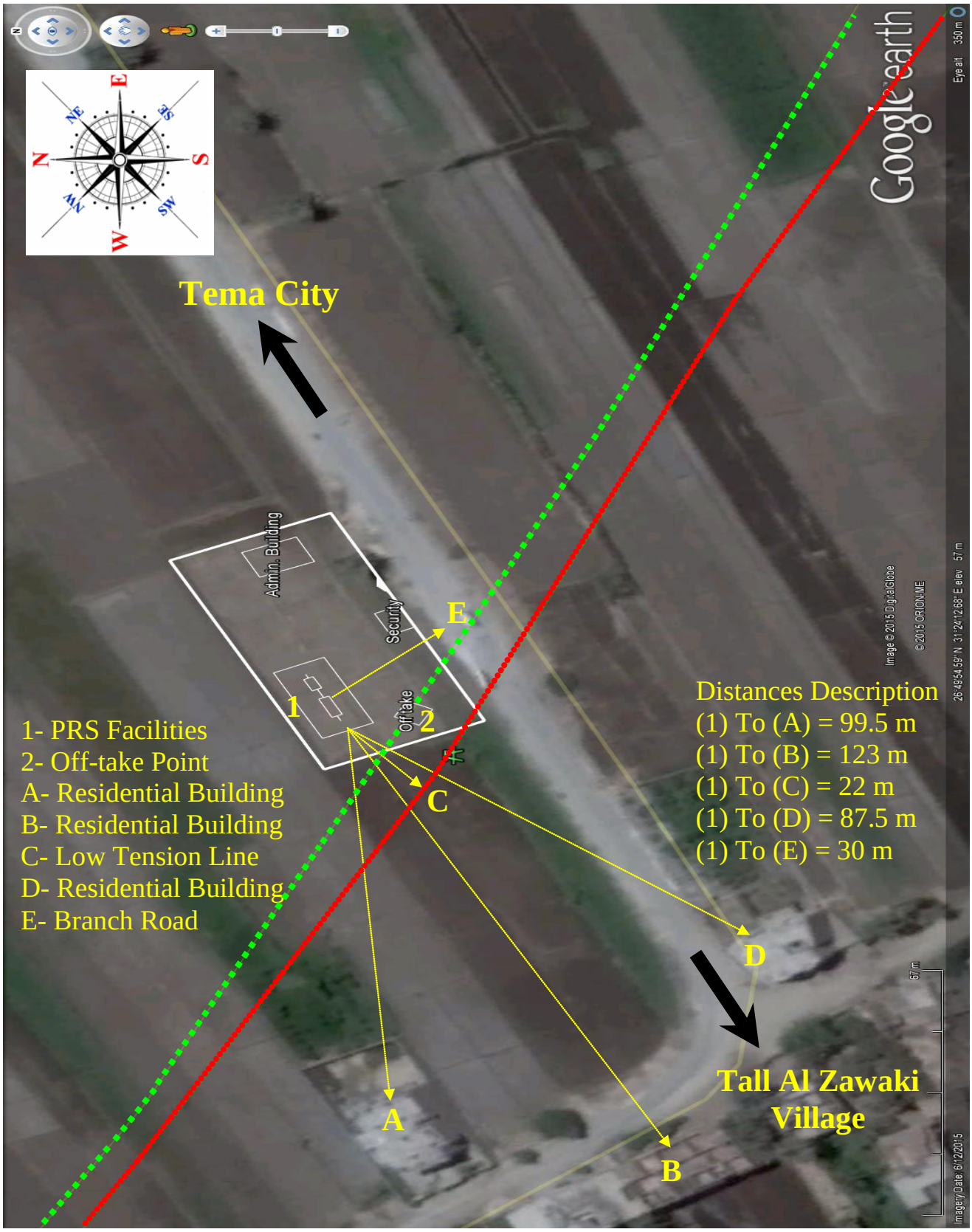


Figure (8) Tema Pressure Reduction Station Plotted on Google Earth Photo and Surroundings

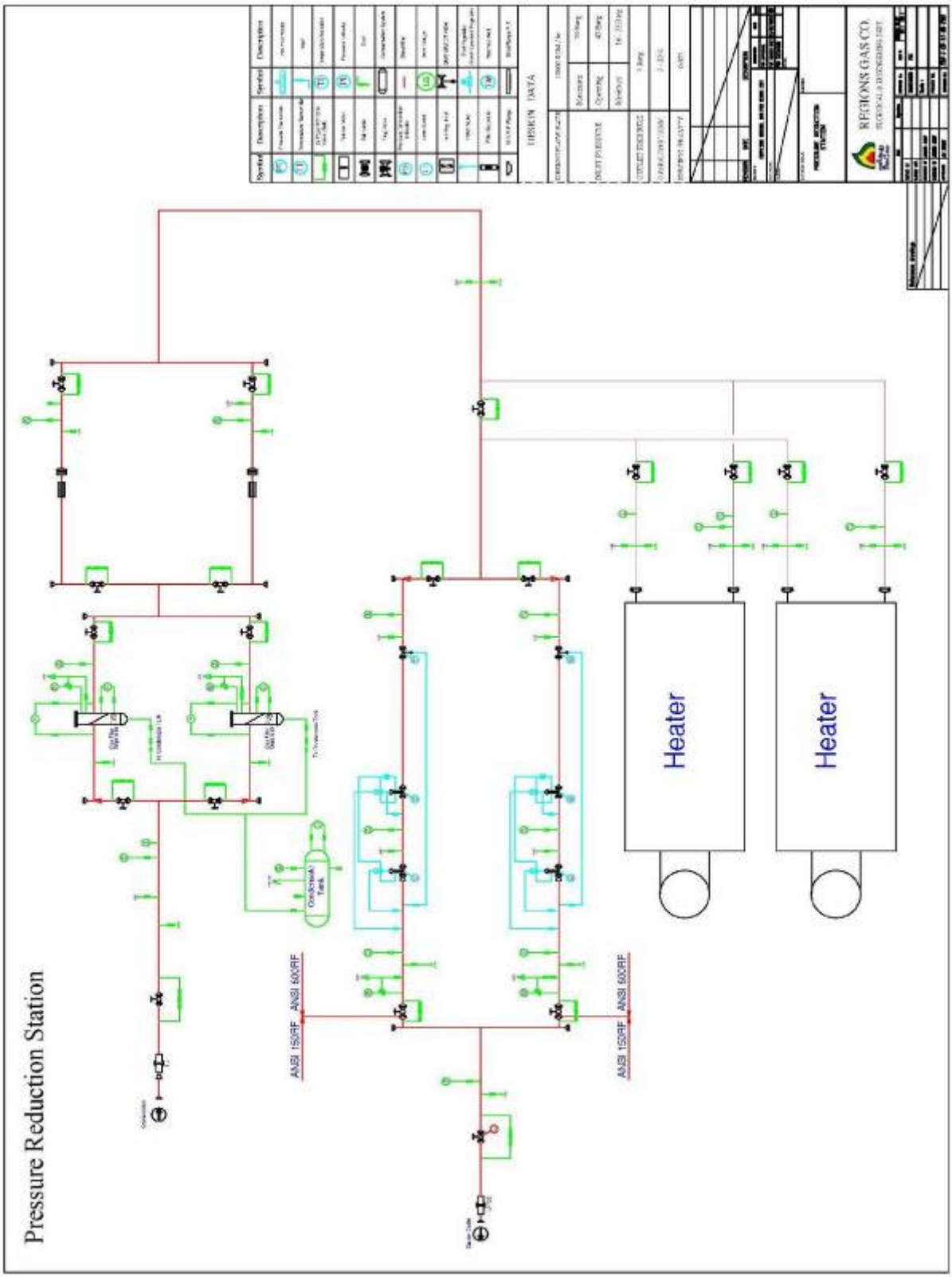


Figure (9) Tema Pressure Reduction Station Piping and Instrumentation Diagram "P&ID" (General)

Design Data (Region Gas Company Data)

- Gas inlet: Max. 70 barg / Oper. 45 barg / Min. 16 – 23 barg
- Gas outlet: 7 barg
- Operating temp: 5 – 25° C
- Specific gravity: 0.625 (air = 1 k/m^3)
- Design flow rate: 10000 scm/hr

Gas Odorant Specs

The odorant is supplied with a Hazard Data Sheet. This is identified as Spotleak 1009. This is based on Aliphatic Mercaptn mixtures in clear liquid form that is extremely flammable, with the following characteristics:

- Boiling Range 60-70° C
- Flash Point -17.8° C
- Freezing Point -45.5° C
- Density (H_2O = 1) 0.812 @ 15.5° C
- Vapor Density 3.0 (air = 1)
- Vapor Pressure (mm Hg) 6.6 @ 37.8° C

Health Hazards

Spotleak is not carcinogenic, but the major health hazards as a result of exposure to Spotleak include the following:

Inhalation

- Short-term exposure: Irritation and central nervous system effects
- Long-term exposure: Irritation

Skin Contact

- Short-term: Irritation
- Long-term: Dermatitis

Eye Contact

- Short-term: Irritation and tearing
- Long-term: Irritation

Ingestion

- Short-term: nausea, vomiting, central nervous system effects
- Long-term: no effects are known

Hygiene Standards and Limits

Occupational Exposure Limit for Spotleak to all components is 45 ppm, and the long-term "MEL" should be below 12 ppm (8 hrs. "TWA").

Fire and Explosion Hazards

Spotleak is a severe fire hazard. Vapor/air mixtures are explosive. Vapor is 3 times heavier than air. Vapor may ignite at distant ignition sources and flash back.

Thermal decomposition products include oxides of sulphur and hydrogen sulphide.

Fire Fighting and Protection Systems and Facilities

As per agreement with EGAS and Civil Defense the PRS will provided by the following fire protection facilities:

- Smoke detector in all admin rooms.
- Heat detectors in buffet rooms.
- Smoke detectors in control rooms according to the area.
- Different sizes of fire extinguishers will be distributed at PRS site.

Emergency Response Plan "ERP"

There is an Emergency Response Plan "ERP" for Sohag Area, including the following items:

Part "1": Introduction

- REGAS HSE Policy
- ERP objectives
- Emergency types
- Emergency levels

Part "2": Calling Plan

- Definition of Calling
- Calling Objective
- Notification Chart
- Types of Calling
- Execution of Calling Plan
- Calling of External Aids / Authorities
- Communication Systems and Facilities

- EGAS Responsible Team Contacts
- Emergency Rooms Contacts for EGAS / Ministry of Petroleum
- REGAS Responsible Team Contacts
- REGAS Emergency Rooms
- Contacts for Main PRSs
- Contacts for External Aids
- Contacts for Assistant Services (Assiut / Sohag)

Part "3": Roles and Responsibilities

- Roles & Responsibilities
  - Operations General Manager Responsibilities
  - PRSs' Managers Responsibilities
  - Area Manager Responsibilities
  - Area Safety Manager Responsibilities
  - Area Communications Manager Responsibilities
  - Area Security Manager Responsibilities
- Emergency Room Facilities
- Emergency Teams Responsibilities

Part "4": Firefighting Facilities

- Firefighting facilities at PRSs with odorants

Part "5": Odorant Hazards

- Definition of Odorant Material
- Odorant Material Hazards
  - Emergency Procedures in case of Odorant Spill/Leak or Fire

Part "6": PRSs Emergency Scenarios

- Emergency Cases at Main PRSs
  - Emergency Procedures in case of Significant Risks
  - Emergency Procedures in case of Normal Risks

Analytical Results of Consequence Modeling

1.0- Pressure Reduction Station Inlet Pipeline (4 inch)

1/1- Consequence Modeling for 1 inch (Pin Hole) Gas Release (Horizontal)

The following table no. (16) Show that:

Table (16) Dispersion Modeling – 1" / 4" Horizontal Gas Release

Gas Release			
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**
4.5 D	UFL	2.90	1.00
	LFL	10.43	1.02
	50 % LFL	10.80	0 – 1.19

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m^2)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
4.5 D	17.69	1.6	29.63	21.57	0
		4	24.59	13.53	0
		9.5	21.15	8.00	0
		12.5	20.17	6.49	20% /60 sec.
		25	17.58	3.11	80.34
		37.5	16.11	1.40	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
4.5 D	0.020	52.25	41.48	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	13.53	25.56	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	10.47	24.30	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

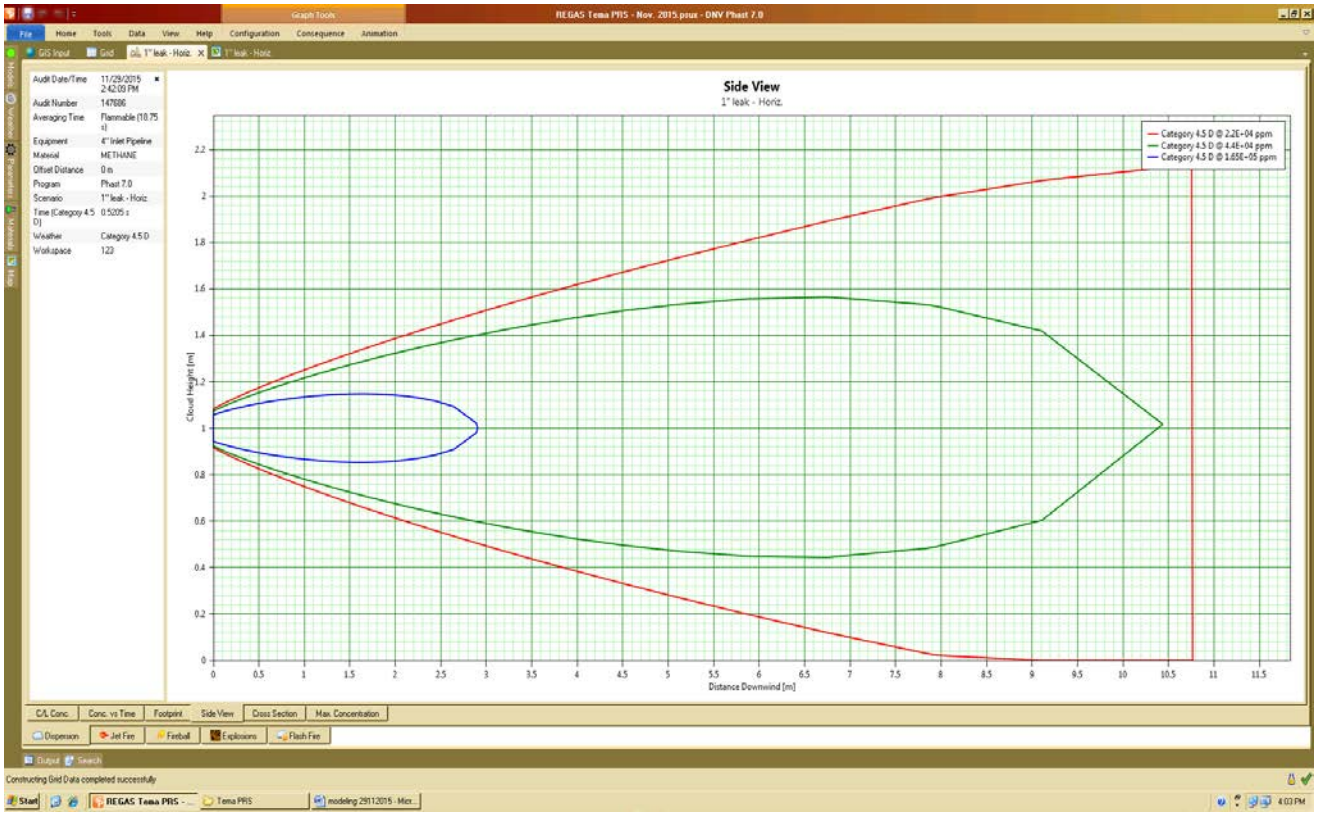


Figure (10) Gas Cloud Side View (UFL/LFL) (1" hole in 4" Inlet Pipeline / 0°)

- The previous figure show that if there is a gas release from 1" hole size at horizontal position for about 20 sec. without ignition, the flammable vapors will reach a distance more than 11 m downwind and over 1.20 m height.
- The UFL will reach a distance of about 2.90 m downwind with a height of 1.0 m. The cloud large width will be 0.36 m crosswind at a distance of 1.50 m from the source and 0.80 m height.
- The LFL will reach a distance of about 10.43 m downwind with a height of 1.02 m. The cloud large width will be 1.12 m crosswind at a distance of 6.50 m from the source and 1.40 m height.
- The 50 % LFL will reach a distance of about 10.80 m downwind with a height from 0 to 1.19 m. The large width will be 2.20 m crosswind at a distance of 10.80 m from the source.

The modeling show that the gas cloud effects will be limited inside the PRS boundary.

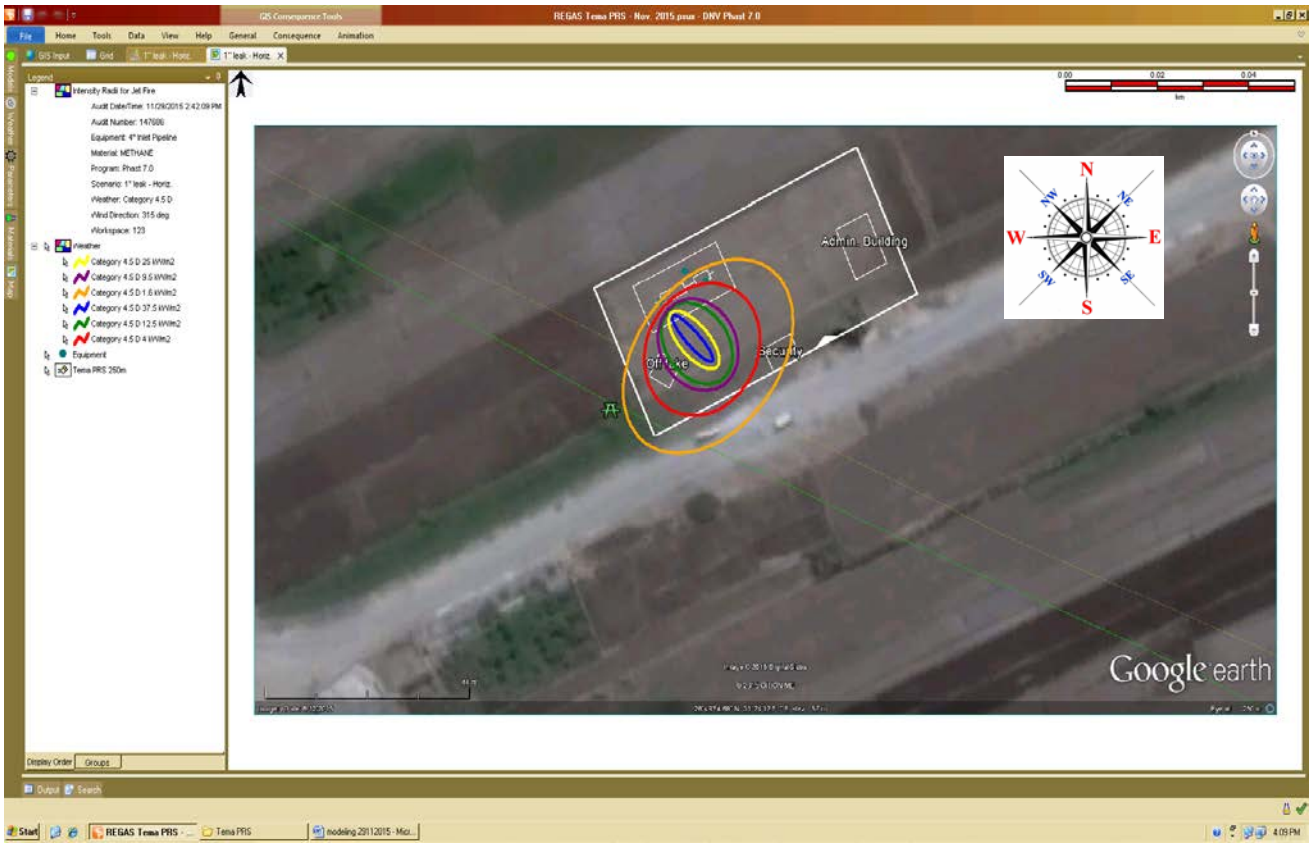


Figure (11) Heat Radiation Contours from Jet Fire (1" hole in 4" Inlet Pipeline / 0°)

- The previous figure show that if there is a gas release from 1" hole size at horizontal position and ignited, the expected flame length is about 17.69 meters downwind.
- The 9.5 kW/m^2 heat radiation contours extend about 21.15 meters downwind and 6.73 meters crosswind.
- The 12.5 kW/m^2 heat radiation contours extend about 20.17 meters downwind and 6.49 meters crosswind.
- The 25 kW/m^2 heat radiation contours extend about 17.58 meters downwind and 3.11 meters crosswind.
- The 37.5 kW/m^2 heat radiation contours extend about 16.11 meters downwind and 1.40 meters crosswind.

The modeling show that the heat radiation value (9.5 kW/m^2 and 12.5 kW/m^2) effects will be limited inside the PRS boundary.

The heat radiation value (4 kW/m^2) effects will be near the security office from the SW side.

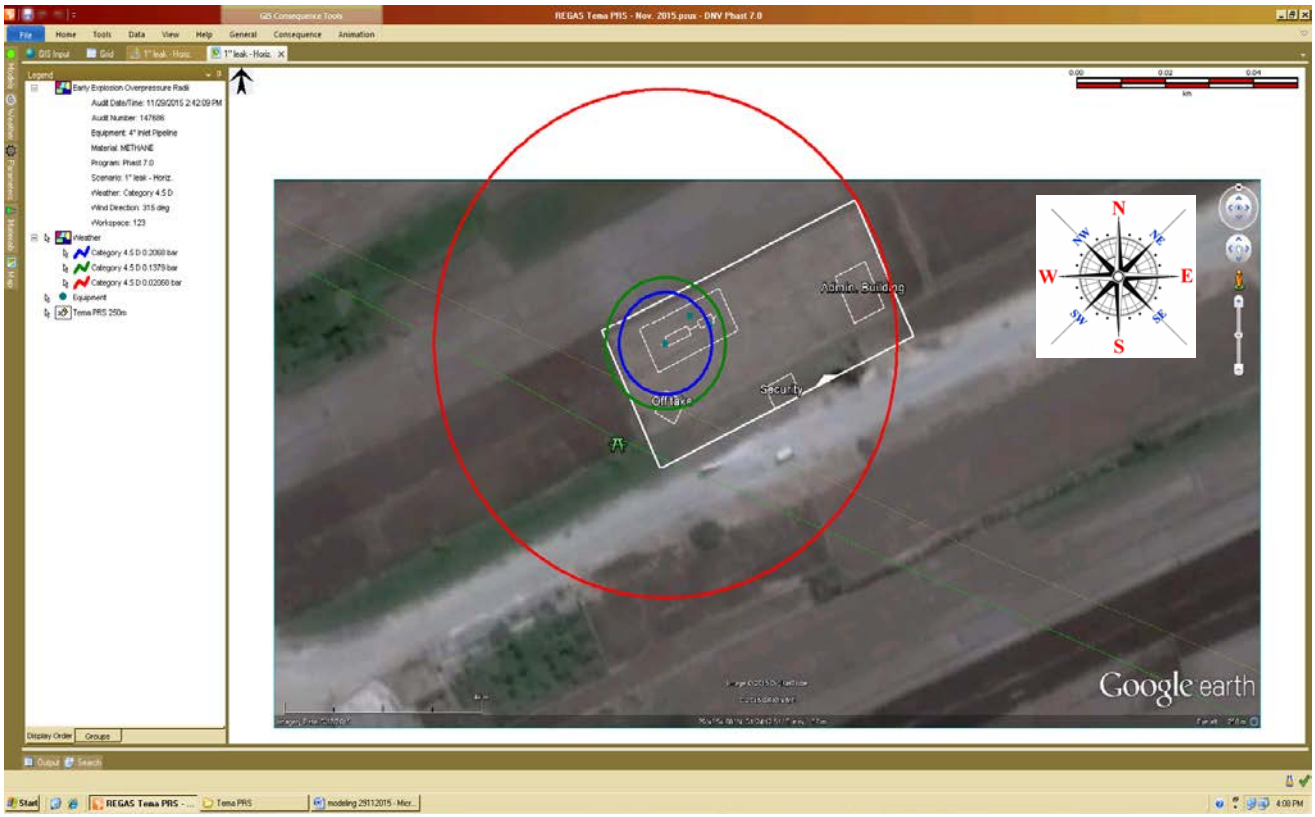


Figure (12) Early Explosion Overpressure Waves (1" hole in 4" Inlet Pipeline / 0°)

- The previous figure show that if there is a gas release from 1" hole size at horizontal position and early ignited, this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 52.25 meters radius.
- The 0.137 bar overpressure waves will extend about 13.53 meters radius.
- The 0.206 bar overpressure waves will extend about 10.47 meters radius.

The modeling show that the value of 0.020 bar will extend outside the PRS fence with a distances of about 45 m NW, 48 SW and 29 m SE reaching the security office and extending the road.

The value of 0.137 bar and 0.206 bar will be limited inside from NE, SW and SE, but extended from 2 to 5 meters out from NW side.

Figure (13) Late Explosion Overpressure Waves (1" hole in 4" Inlet Pipeline / 0^{o})

- The previous figure show that if there is a gas release from 1" hole size at horizontal position and late ignited, this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 41.48 meters radius and will not reaching the admin and security buildings.
- The 0.137 bar overpressure waves will extend about 25.56 meters radius.
- The 0.206 bar overpressure waves will extend about 24.30 meters radius.

The modeling show that the 0.020 bar will reach a distance of 32 m SE covering the security office, at NE fence covering the office building, 48 m NW and 40 SW.

The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary from NE, SE and NW, with extending of about 2 m for 0.137 bar from NW side.

1/2- Consequence Modeling for 1 inch (Pin Hole) Gas Release (Angle 45 º)

The following table no. (17) Show that:

Table (17) Dispersion Modeling – 1" / 4" 45 º - Gas Release

Gas Release			
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**
4.5 D	UFL	1.76	2.65
	LFL	5.59	5.42
	50 % LFL	9.11	7.23

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m^2)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
4.5 D	14.61	1.6	30.51	23.48	0
		4	20.79	13.95	0
		9.5	14.60	6.76	0
		12.5	12.47	4.29	20% /60 sec.
		25	Not Reached	----------	80.34
		37.5	Not Reached	----------	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
4.5 D	0.020	52.25	N/D	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	13.53	N/D	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	10.47	N/D	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

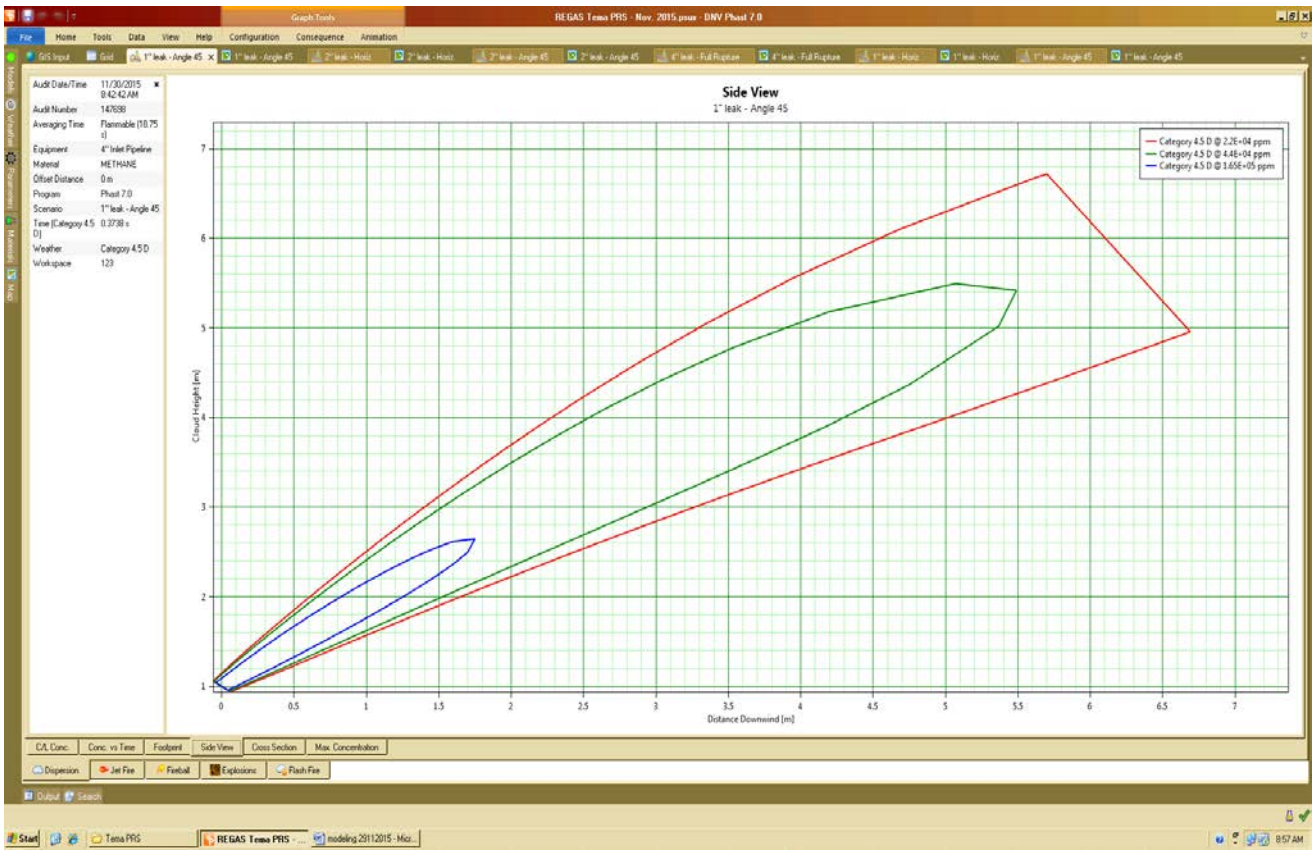


Figure (14) Gas Cloud Side View (UFL/LFL) (1" hole in 4" Inlet Pipeline / 45°)

- The previous figure show that if there is a gas release from 1" hole size with 45° angle position for about 20 sec. without ignition, the flammable vapors will reach a distance more than 10 m downwind and over 7.50 m height.
- The UFL will reach a distance of about 1.76 m downwind with a height of 2.65 m. The cloud large width will be 0.50 m crosswind at a distance of 1.0 m from the source and 2.60 m height.
- The LFL will reach a distance of about 5.59 m downwind with a height of 5.42 m. The cloud large width will be 2.0 m crosswind at a distance of 3 m from the source and 5.40 m height.
- The 50 % LFL will reach a distance of about 9.11 m downwind with a height of 7.23 m. The large width will be 2.60 m crosswind at a distance of 5 m from the source and 6 m height.

The modeling show that the gas cloud effects seems to be limited inside the PRS boundary.

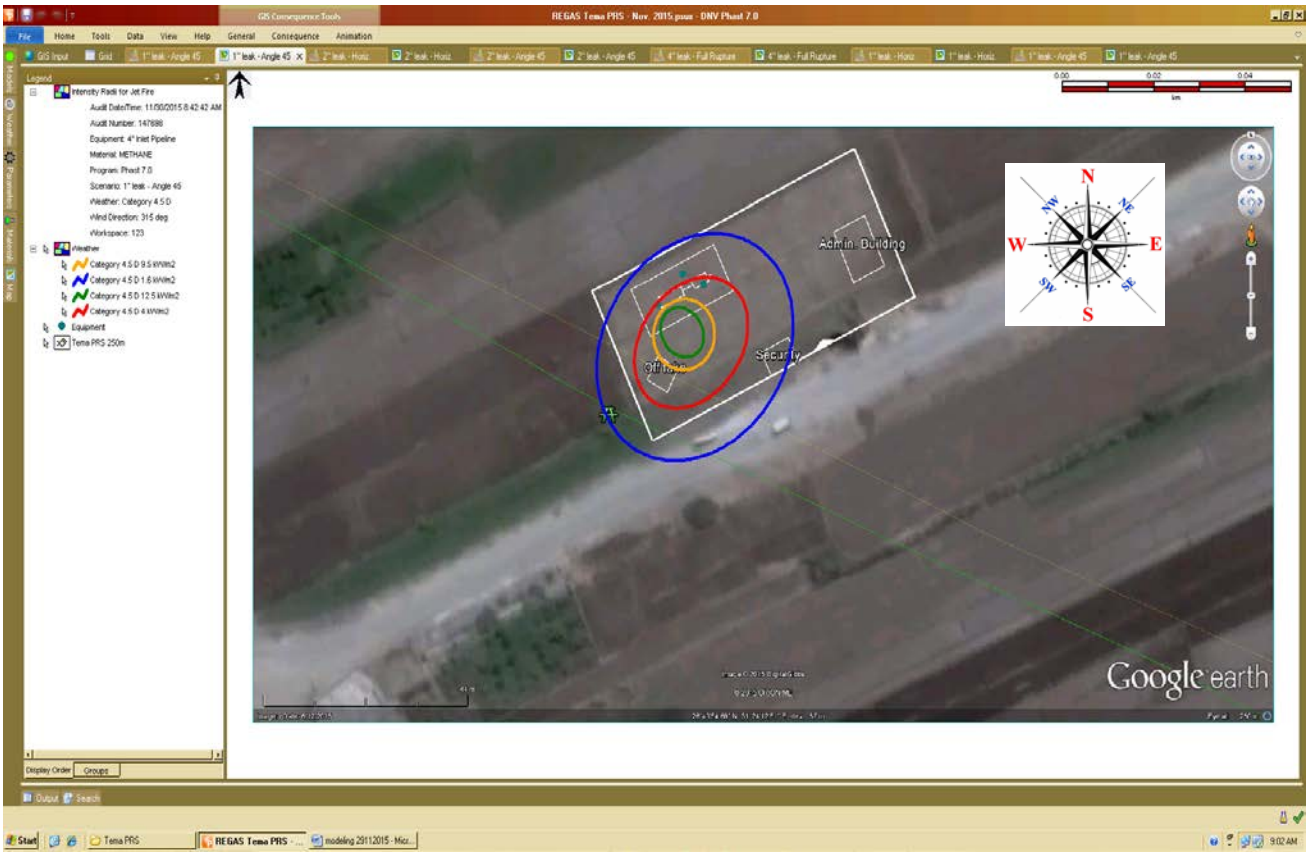


Figure (15) Heat Radiation Contours from Jet Fire (1" hole in 4" Inlet Pipeline / 45^{o})

- The previous figure show that if there is a gas release from 1" hole size with 45^{o} angle position and ignited, the expected flame length is about 14.61 meters downwind.
- The 9.5 kW/m^2 heat radiation contours extend about 14.60 meters downwind and 6.76 meters crosswind.
- The 12.5 kW/m^2 heat radiation contours extend about 12.47 meters downwind and 4.29 meters crosswind.

The modeling show that the heat radiation value (9.5 kW/m^2 and 12.5 kW/m^2) effects will be limited inside the PRS boundary.

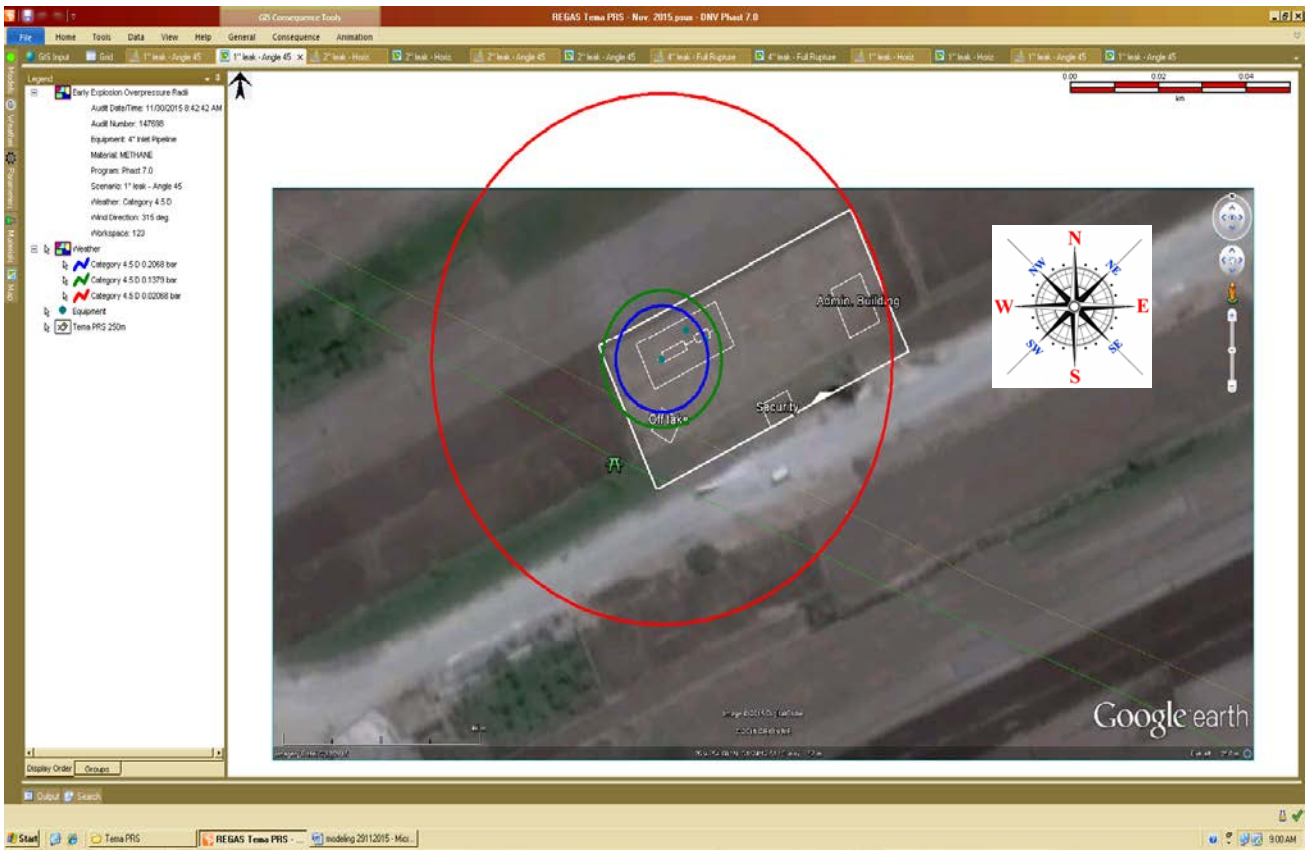


Figure (16) Early Explosion Overpressure Waves (1" hole in 4" Inlet Pipeline / 45°)

- The previous figure show that if there is a gas release from 1" hole size with 45° angle position and early ignited, this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 52.25 meters radius.
- The 0.137 bar overpressure waves will extend about 13.53 meters radius and will not reaching the admin and security buildings.
- The 0.206 bar overpressure waves will extend about 11.74 meters radius and will not reaching the admin and security buildings.

The modeling show that the value of 0.020 bar will extend outside the PRS fence with a distances of about 47 m NW, 38 SW and 30 m SE and reaching the security office and the road direction.

The value of 0.137 bar and 0.206 bar will be limited inside from NE and SE, but extended from 2 to 5 meters out from NW side.

1/3- Consequence Modeling for 2 inch (Half Rup.) Gas Release (Horizontal)

The following table no. (18) Show that:

Table (18) Dispersion Modeling – 2" / 4" Horizontal - Gas Release

Gas Release			
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**
4.5 D	UFL	6.65	1.003
	LFL	15.12	1.28
	50 % LFL	15.24	2.18

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m^2)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
4.5 D	34.78	1.6	71.24	58.24	0
		4	55.84	37.02	0
		9.5	46.72	23.62	0
		12.5	44.36	20.17	20% /60 sec.
		25	38.86	12.48	80.34
		37.5	29.52	8.56	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
4.5 D	0.020	52.25	62.09	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	13.53	36.19	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	10.47	34.79	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

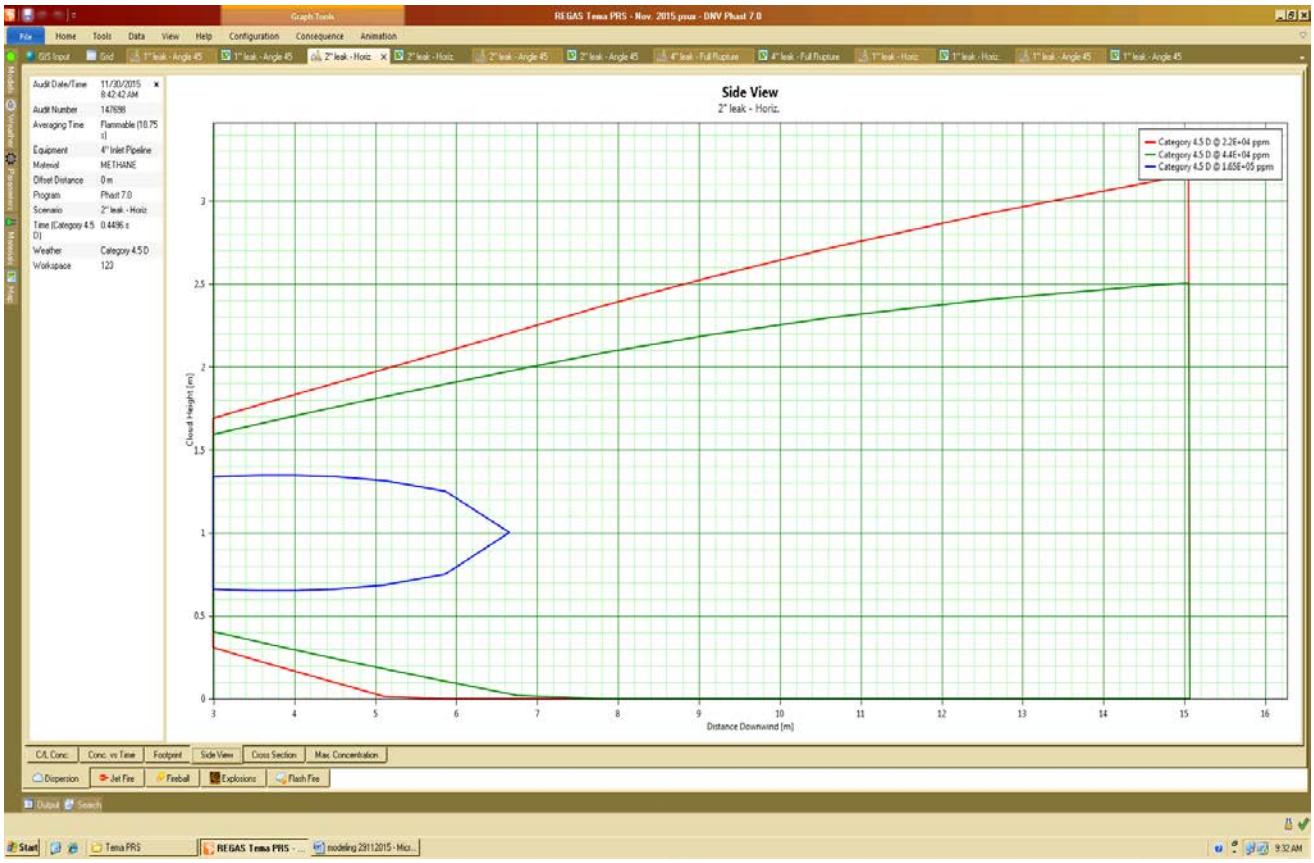


Figure (17) Gas Cloud Side View (UFL/LFL) (2" hole in 4" Inlet Pipeline / 0°)

- The previous figure show that if there is a gas release from 2" hole size at horizontal position for about 20 sec. without ignition, the flammable vapors will reach a distance more than 63 m downwind and over 2.50 m height.
- The UFL will reach a distance of about 6.65 m downwind with a height of 1.00 m. The cloud large width will be 0.70 m (crosswind) at a distance of 4.00 m from the source and 0.35 m height.
- The LFL will reach a distance of about 15 m downwind with a height of 1.28 m. The cloud large width will be 3 m (crosswind) at a distance of 15 m from the source and 0.00 m to 2.50 m height.
- The 50 % LFL will reach a distance of about 15.20 m downwind with a height of 2.18 m. The large width will be 4.40 m (crosswind) at a distance of 15.20 m from the source and 0 m to 3.40 m height.

The modeling show that the gas cloud will be limited inside the PRS boundary.

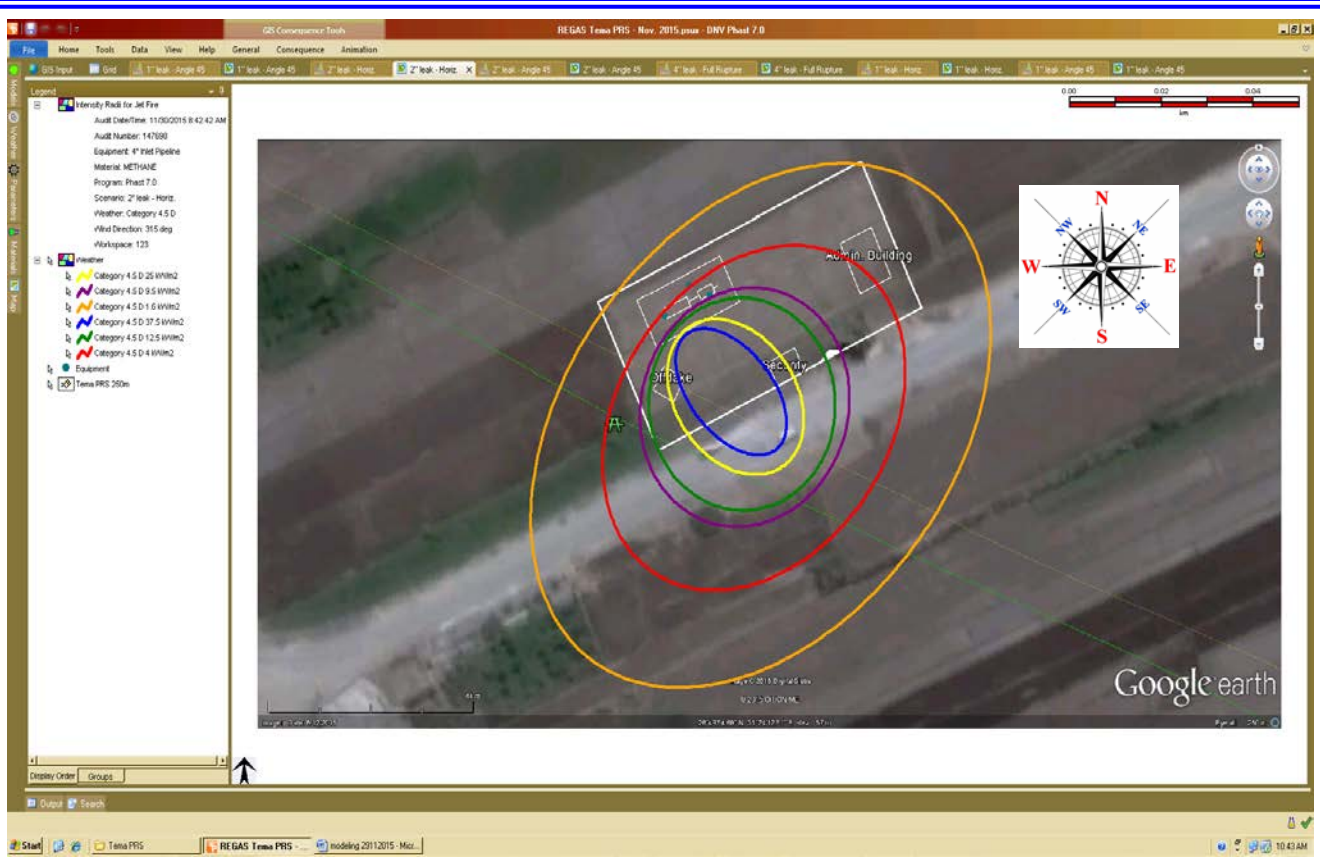


Figure (18) Heat Radiation Contours from Jet Fire (2" hole in 4" Inlet Pipeline / 0°)

- The previous figure show that if there is a gas release from 2" hole size at horizontal position and ignited, the expected flame length is about 34.78 meters downwind.
- The 9.5 kW/m^2 heat radiation contours extend about 46.72 meters downwind and 23.62 meters crosswind.
- The 12.5 kW/m^2 heat radiation contours extend about 44.36 meters downwind and 20.17 meters crosswind.
- The 25 kW/m^2 heat radiation contours extend about 38.86 meters downwind and 12.48 meters crosswind.
- The 37.5 kW/m^2 heat radiation contours extend about 29.52 meters downwind and 8.56 meters crosswind.

The modeling show that the heat radiation value of (9.5, 12.5, 25 & 37.5 kW/m^2) effects will extended the SE fence downwind, effecting the security office and the public road with different distances as per table (18).

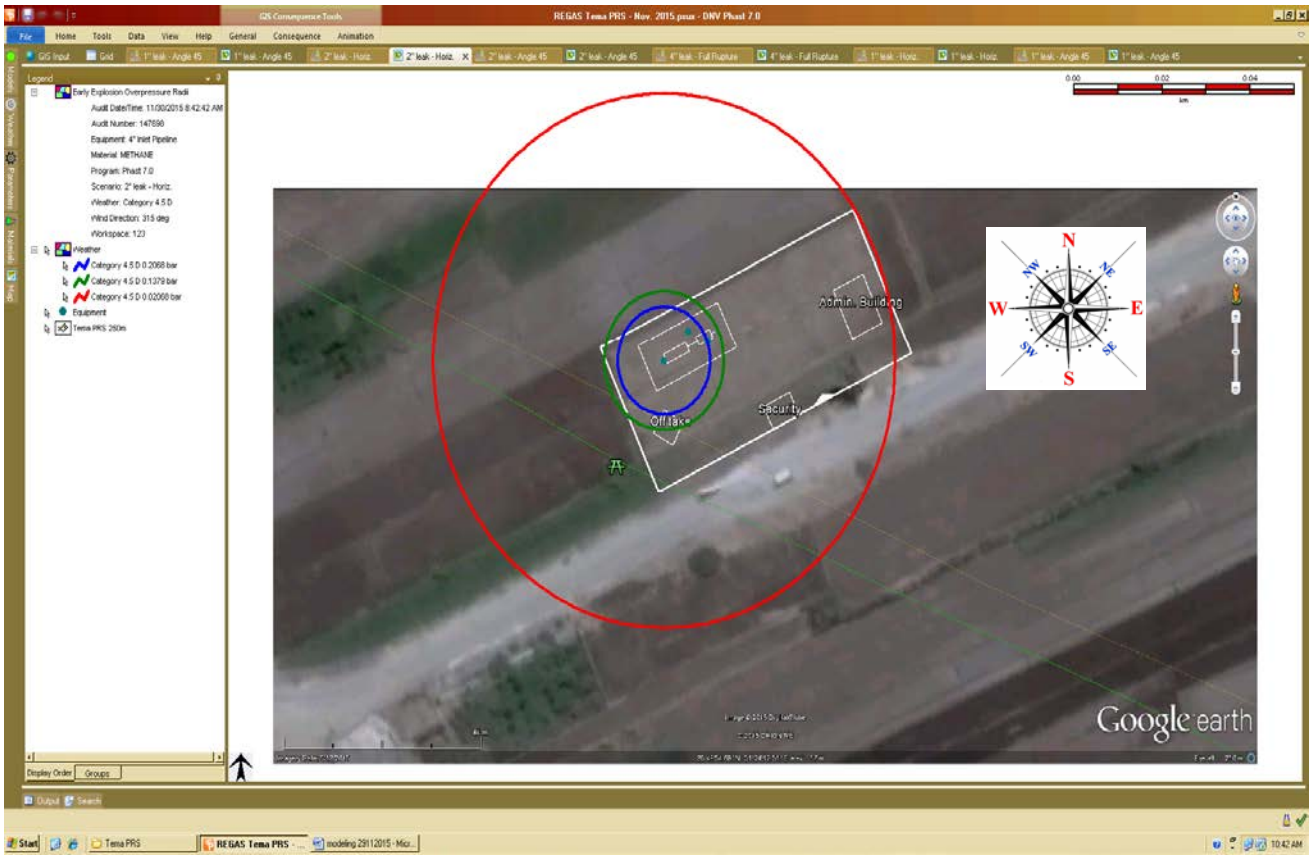


Figure (19) Early Explosion Overpressure Waves (2" hole in 4" Inlet Pipeline / 0°)

- The previous figure show that if there is a gas release from 2" hole size at horizontal position and early ignited, this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 52.25 meters radius.
- The 0.137 bar overpressure waves will extend about 13.53 meters radius and will not reaching the admin and security buildings.
- The 0.206 bar overpressure waves will extend about 10.47 meters radius and will not reaching the admin and security buildings.

The modeling show that the value of 0.020 bar will extend outside PRS fence with a distances of about 47 m NW, 29.5 m NE and 39.5 SE reaching the security office and the road.

The value of 0.137 bar and 0.206 bar will be limited inside from NE, SW and SE, but extended from 2 & 4 meters outside from NW side.

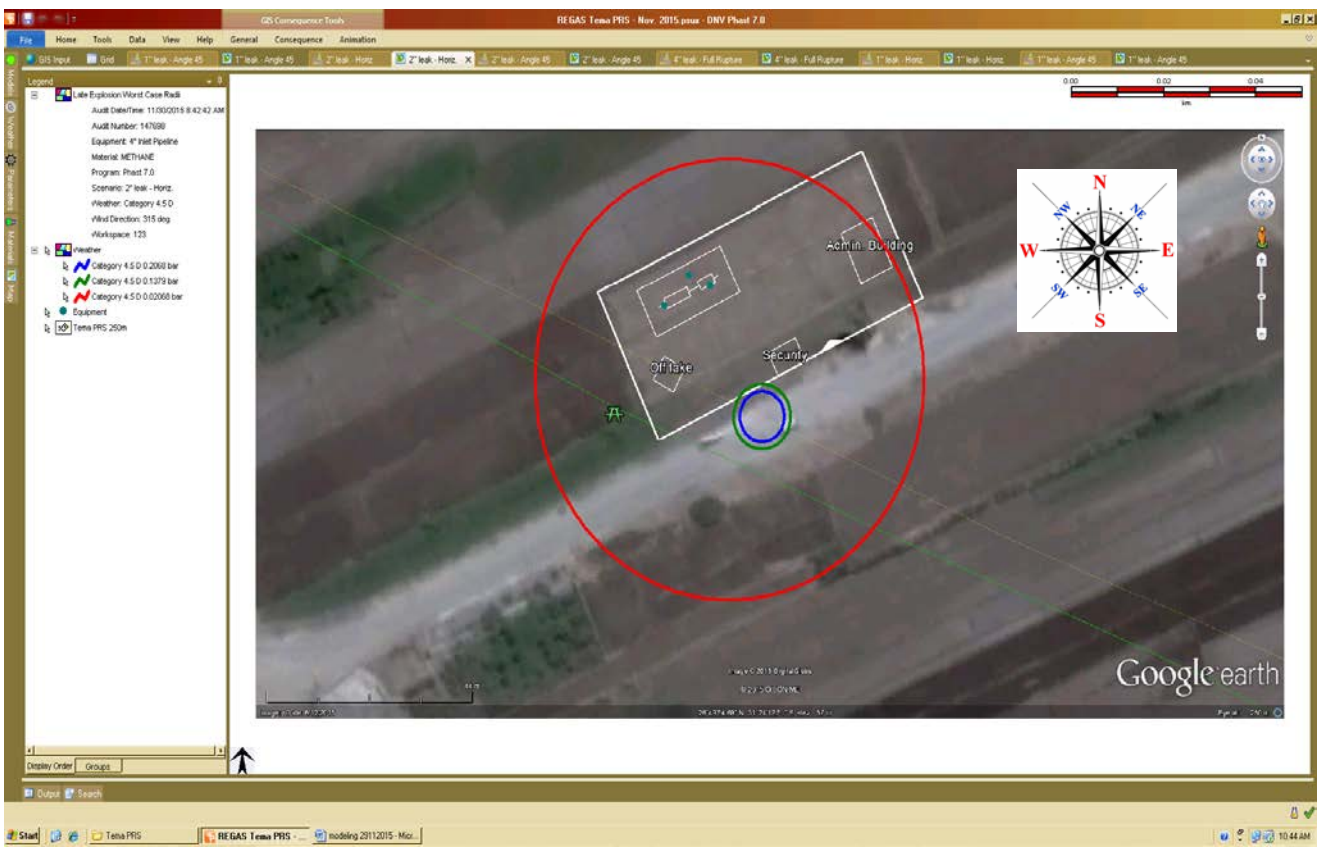


Figure (20) Late Explosion Overpressure Waves (2" hole in 4" Inlet Pipeline / 0°)

- The previous figure show that if there is a gas release from 2" hole size at horizontal position and late ignited, this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 62.09 meters radius.
- The 0.137 bar overpressure waves will extend about 36.19 meters radius and will not reaching the admin and security buildings.
- The 0.206 bar overpressure waves will extend about 34.97 meters radius and will not reaching the administration and security buildings.

The modeling show that the value of 0.020 bar will extended the PRS NW fence to a distance of 15 m, SW fence 22 m and SE fence 40 m covering the security office the road.

The value of 0.137 bar and 0.206 bar will be extended outside the PRS from the SE side to a distance of 10 & 12 m.

1/4- Consequence modeling for 2 inch (Half Rup.) Gas Release (Angle 45º)

The following table no. (19) Show that:

Table (19) Dispersion Modeling – 2" / 4" 45º - Gas Release

Gas Release			
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**
4.5 D	UFL	4.10	4.79
	LFL	10.52	10.59
	50 % LFL	11.20	13.85

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m^2)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
4.5 D	30.95	1.6	68.12	54.47	0
		4	46.63	32.41	0
		9.5	32.99	17.51	0
		12.5	29.05	12.77	20% /60 sec.
		25	Not Reached	----------	80.34
		37.5	Not Reached	----------	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
4.5 D	0.020	52.25	50.92	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	13.53	20.59	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	10.47	18.20	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

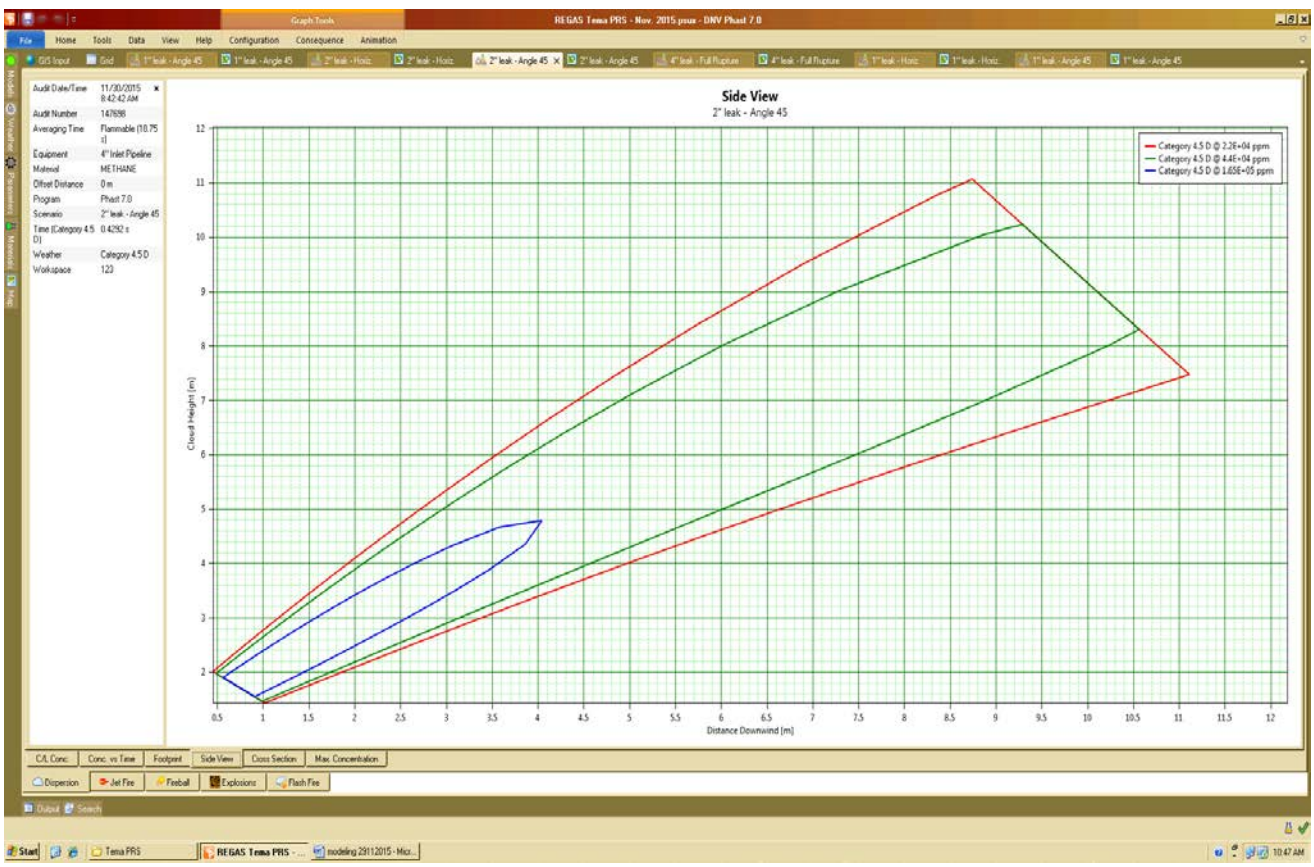


Figure (21) Gas Cloud Side View (UFL/LFL) (2" hole in 4" Inlet Pipeline / 45°)

- The previous figure show that if there is a gas release from 2" hole size with 45° position for about 20 sec. without ignition, the flammable vapors will reach a distance more than 12 m downwind and over 30.95 m height.
- The UFL will reach a distance of about 4.10 m downwind with a height of 4.79 m. The cloud large width will be 1.60 m crosswind at a distance of 2.50 m from the source and 3 m height.
- The LFL will reach a distance of about 10.52 m downwind with a height of 10.59 m. The cloud large width will be 3 m crosswind at a distance of 7 m from the source and 7.5 m height.
- The 50 % LFL will reach a distance of about 11.20 m downwind with a height of 13.85 m. The large width will be 4 m crosswind at a distance of 8.50 m from the source and 8.40 m height.

The modeling show that the gas cloud effects will be limited inside the PRS boundary.

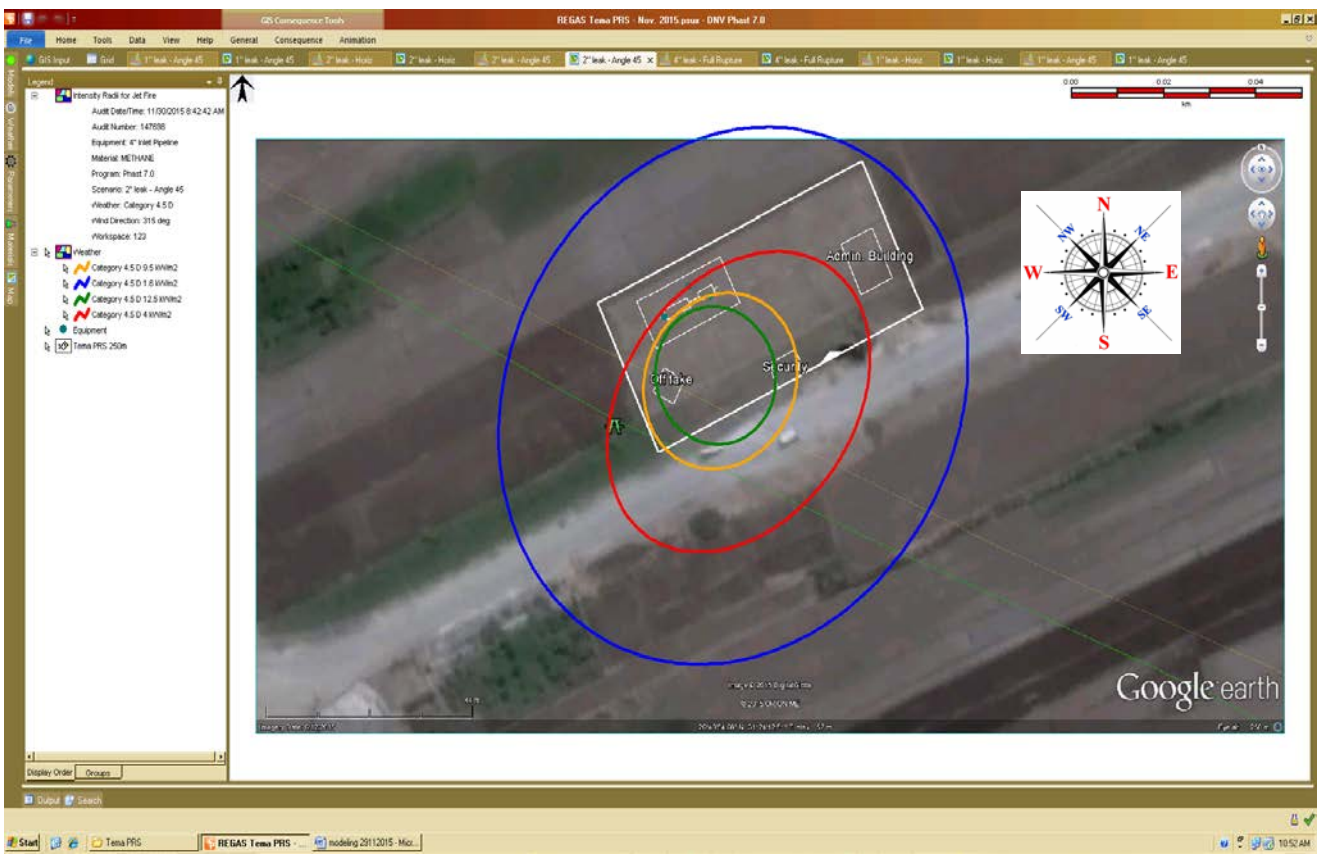


Figure (22) Heat Radiation Contours from Jet Fire (2" hole in 4" Inlet Pipeline / 45^{o})

- The previous figure show that if there is a gas release from 2" hole size with 45^{o} position and ignited, the expected flame length is about 30.95 meters downwind.
- The 9.5 kW/m^2 heat radiation contours extend about 32.99 meters downwind and 17.51 meters crosswind.
- The 12.5 kW/m^2 heat radiation contours extend about 29.05 meters downwind and 12.77 meters crosswind.

The modeling show that the heat radiation of 9.5 kW/m^2 will effects the security office and extended the PRS SE fence with about 10 m reaching the road.

The heat radiation of 12.5 kW/m^2 will be near the SW side of the security office and will extended the PRS SE fence with about 5 m.

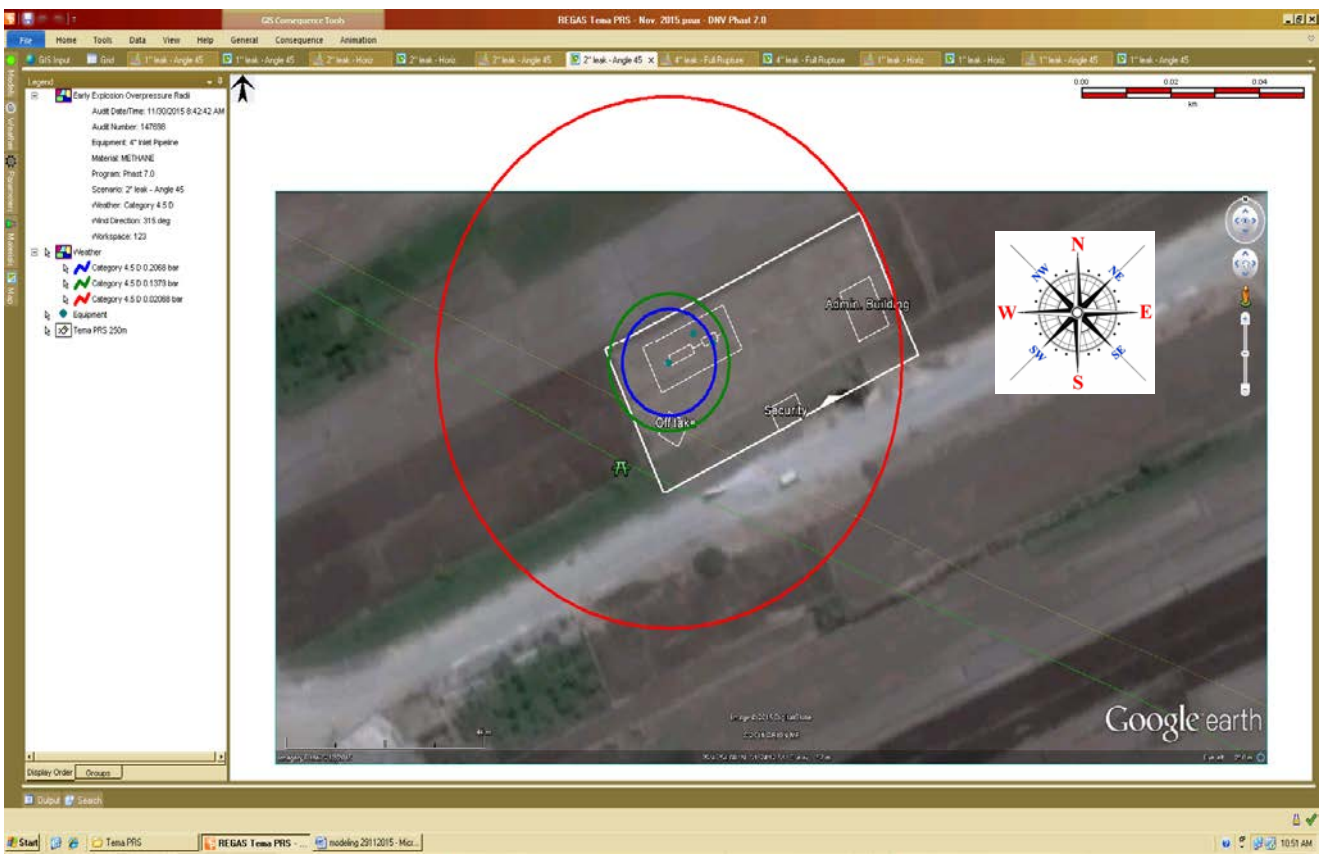


Figure (23) Early Explosion Overpressure Waves (2" hole in 4" Inlet Pipeline / 45°)

- The previous figure show that if there is a gas release from 2" hole size with 45° position and early ignited, this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 52.25 meters radius.
- The 0.137 bar overpressure waves will extend about 13.53 meters radius.
- The 0.206 bar overpressure waves will extend about 10.47 meters radius.

The modeling show that the value of 0.020 bar will extended outside the PRS fences with a distances of about 42 m NW, 38 SW and 29 m SE covering the security office and the road. This value will limited inside the PRS NE fence (at fence) and covering the office building.

The value of 0.137 bar and 0.206 bar will be limited inside from NE, SW and SE, but extended from 5 & 2 meters outside from NW side.

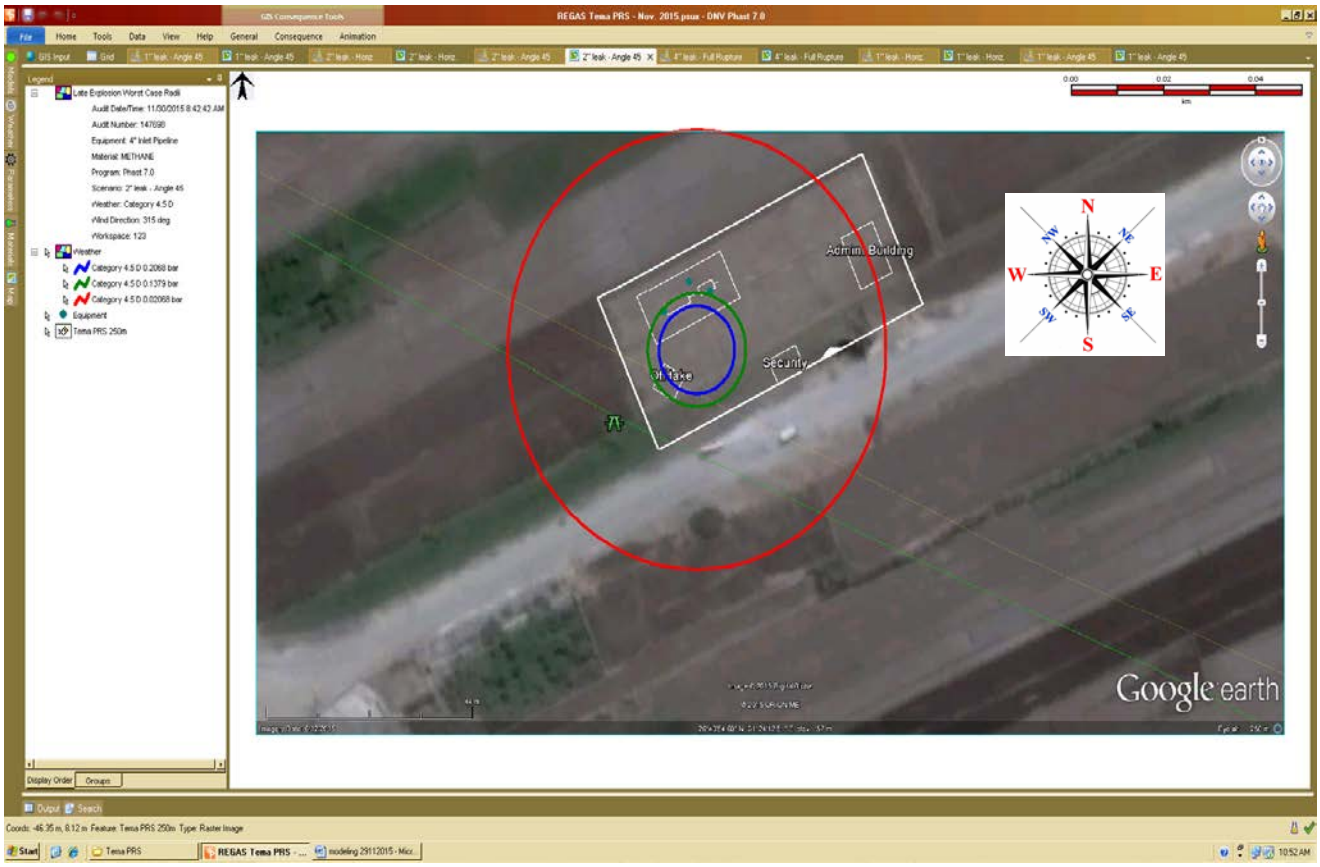


Figure (24) Late Explosion Overpressure Waves (2" hole in 4" Inlet Pipeline / 45°)

- The previous figure show that if there is a leak from 1" hole size with 45° position and late ignited, this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 50.92 meters radius.
- The 0.137 bar overpressure waves will extend about 20.59 meters radius.
- The 0.206 bar overpressure waves will extend about 18.20 meters radius.

The modeling show that the value of 0.020 bar will extend outside the PRS fences with a distance of about 25 m SW, 24 NW and 29 m SE effecting the security office and the road. This value will reach the administration building at the NE side, but not extending the fence.

The value of 0.137 bar and 0.206 bar will be limited inside PRS boundary and covering the off-take point.

1/5- Consequence Modeling for 4 inch (Full Rupture) Gas Release

The following table no. (20) Show that:

Table (20) Dispersion Modeling – 4" Gas Release

Gas Release			
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**
4.5 D	UFL	17.04	1.03
	LFL	52.39	1.57
	50 % LFL	76.92	2.52

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m^2)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
4.5 D	63.45	1.6	154.79	133.93	0
		4	116.92	86.07	0
		9.5	94.50	55.84	0
		12.5	88.85	48.34	20 %/60 sec.
		25	76.35	32.37	80.34
		37.5	68.48	24.36	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
4.5 D	0.020	52.25	72.42	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	13.53	55.14	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	10.47	53.97	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

Fireball			
Wind Category	**Heat Radiation (kW/m^2)**	**Distance (m)**	**Heat Radiation (kW/m^2) Effects on People & Structures**
4.5 D	1.6	49.27	**12.5** *20 % Chance of fatality for 60 sec exposure*
	4	30.94	**25** *100 % Chance of fatality for continuous exposure* *50 % Chance of fatality for 30 sec exposure*
	9.5	19.10	
	12.5	16.07	
	25	9.28	**37.5** *Sufficient of cause process equipment damage*
	37.5	5.31	

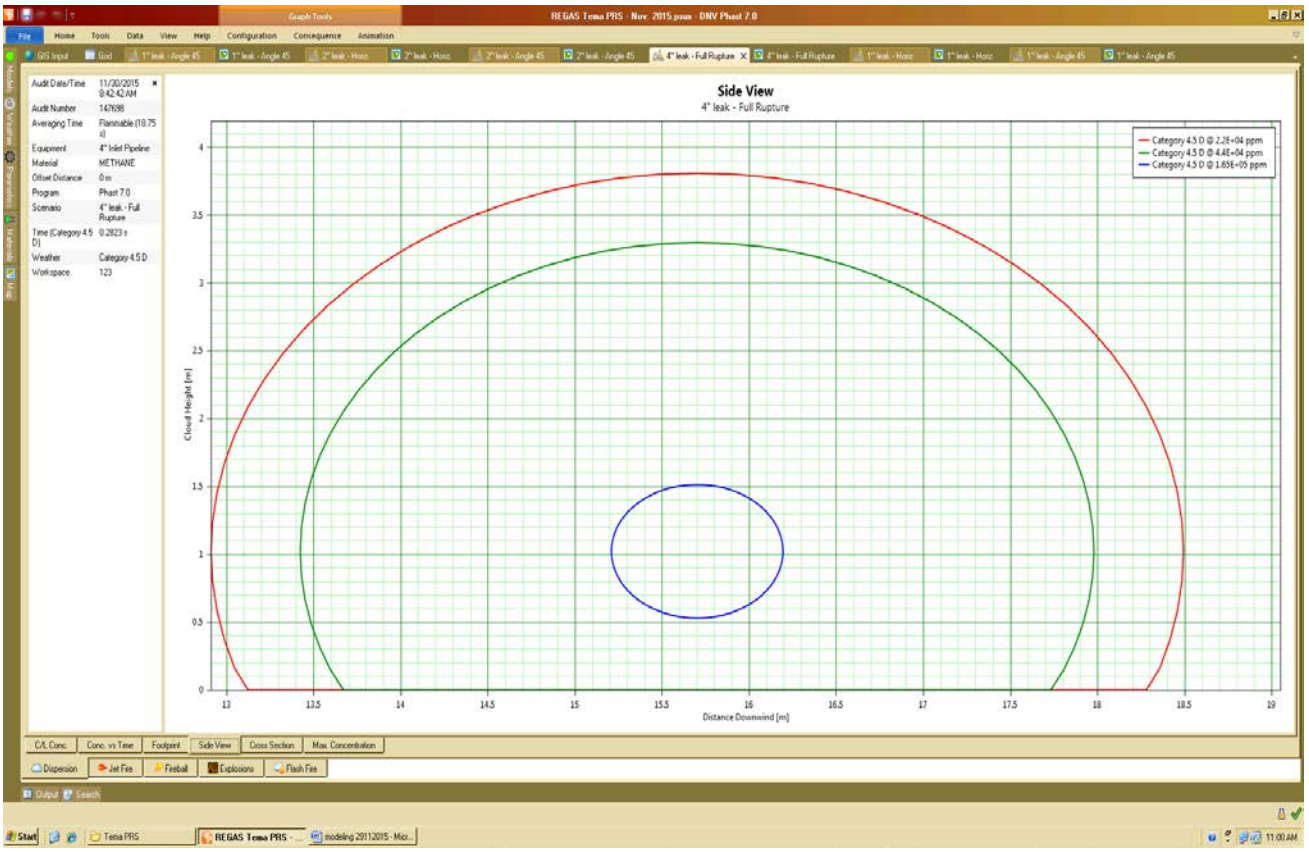


Figure (25) Gas Cloud Side View (UFL/LFL) (4" Inlet Pipeline Full Rupture)

- The previous figure show that if there is a gas release from 4" pipeline full rupture without ignition, the flammable vapors will reach a distance more than 77 m downwind and over 3 m height.
- The UFL will reach a distance of about 17.04 m downwind with a height of 1.03 m. The cloud large width will be 1 m crosswind at a distance of 15.70 m from the source and from 0 to 1.50 m height.
- The LFL will reach a distance of about 52.39 m downwind with a height of 1.57 m. The cloud large width will be 4.50 m crosswind at a distance of 18 m from the source and from 0 to 3.30 m height.
- The 50 % LFL will reach a distance of about 76.92 m downwind with a height of 2.52 m. The large width will be 5 m crosswind at a distance of 18.50 m from the source and from 0 to 3.80 m height.

The modeling show that the gas cloud effects (LFL and 50 % LFL) will extend outside the PRS boundary about 76.92 m.

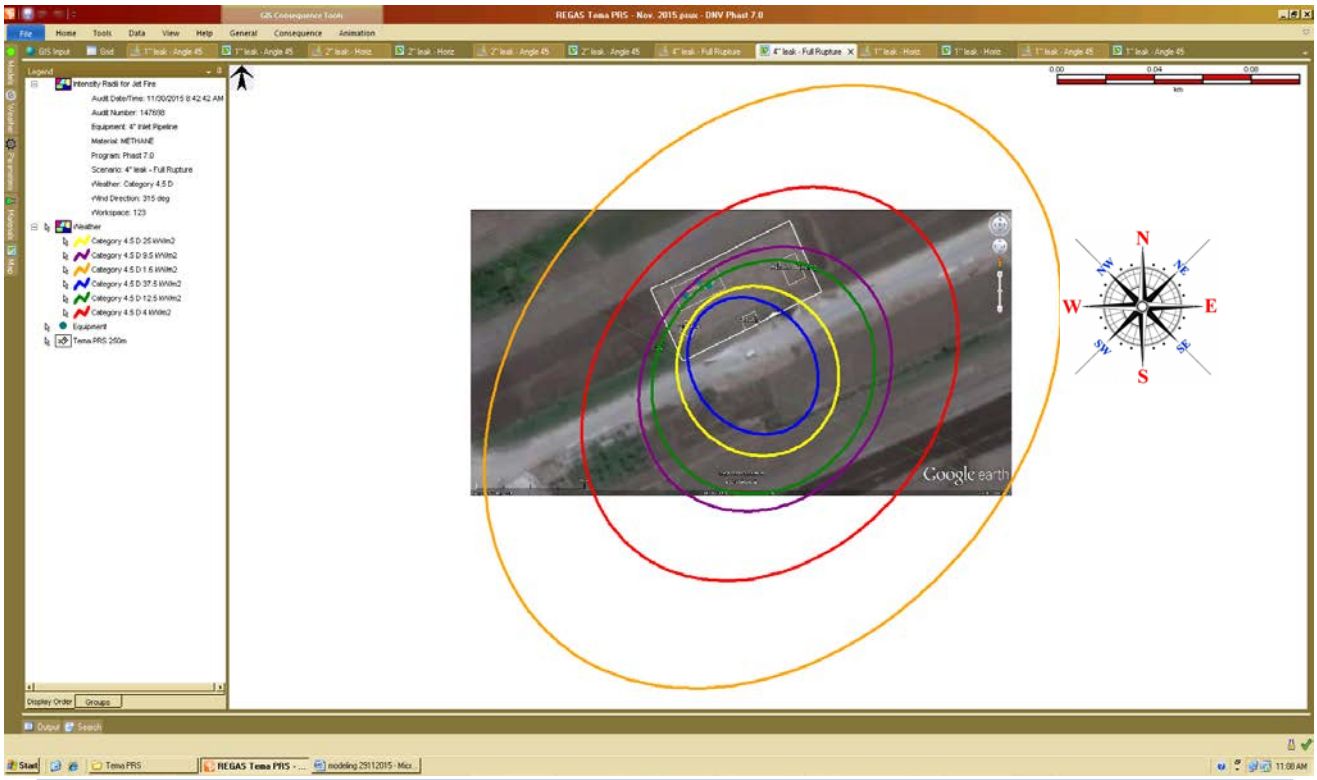


Figure (26) Heat Radiation Contours from Jet Fire (4" Inlet Pipeline Full Rupture)

- The previous figure show that if there is a gas release from 4" pipeline full rupture and ignited, the expected flame length is about 63.45 meters downwind.
- The 9.5 kW/m^2 heat radiation contours extend about 94.50 meters downwind and 55.84 meters crosswind – *extended SE fence with 40 m, SW and NE fences with 7 m.*
- The 12.5 kW/m^2 heat radiation contours extend about 88.85 meters downwind and 48.34 meters crosswind – *extended SE fence with 37 m, SW fence with 7 m and NE fence with 3 m.*
- The 25 kW/m^2 heat radiation contours extend about 76.35 meters downwind and 32.37 meters crosswind – *extended SE fence with 30 m and SW fence with 2 m.*
- The 37.5 kW/m^2 heat radiation contours extend about 68.48 meters downwind and 24.36 meters crosswind – *extend SE fence with 22 m.*

The modeling show that the heat radiation values (9.5 & 12.5 kW/m^2) will cover the security office and administration building down & crosswind, and extended outside the PRS SE fence to the road.

The heat radiation values of 25 & 37.5 kW/m^2 will cover security office, off-take surface point and extended the PRS SE fence to the road.

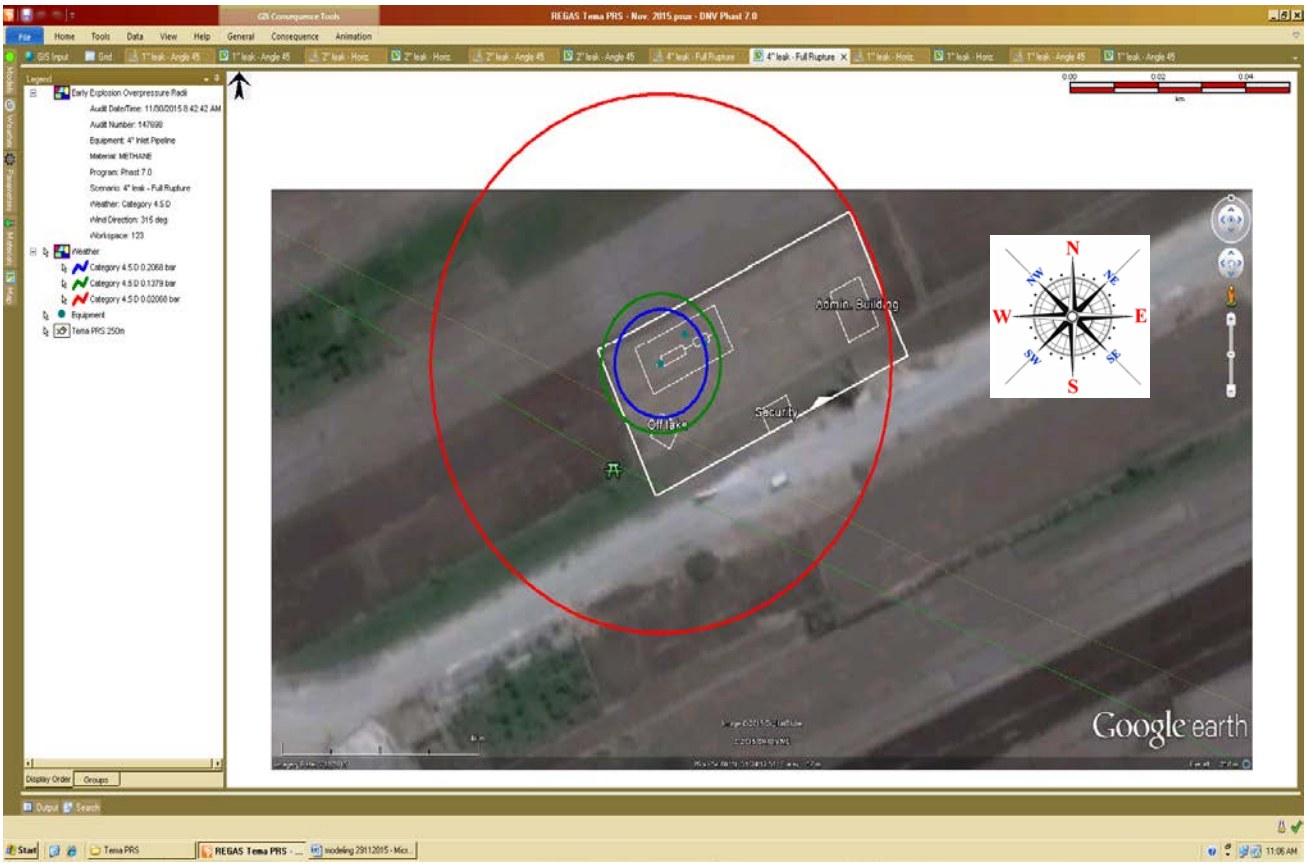


Figure (27) Early Explosion Overpressure Waves (4" Inlet Pipeline Full Rupture)

- The previous figure show that if there is gas release from 4" pipeline full rupture and early ignited, this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 52.25 meters radius.
- The 0.137 bar overpressure waves will extend about 13.53 meters radius.
- The 0.206 bar overpressure waves will extend about 10.47 meters radius.

The modeling show that the value of 0.020 bar will extend outside the PRS fences with a distance of about 42 m NW, 36 SW and 27 m SE covering the security office and reaching the road, and at NE fence covering the office building.

The value of 0.137 bar and 0.206 bar will be limited inside PRS boundary from NE & SE, but extended from 5 & 2 meters out from NW side and 1 m SW effecting the off-take surface.

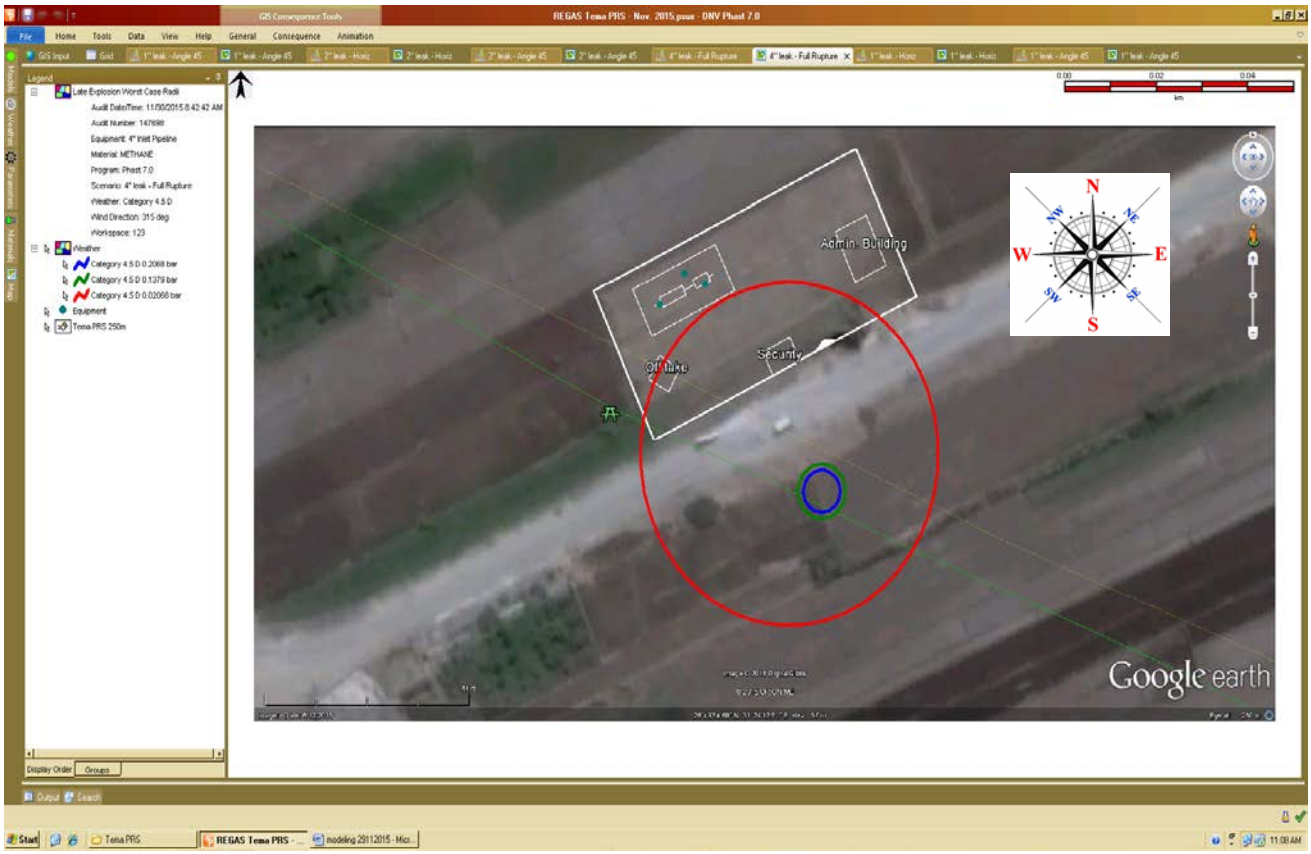


Figure (28) Late Explosion Overpressure Waves (4" Inlet Pipeline Full Rupture)

- The previous figure show that if there is gas release from 4" pipeline full rupture and late ignited, this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 72.42 meters radius.
- The 0.137 bar overpressure waves will extend about 55.14 meters radius.
- The 0.206 bar overpressure waves will extend about 53.97 meters radius.

The modeling show that the value of 0.020 bar will extended outside the PRS fence SE with a distance of 48 m effecting the security office and the road.

The overpressure wave values of 0.137 bar and 0.206 bar will be outside the PRS boundary (SE fence) with a distance from 20 to 22 m downwind.

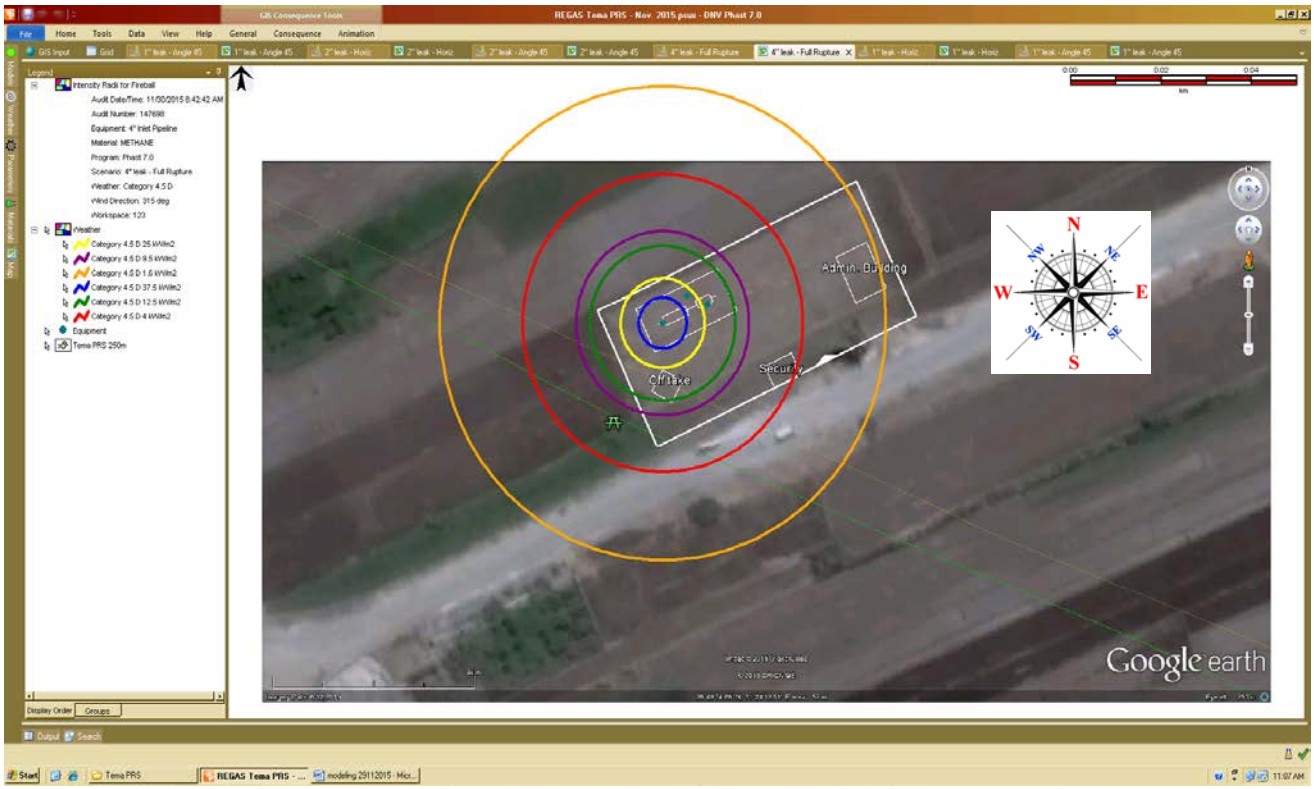


Figure (29) Heat Radiation Contours from Fireball (4" Inlet Pipeline Full Rupture)

- The previous figure show that if there is a gas release from 4" pipeline full rupture and ignited forming fireball this will gives a heat radiation with different values and contours and will extended in four dimensions.
- The 9.5 kW/m^2 heat radiation contours extend about 19.10 meters radius.
- The 12.5 kW/m^2 heat radiation contours extend about 16.07 meters radius.
- The 25 kW/m^2 heat radiation contours extend about 9.28 meters radius.
- The 37.5 kW/m^2 heat radiation contours extend about 5.31 meters radius.

The modeling show that the heat radiation value of:

9.5 kW/m^2 will be limited from NE & SE and extended 7 m SW & 10 m NW.

12.5 kW/m^2 will be limited from NE & SE and extended 3 m SW & 9m NW.

25 kW/m^2 will be limited from NE, SE & SW and extended 1 m NW.

37.5 kW/m^2 will be limited inside the PRS boundary.

2.0- Pressure Reduction Station Outlet Pipeline (10 inch)

2/1- Consequence Modeling for 1 inch (Pin Hole) Gas Release (Horizontal)

The following table no. (21) Show that:

Table (21) Dispersion Modeling – 1" / 10" Horizontal Gas Release

Gas Release			
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**
4.5 D	UFL	1.61	1.00
	LFL	5.64	1.007
	50 % LFL	9.97	1.028

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m^2)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
4.5 D	10.44	1.6	15.46	7.63	0
		4	13.08	5.74	0
		9.5	10.99	2.84	0
		12.5	10.39	2.00	20% /60 sec.
		25	Not Reached	----------	80.34
		37.5	Not Reached	----------	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
4.5 D	0.020	29.60	N/D	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	7.66	N/D	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	5.93	N/D	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

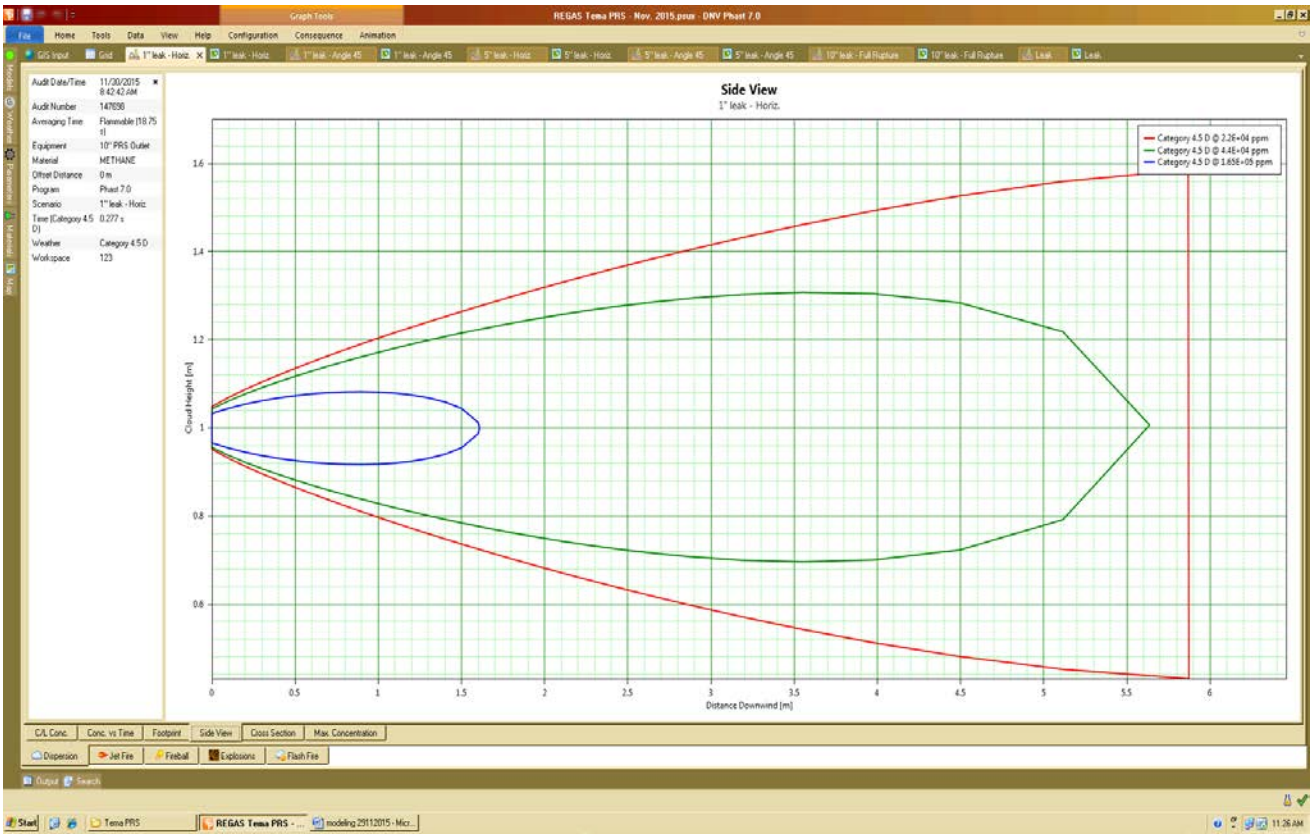


Figure (30) Gas Cloud Side View (UFL/LFL) (1" hole in 10" Outlet Pipeline / 0°)

- The previous figure show that if there is a gas release from 1" hole size at horizontal position for about 20 sec. without ignition, the flammable vapors will reach a distance more than 10 m downwind and over 1.0 m height.
- The UFL will reach a distance of about 1.61 m downwind with a height of 1 m. The cloud large width will be 0.20 m crosswind at a distance of 1 m from the source and 1.08 m height.
- The LFL will reach a distance of about 5.64 m downwind with a height of 1.01 m. The cloud large width will be 0.60 m crosswind at a distance of 3.50 m from the source and 1.32 m height.
- The 50 % LFL will reach a distance of about 9.97 m downwind with a height of from 0 to 1.4 m. The large width will be 1.20 m crosswind at a distance of 5.90 m from the source.

The modeling show that the gas cloud effects will be limited inside the PRS boundary.

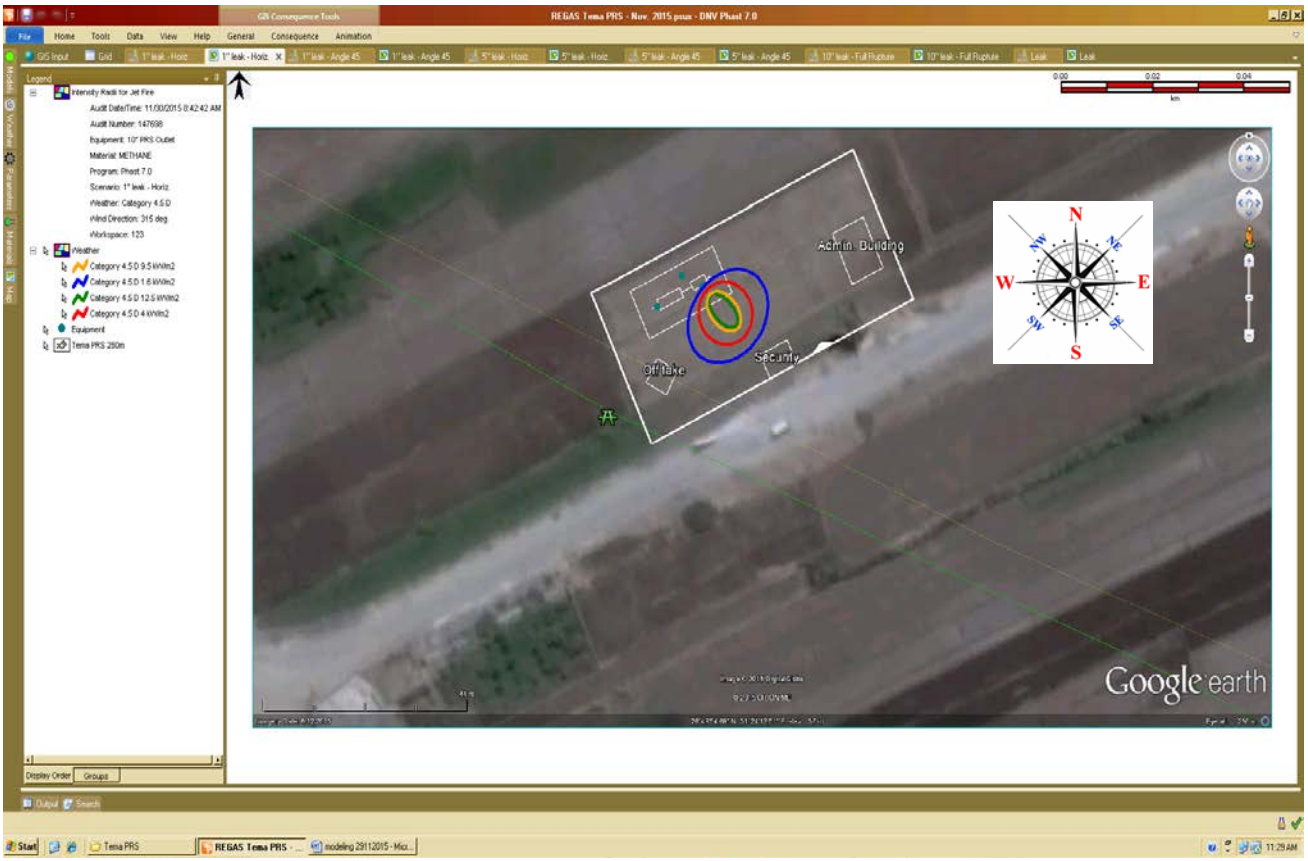


Figure (31) Heat Radiation Contours from Jet Fire (1" hole in 10" Outlet Pipeline / 0°)

- The previous figure show that if there is a gas release from 1" hole size at horizontal position and ignited, the expected flame length is about 10.44 meters downwind.
- The 9.5 kW/m^2 heat radiation contours extend about 10.99 meters downwind and 2.84 meters crosswind.
- The 12.5 kW/m^2 heat radiation contours extend about 10.39 meters downwind and 2 meters crosswind.

The modeling show that the heat radiation value (9.5 kW/m^2 & 12.5 kW/m^2) effects will be limited inside the PRS boundary.

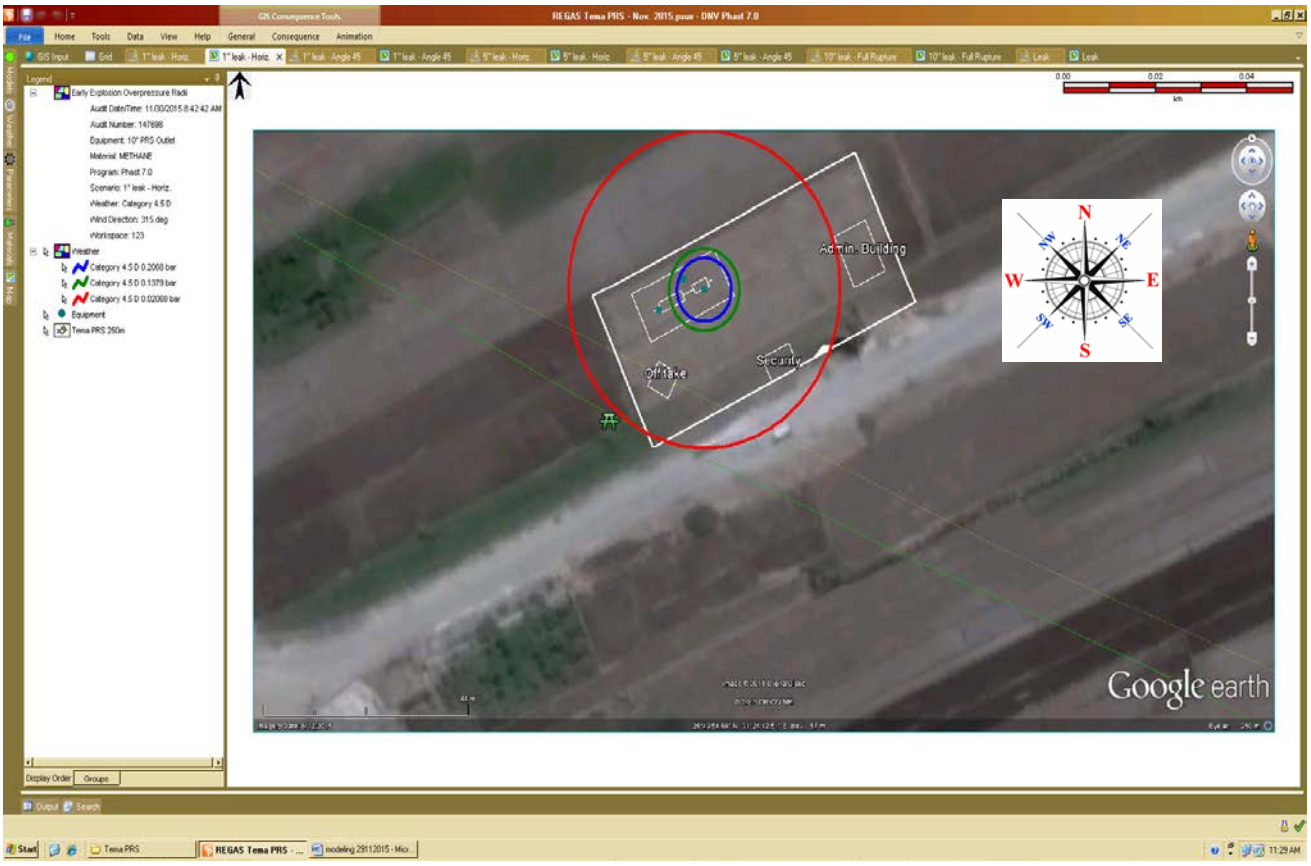


Figure (32) Early Explosion Overpressure Waves (1" hole in 10" Outlet Pipeline / 0^{o})

- The previous figure show that if there is a gas release from 1" hole size at horizontal position and early ignited, this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 29.60 meters radius.
- The 0.137 bar overpressure waves will extend about 7.66 meters radius.
- The 0.206 bar overpressure waves will extend about 5.93 meters radius.

The modeling show that the value of 0.020 bar will extend outside the PRS boundary with a distances of about 8 m SE effecting the security office, 7 m SW and 22 m NW.

The value of 0.137 bar and 0.206 bar will be limited inside PRS boundary.

2/2- Consequence Modeling for 1 inch (Pin Hole) Gas Release (Angle 45 º)

The following table no. (22) Show that:

Table (22) Dispersion Modeling – 1" / 10" 45 º - Gas Release

Gas Release			
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**
4.5 D	UFL	0.97	1.91
	LFL	3.06	3.49
	50 % LFL	5.07	4.56

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m^2)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
4.5 D	7.31	1.6	17.44	12.68	0
		4	11.74	7.64	0
		9.5	8.05	3.13	0
		12.5	6.15	1.11	20% /60 sec.
		25	Not Reached	----------	80.34
		37.5	Not Reached	----------	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
4.5 D	0.020	29.60	N/D	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	7.66	N/D	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	5.93	N/D	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

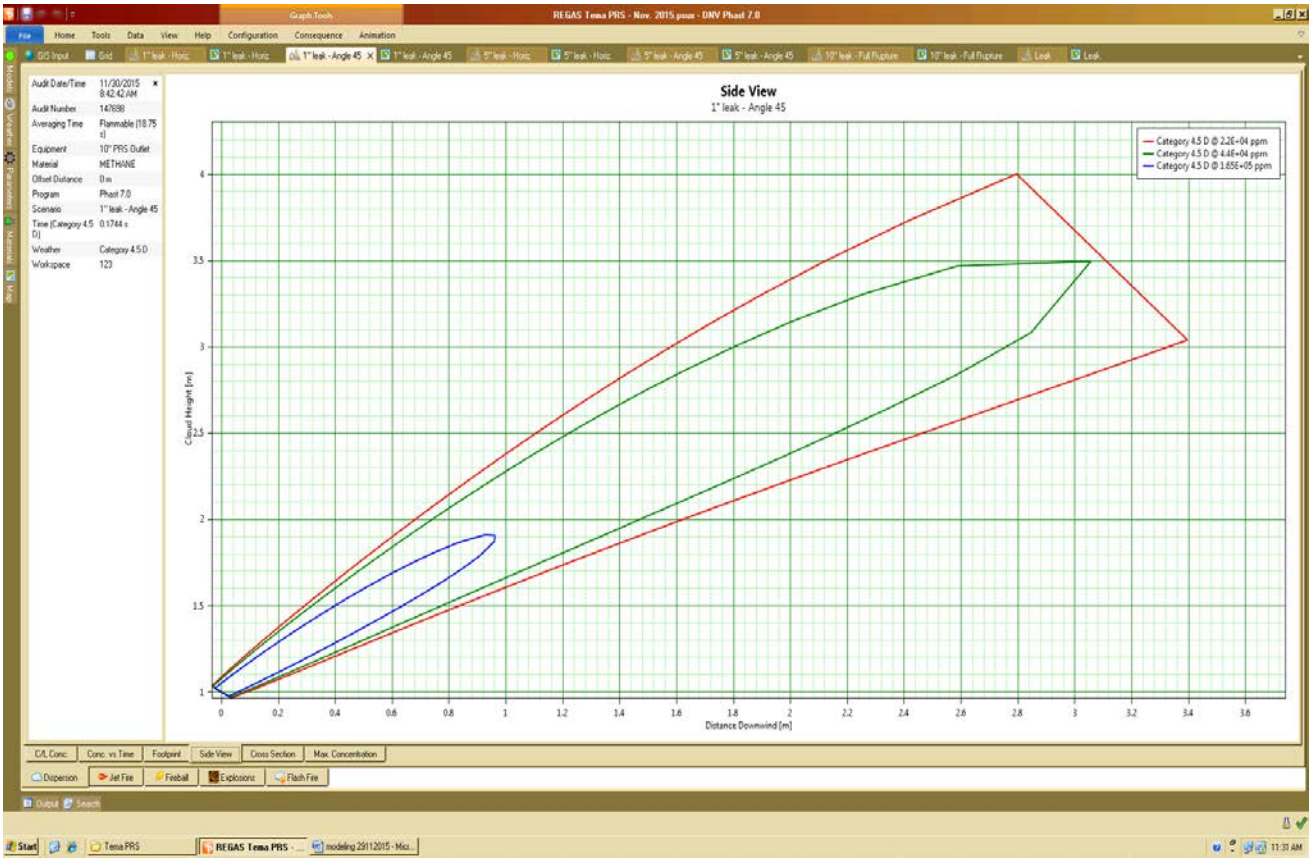


Figure (33) Gas Cloud Side View (UFL/LFL) (1" hole in 10" Outlet Pipeline / 45^{o})

- The previous figure show that if there is a gas release from 1" hole size with 45^{o} position for about 20 sec. without ignition, the flammable vapors will reach a distance more than 5 m downwind and over 4 m height.
- The UFL will reach a distance of about 0.97 m downwind with a height of 1.91 m. The cloud large width will be 0.20 m crosswind at a distance of 0.60 m from the source and 1.70 m height.
- The LFL will reach a distance of about 3.06 m downwind with a height of 3.49 m. The cloud large width will be 0.80 m crosswind at a distance of 1.88 m from the source and 3 m height.
- The 50 % LFL will reach a distance of about 5.07 m downwind with a height of 4.56 m. The large width will be 1.30 m crosswind at a distance of 2.80 m from the source and 4 m height.

The modeling show that the gas cloud effects will be limited inside the PRS boundary.

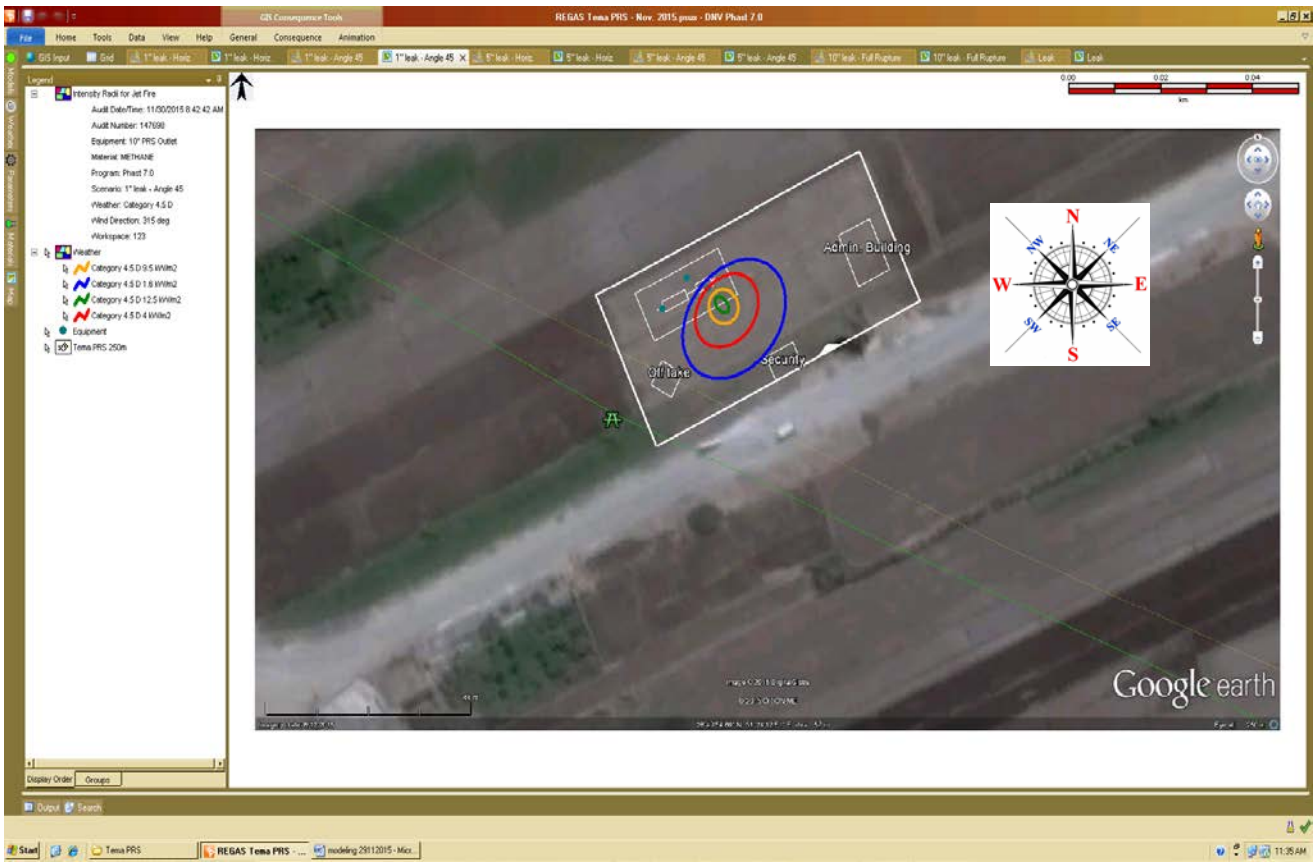


Figure (34) Heat Radiation Contours from Jet Fire (1" hole in 10" Outlet Pipeline / 45^{o})

- The previous figure show that if there is a gas release from 1" hole size with 45^{o} position and ignited, the expected flame length is about 7.31 meters downwind.
- The 9.5 kW/m^2 heat radiation contours extend about 48.05 meters downwind and 3.13 meters crosswind.
- The 12.5 kW/m^2 heat radiation contours extend about 6.15 meters downwind and 1.11 meters crosswind.

The modeling show that the heat radiation value (9.5 kW/m^2 & 12.5 kW/m^2) effects will be limited inside the PRS boundary.

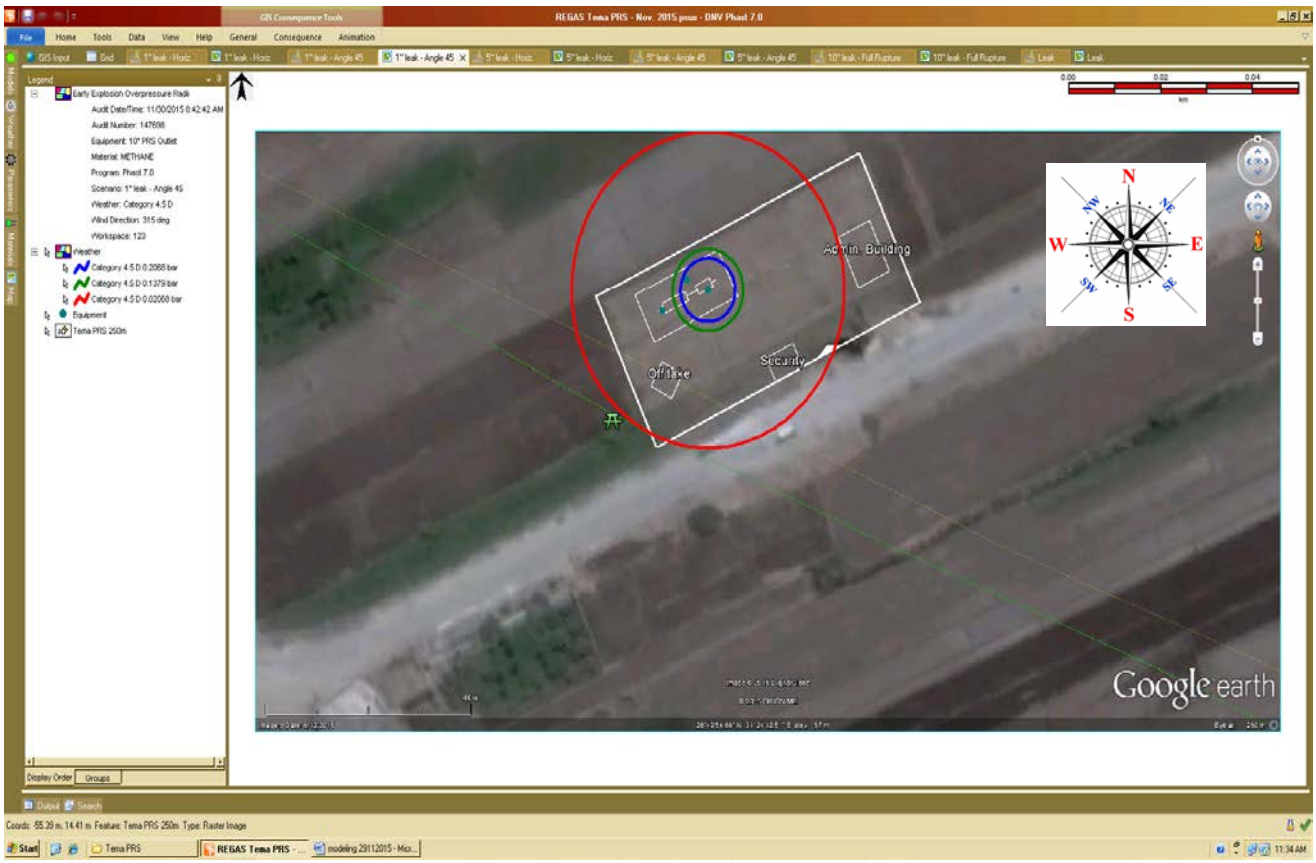


Figure (35) Early Explosion Overpressure Waves (1" hole in 10" Outlet Pipeline / 45^{o})

- The previous figure show that if there is a gas release from 1" hole size with 45^{o} position and early ignited, this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 29.60 meters radius.
- The 0.137 bar overpressure waves will extend about 7.66 meters radius.
- The 0.206 bar overpressure waves will extend about 5.93 meters radius.

The modeling show that the value of 0.020 bar will extend outside the PRS boundary with a distances of about 22 m NW, 8 m SW and 9 SE effecting the security office and reaching the road, also will be very close to the administration building from the NE side

The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary.

2/3- Consequence Modeling for 5 inch (Half Rup.) Gas Release (Horizontal)

The following table no. (23) Show that:

Table (23) Dispersion Modeling – 5" / 10" Horizontal - Gas Release

Gas Release			
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**
4.5 D	UFL	8.63	1.01
	LFL	24.18	1.13
	50 % LFL	36.19	1.40

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m^2)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
4.5 D	31.77	1.6	92.39	77.47	0
		4	71.31	49.39	0
		9.5	58.95	31.74	0
		12.5	55.79	27.29	20% /60 sec.
		25	48.63	17.52	80.34
		37.5	43.75	12.49	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
4.5 D	0.020	29.60	36.51	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	7.66	24.27	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	5.93	23.31	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

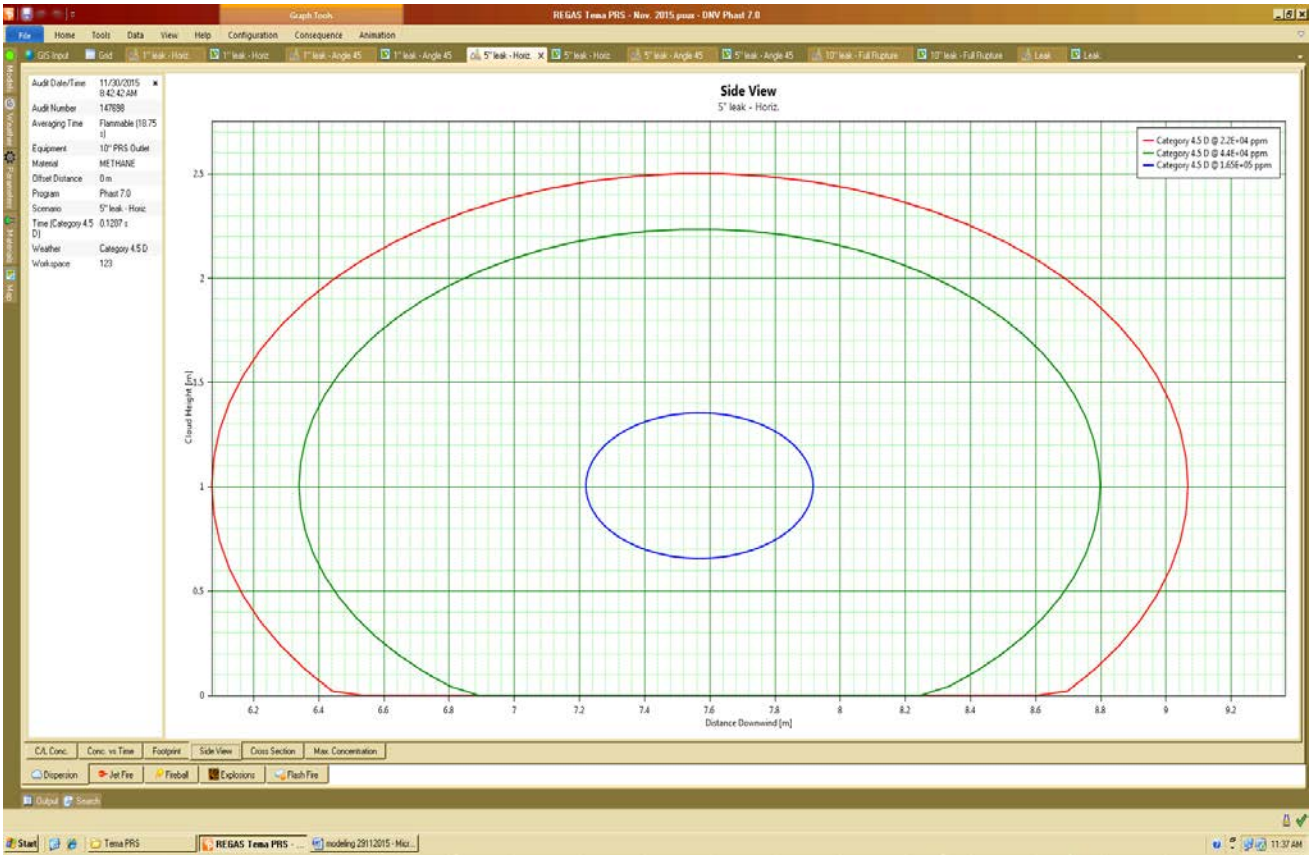


Figure (36) Gas Cloud Side View (UFL/LFL) (5" hole in 10" Outlet Pipeline / 0°)

- The previous figure show that if there is a gas release from 5" hole size at horizontal position for about 20 sec. without ignition, the flammable vapors will reach a distance more than 36 m downwind and over 1.50 m height.
- The UFL will reach a distance of about 8.63 m downwind with a height of 1.01 m. The cloud large width will be 0.68 m crosswind at a distance of 7.20 m from the source and 1.35 m height.
- The LFL will reach a distance of about 24.18 m downwind with a height of 1.13 m. The cloud large width will be 2.44 m crosswind at a distance of 8 m from the source and from 0 to 2.23 m height.
- The 50 % LFL will reach a distance of about 36.19 m downwind with a height of 1.40 m. The large width will be 3 m crosswind at a distance of 9 m from the source and from 0 to 2.50 m height.

The modeling show that the gas cloud (UFL & LFL) will be limited inside the PRS boundary and the 50 % LFL may extended outside with about 3 m SE direction.

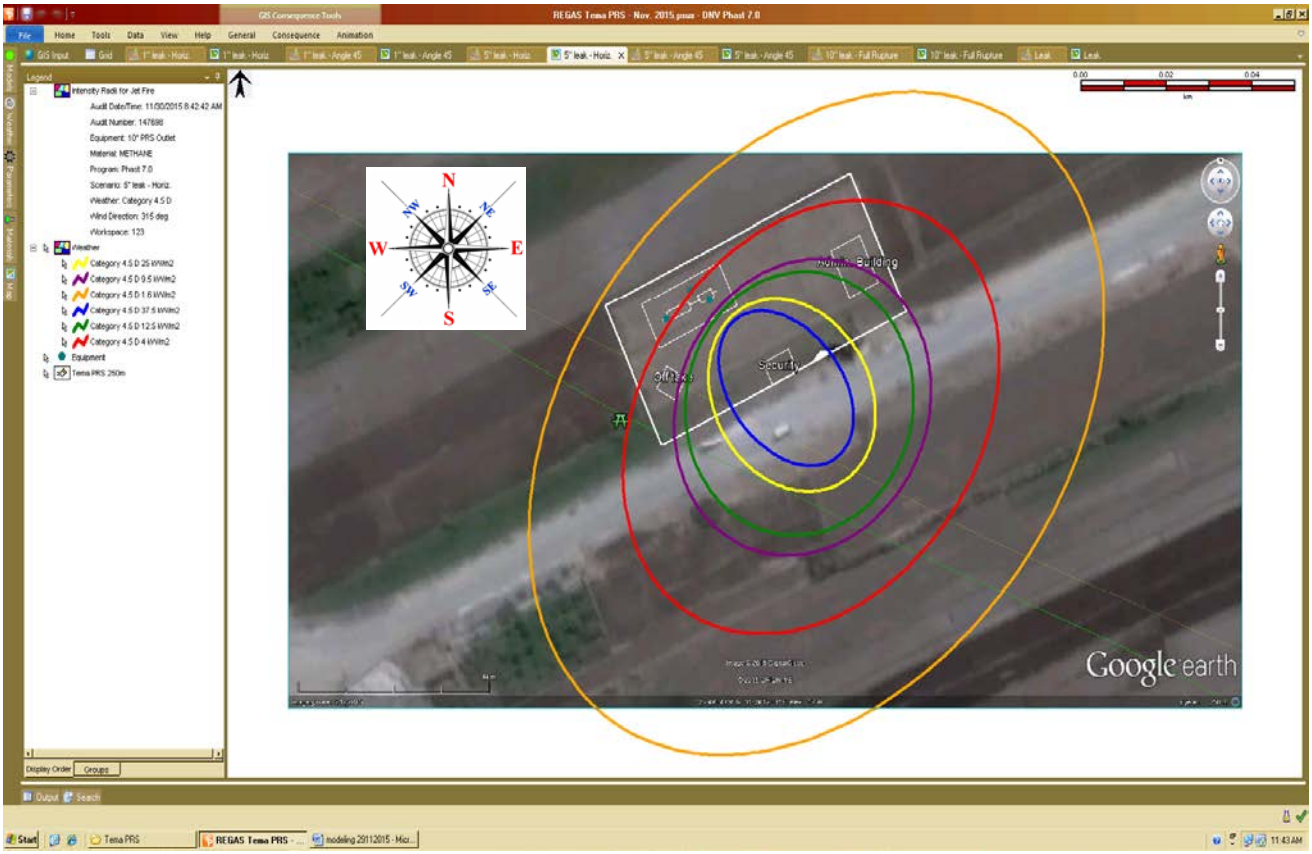


Figure (37) Heat Radiation Contours from Jet Fire (5" hole in 10" Outlet Pipeline / 0°)

- The previous figure show that if there is a gas release from 5" hole size at horizontal position and ignited, the expected flame length is about 31.77 meters downwind.
- The 9.5 kW/m^2 heat radiation contours extend about 58.95 meters downwind and 31.74 meters crosswind.
- The 12.5 kW/m^2 heat radiation contours extend about 55.79 meters downwind and 27.29 meters crosswind.
- The 25 kW/m^2 heat radiation contours extend about 48.63 meters downwind and 17.52 meters crosswind.
- The 37.5 kW/m^2 heat radiation contours extend about 43.75 meters downwind and 12.49 meters crosswind.

The modeling show that the heat radiation value of 9.5, 12.5 kW/m^2 will effects the security and administration buildings down and crosswind (NE/SE).

The values of 25 & 37.5 kW/m^2 effects the security office and extended outside the PRS SE fence to the road.

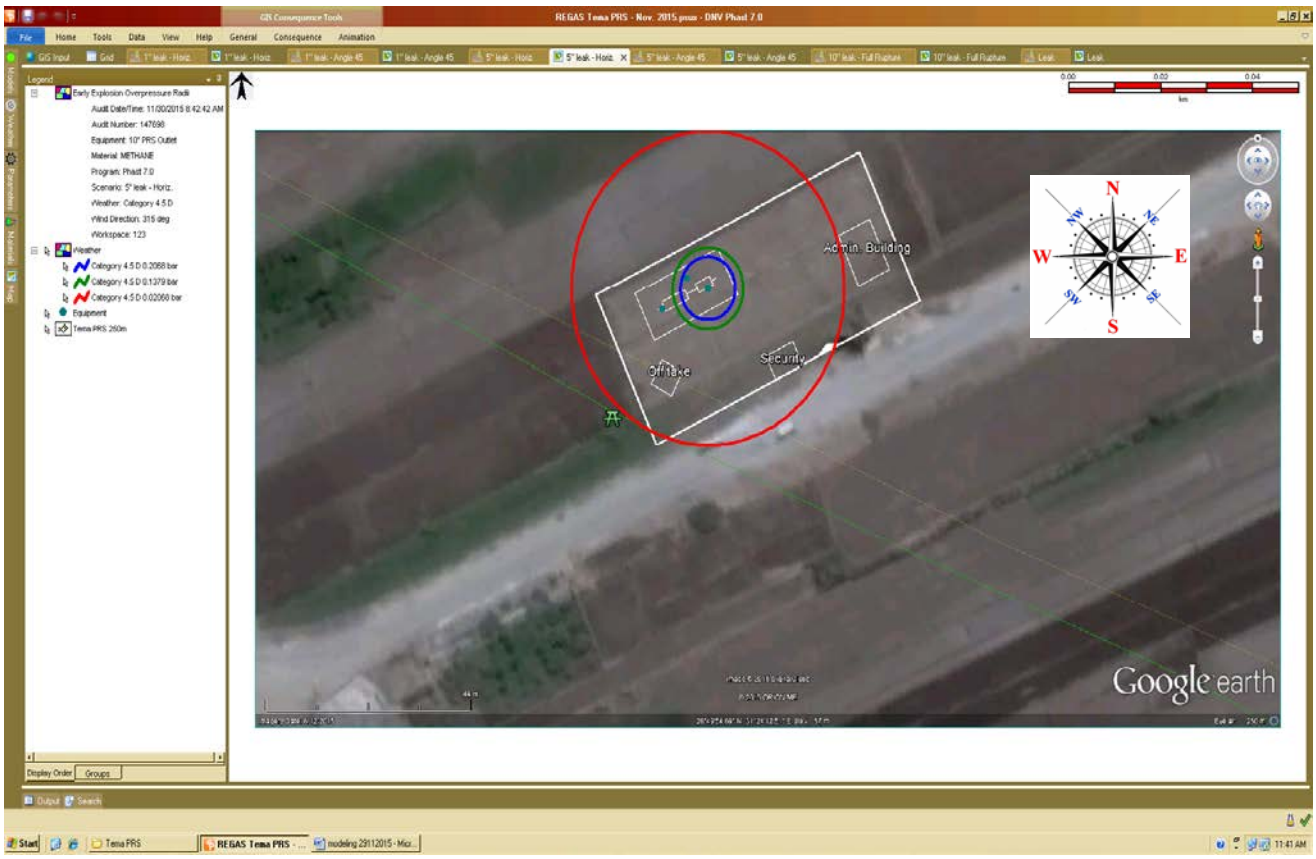


Figure (38) Early Explosion Overpressure Waves (5" hole in 10" Outlet Pipeline / 0^{o})

- The previous figure show that if there is a leak from 5" hole size at horizontal position and early ignited, this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 29.60 meters radius.
- The 0.137 bar overpressure waves will extend about 7.66 meters radius.
- The 0.206 bar overpressure waves will extend about 5.93 meters radius.

The modeling show that the value of 0.020 bar will extended outside the PRS fences with a distance of about 21 m NW, 7 SW and 9 m SE effecting the security office and the road.

The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary.

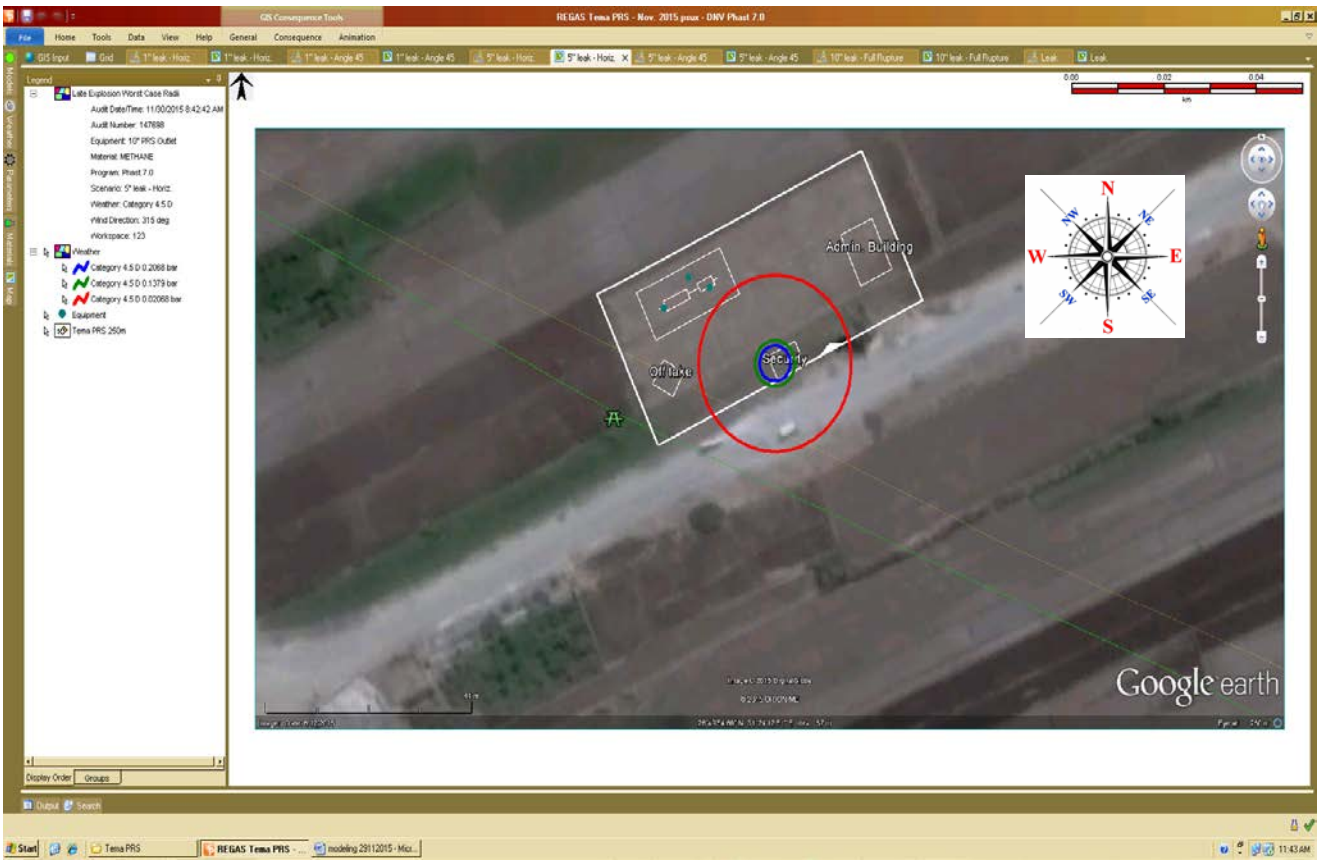


Figure (39) Late Explosion Overpressure Waves (5" hole in 10" Outlet Pipeline / 0°)

- The previous figure show that if there is a gas release from 5" hole size at horizontal position and late ignited, this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 36.51 meters radius.
- The 0.137 bar overpressure waves will extend about 24.27 meters radius.
- The 0.206 bar overpressure waves will extend about 23.31 meters radius.

The modeling show that the value of 0.020 bar will extended the PRS fence from SE side with a distance of 14 m reaching the road, and limited inside the boundary from NE, NW & SW sides.

The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary reaching the security office.

2/4- Consequence Modeling for 5 inch (Half Rup.) Gas Release (Angle 45º)

The following table no. (24) Show that:

Table (24) Dispersion Modeling – 5" / 10" 45º - Gas Release

Gas Release			
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**
4.5 D	UFL	4.31	4.83
	LFL	11.30	10.63
	50 % LFL	15.06	11.92

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m^2)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
4.5 D	39.62	1.6	87.87	70.91	0
		4	60.18	42.32	0
		9.5	42.59	23.33	0
		12.5	39.68	17.41	20% /60 sec.
		25	Not Reached	----------	80.34
		37.5	Not Reached	----------	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
4.5 D	0.020	29.60	28.36	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	7.66	14.75	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	5.93	13.68	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

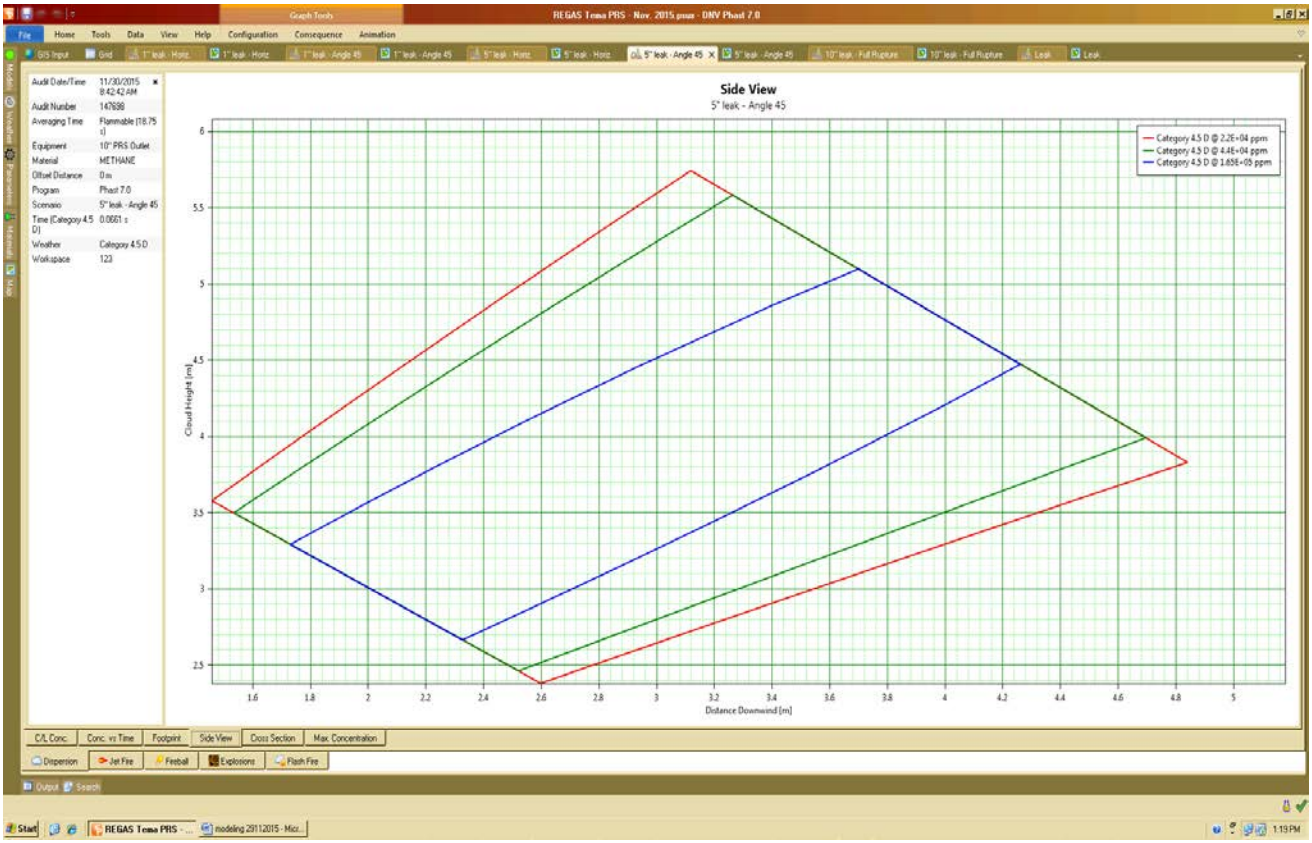


Figure (40) Gas Cloud Side View (UFL/LFL) (5" hole in 10" Outlet Pipeline / 45°)

- The previous figure show that if there is a gas release from 5" hole size with 45° position for about 20 sec. without ignition, the flammable vapors will reach a distance more than 15 m downwind and over 12 m height.
- The UFL will reach a distance of about 4.31 m downwind with a height of 4.83 m. The cloud large width will be 0.90 m crosswind at a distance of 3.20 m from the source and 3.50 m height.
- The LFL will reach a distance of about 11.30 m downwind with a height of 10.63 m. The cloud large width will be 2 m crosswind at a distance of 3.80 m from the source and 5.60 m height.
- The 50 % LFL will reach a distance of about 15.06 m downwind with a height of 11.92 m. The large width will be 2.50 m crosswind at a distance of 4.80 m from the source and 5.82 m height.

The modeling show that the gas cloud effects will be limited inside the PRS boundary.

Figure (41) Heat Radiation Contours from Jet Fire (5" hole in 10" Outlet Pipeline / 45°)

- The previous figure show that if there is a gas release from 5" hole size with 45° position and ignited, the expected flame length is about 39.62 meters downwind.
- The 9.5 kW/m^2 heat radiation contours extend about 42.59 meters downwind and 23.33 meters crosswind.
- The 12.5 kW/m^2 heat radiation contours extend about 37.68 meters downwind and 17.41 meters crosswind.

The modeling show that the heat radiation value of 9.5 kW/m^2 & 12.5 kW/m^2 will extended outside the PRS fence from the SE side with a distance of 15 & 20 m covering the security office and reaching the road.

The value of 9.5 kW/m^2 will be close to the administration building from the NE side.

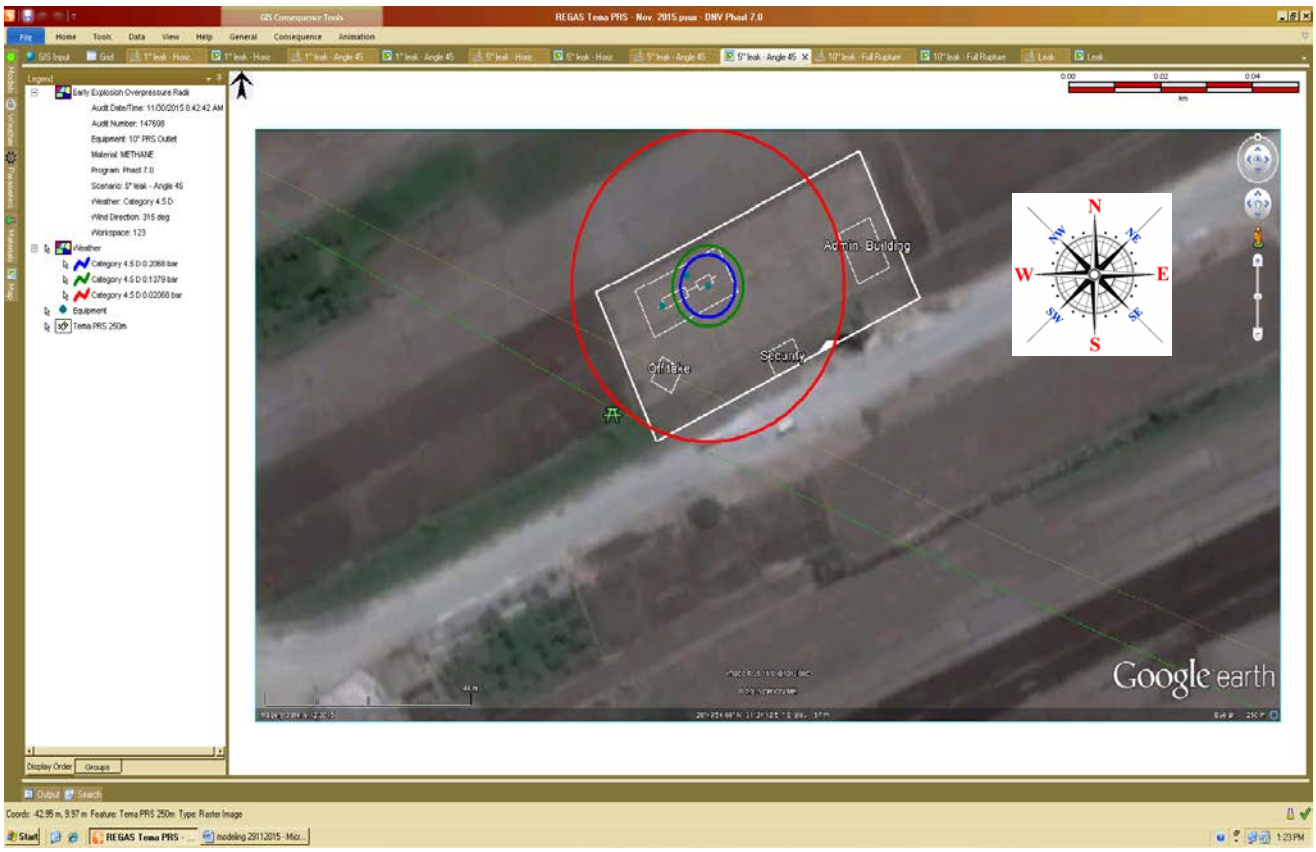


Figure (42) Early Explosion Overpressure Waves (5" hole in 10" Outlet Pipeline / 45°)

- The previous figure show that if there is a gas release from 5" hole size with 45° position and early ignited, this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 29.60 meters radius.
- The 0.137 bar overpressure waves will extend about 7.66 meters radius.
- The 0.206 bar overpressure waves will extend about 5.93 meters radius.

The modeling show that the value of 0.020 bar will extended outside the PRS fence with a distance of about 21 m NW, 8 m SW and 8 SE effecting the security office and reaching the road. This value will be close to the administration building from the NE side.

The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary.

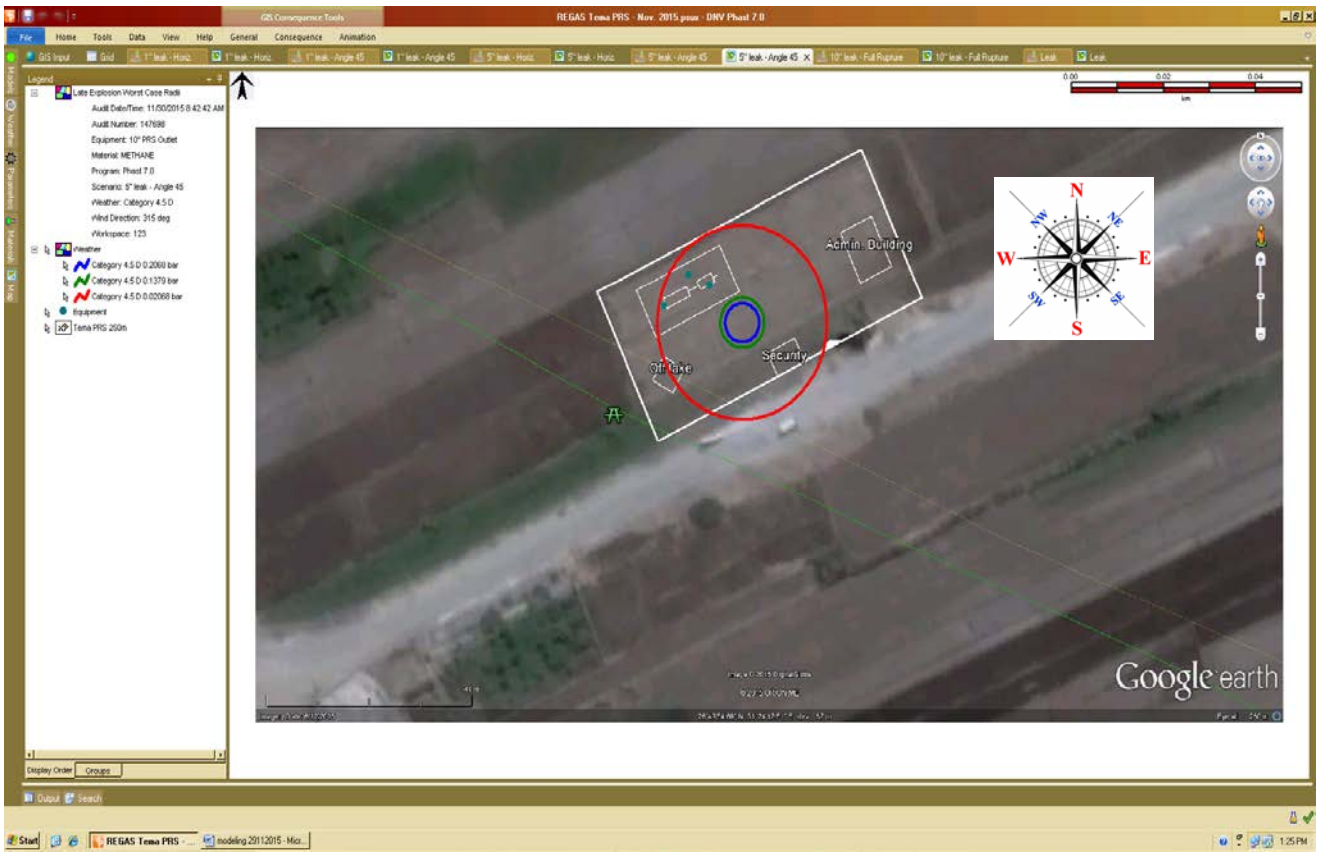


Figure (43) Late Explosion Overpressure Waves (5" hole in 10" Outlet Pipeline / 45°)

- The previous figure show that if there is a gas release from 5" hole size with 45° position and late ignited, this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 28.36 meters radius.
- The 0.137 bar overpressure waves will extend about 14.75 meters radius.
- The 0.206 bar overpressure waves will extend about 13.68 meters radius.

The modeling show that the value of 0.020 bar will be limited inside the PRS fence from NE, SW and NW, but extended outside from the SE side covering the security office and reaching the road.

The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary and may be close to the security office.

2/5- Consequence Modeling for 10 inch (Full Rup.) Gas Release

The following table no. (25) Show that:

Table (25) Dispersion Modeling – 10" – Gas Release

Gas Release			
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**
4.5 D	UFL	11.67	1.02
	LFL	27.11	1.15
	50 % LFL	39.74	1.41

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m^2)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
4.5 D	70.53	1.6	17591	152.88	0
		4	132.44	98.43	0
		9.5	106.53	64.00	0
		12.5	100.10	55.46	20% /60 sec.
		25	85.64	37.46	80.34
		37.5	76.82	28.36	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
4.5 D	0.020	29.60	39.88	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	7.66	23.98	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	5.93	15.15	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

Fireball			
Wind Category	**Heat Radiation (kW/m^2)**	**Distance (m)**	**Heat Radiation (kW/m^2) Effects on People & Structures**
4.5 D	1.6	20.25	**12.5** *20 % Chance of fatality for 60 sec exposure*
	4	12.31	**25** *100 % Chance of fatality for continuous exposure*
	9.5	6.92	*50 % Chance of fatality for 30 sec exposure*
	12.5	5.42	**37.5** *Sufficient of cause process equipment damage*
	25	Not Reached	
	37.5	Not Reached	

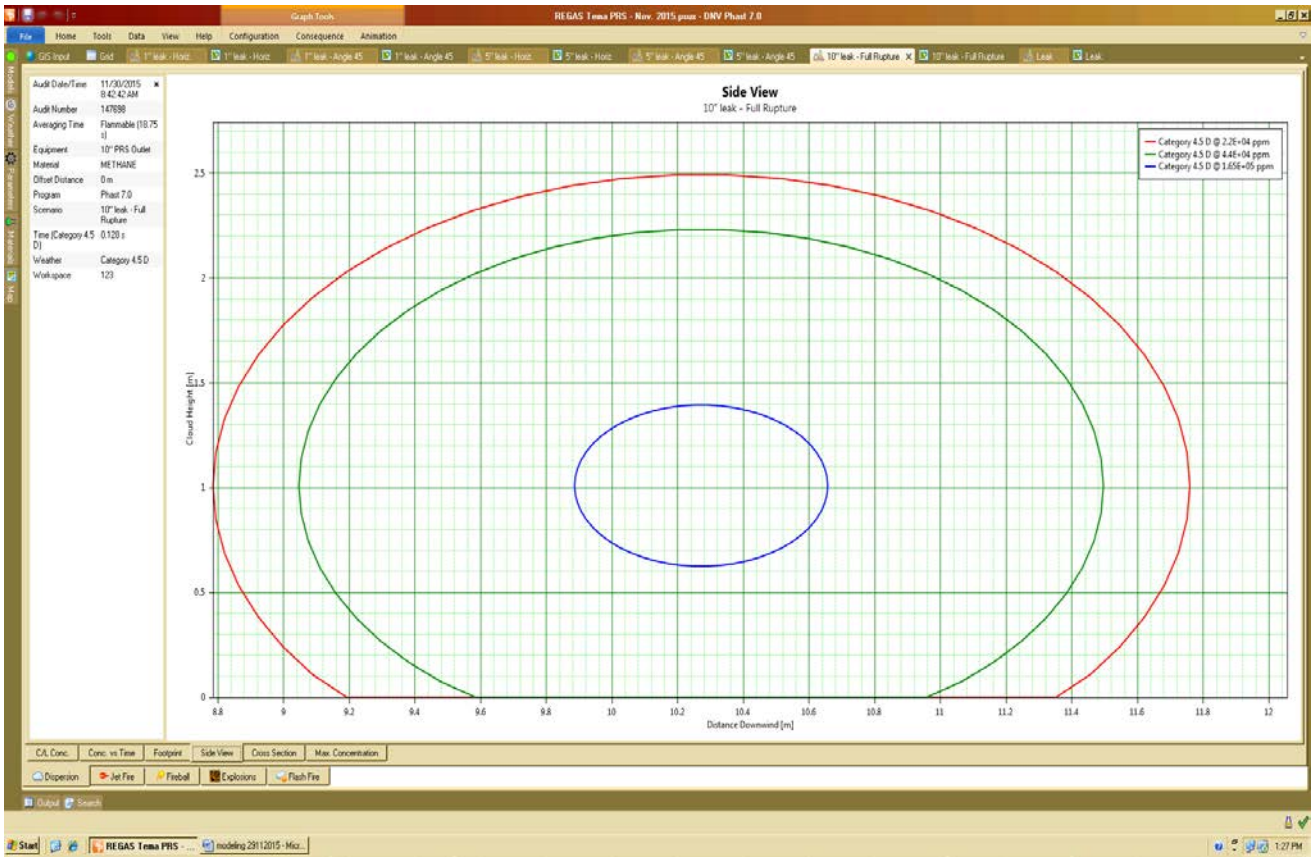


Figure (44) Gas Cloud Side View (UFL/LFL) (10" Outlet Pipeline Full Rupture)

- The previous figure show that if there is a gas release from 10" pipeline full rupture without ignition, the flammable vapors will reach a distance more than 39 m downwind and over 1.41 m height.
- The UFL will reach a distance of about 11.67 m downwind with a height of 1.02 m. The cloud large width will be 0.80 m crosswind at a distance of 10.30 m from the source and 1.40 m height.
- The LFL will reach a distance of about 27.11 m downwind with a height of 1.15 m. The cloud large width will be 2.32 m crosswind at a distance of 11.40 m from the source and from 0 to 2.23 m height.
- The 50 % LFL will reach a distance of about 39.74 m downwind with a height of 1.41 m. The large width will be 3 m crosswind at a distance of 0 m from the source and from 0 to 2.50 m height.

The modeling show that the gas cloud effects will be limited inside the PRS boundary for the (LFL & UFL) but may extended outside from SE side with a distance of about 6 m.

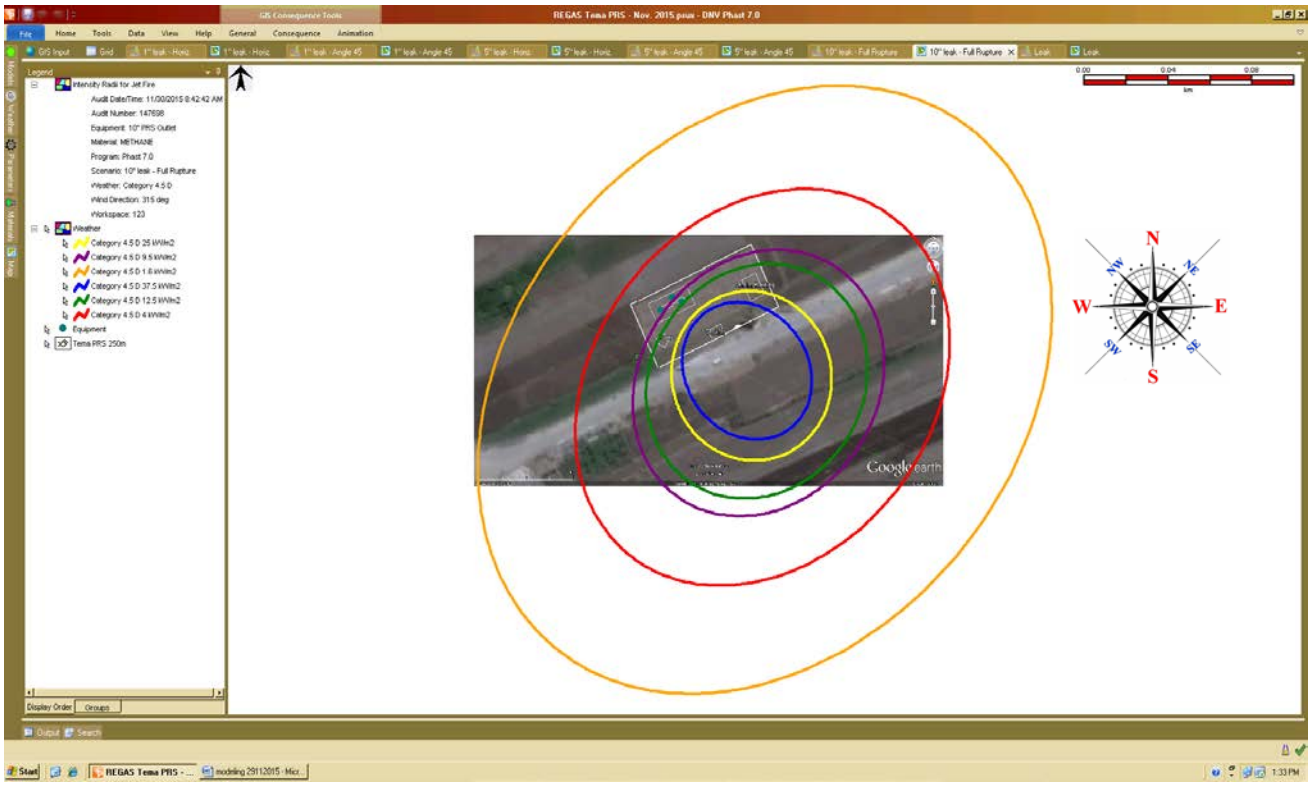


Figure (45) Heat Radiation Contours from Jet Fire (10" Outlet Pipeline Full Rupture)

- The previous figure show that if there is a gas release from 10" pipeline full rupture and ignited, the expected flame length is about 70.53 meters downwind.
- The 9.5 kW/m^2 heat radiation contours extend about 106.53 meters downwind and 64 meters crosswind.
- The 12.5 kW/m^2 heat radiation contours extend about 100.10 meters downwind and 55.46 meters crosswind.
- The 25 kW/m^2 heat radiation contours extend about 85.64 meters downwind and 37.36 meters crosswind.
- The 37.5 kW/m^2 heat radiation contours extend about 76.28 meters downwind and 28.36 meters crosswind.

The modeling show that the heat radiation of:

9.5 kW/m^2 will extend to 40 m SE / 13 m NE / 5 m SW / at fence NW.
12.5 kW/m^2 will extend to 38 m SE / 10 m NE / 1 m SW.
25 kW/m^2 will extend to 30 m SE / 2 m NE.
37.5 kW/m^2 will extend to 25 m SE.

The heat radiations of 9.5, 12.5 and 25 kW/m^2 will affect the administration and security buildings, reaching the road.

The heat radiation of 37.5 kW/m^2 will affect the security office and reaching the road, also close to the admin building.

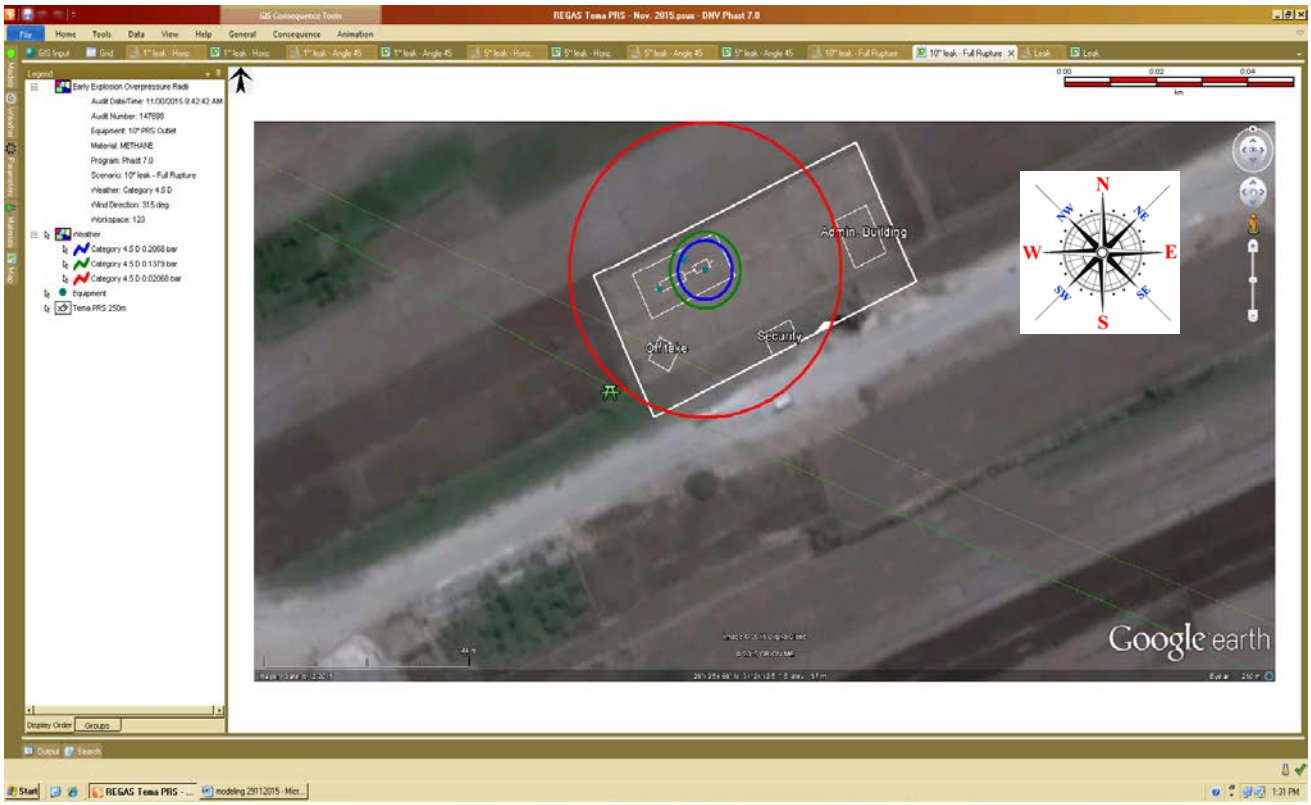


Figure (46) Early Explosion Overpressure Waves (10" Outlet Pipeline Full Rupture)

- The previous figure show that if there is a gas release from 10" pipeline full rupture and early ignited, this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 29.60 meters radius.
- The 0.137 bar overpressure waves will extend about 7.66 meters radius.
- The 0.206 bar overpressure waves will extend about 5.93 meters radius.

The modeling show that the value of 0.020 bar will extended outside the PRS boundary with a distances of about 21 m NW, 8 m SW and 8 SE covering the security office and reach the road. This value will be close to administration building from the NE side.

The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary.

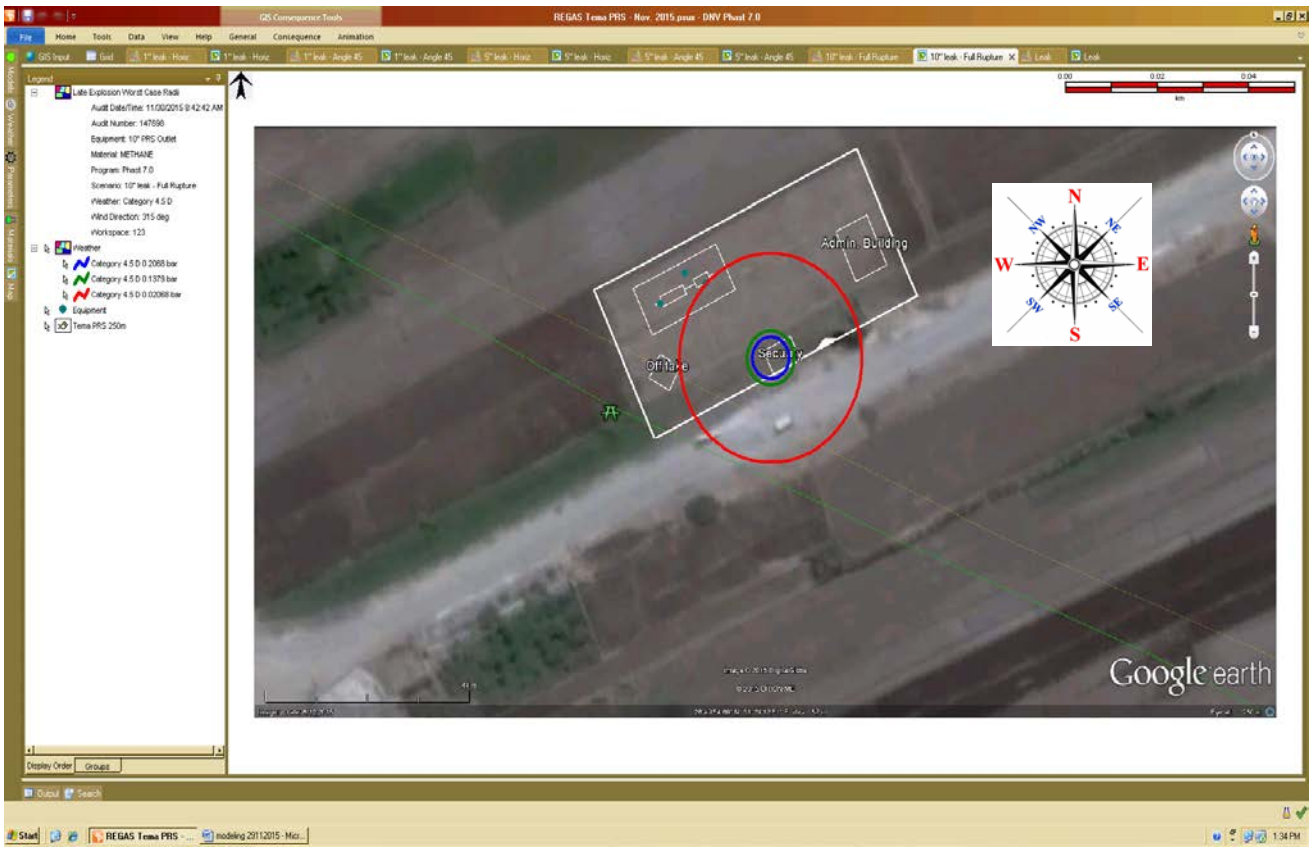


Figure (47) Late Explosion Overpressure Waves (10" Outlet Pipeline Full Rupture)

- The previous figure show that if there is a gas release from 10" pipeline full rupture and late ignited, this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 39.88 meters radius.
- The 0.137 bar overpressure waves will extend about 23.31 meters radius.
- The 0.206 bar overpressure waves will extend about 15.15 meters radius.

The modeling show that the value of 0.020 bar will extended outside the PRS fence from SE side with a distance of 26 m covering the security office and reaching the road, and limited inside the boundary from NE, NW & SW sides.

The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary covering the security office.

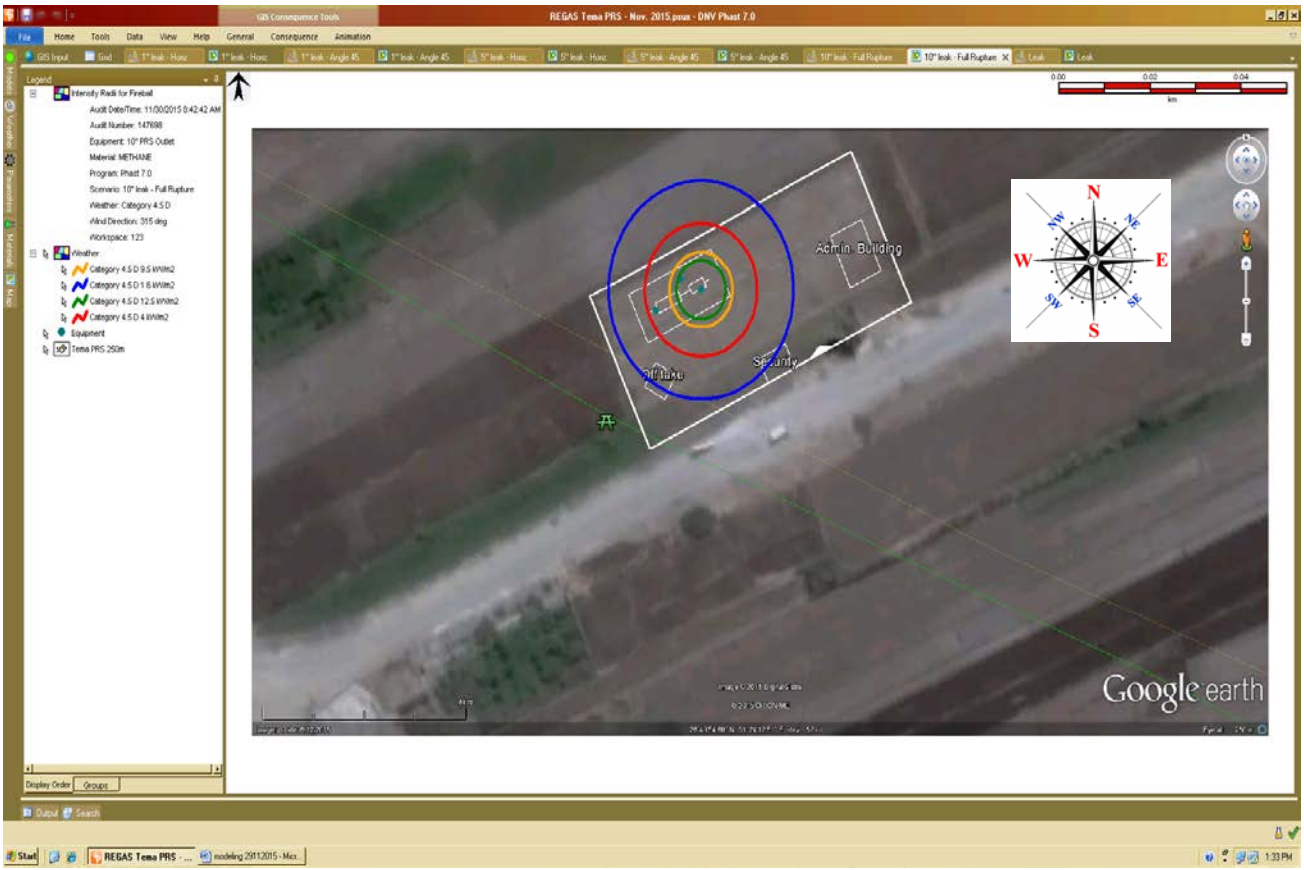


Figure (48) Heat Radiation Contours from Fireball (10" Outlet Pipeline Full Rupture)

- The previous figure show that if there is a gas release from 10" pipeline full rupture and ignited forming fireball this will gives a heat radiation with different values and contours and will extended in four dimensions.
- The 9.5 kW/m^2 heat radiation contours extend about 6.92 meters radius.
- The 12.5 kW/m^2 heat radiation contours extend about 5.42 meters radius.

The modeling show that the heat radiation value (9.5 kW/m^2 and 12.5 kW/m^2) will be limited inside the PRS boundary.

3.0- Pressure Reduction Station Odorant Tank (Spotleak)

The following table no. (26) Show 1" hole leak form odorant Modeling:

Table (26) Dispersion Modeling for Odorant Tank

Gas Release			
Wind Category	**Flammability Limits**	**Distance (m)**	**Height (m)**
4.5 D	UFL	21.72	0.34
	LFL	27.74	0.46
	50 % LFL	38.38	0.72

Jet Fire					
Wind Category	**Flame Length (m)**	**Heat Radiation (kW/m^2)**	**Distance Downwind (m)**	**Distance Crosswind (m)**	**Lethality Level (%)**
4.5 D	17.81	1.6	33.97	33.97	0
		4	21.62	21.62	0
		9.5	14.82	14.29	0
		12.5	13.67	12.45	20% /60 sec.
		25	11.32	8.40	80.34
		37.5	9.98	6.29	98.74

Explosion Overpressure					
Wind Category	**Pressure Value (bar)**	**Over Pressure Radius (m)**		**Overpressure Waves Effect / Damage**	
		Early	**Late**		
4.5 D	0.020	N/D	70.09	**0.021 bar**	*Probability of serious damage beyond this point = 0.05 - 10 % glass broken*
	0.137	N/D	40.38	**0.137 bar**	*Some severe injuries, death unlikely*
	0.206	N/D	38.03	**0.206 bar**	*Steel frame buildings distorted / pulled from foundation*

Figure (49) Vapor Cloud (UFL/LFL) Side View Graph (Odorant leak)

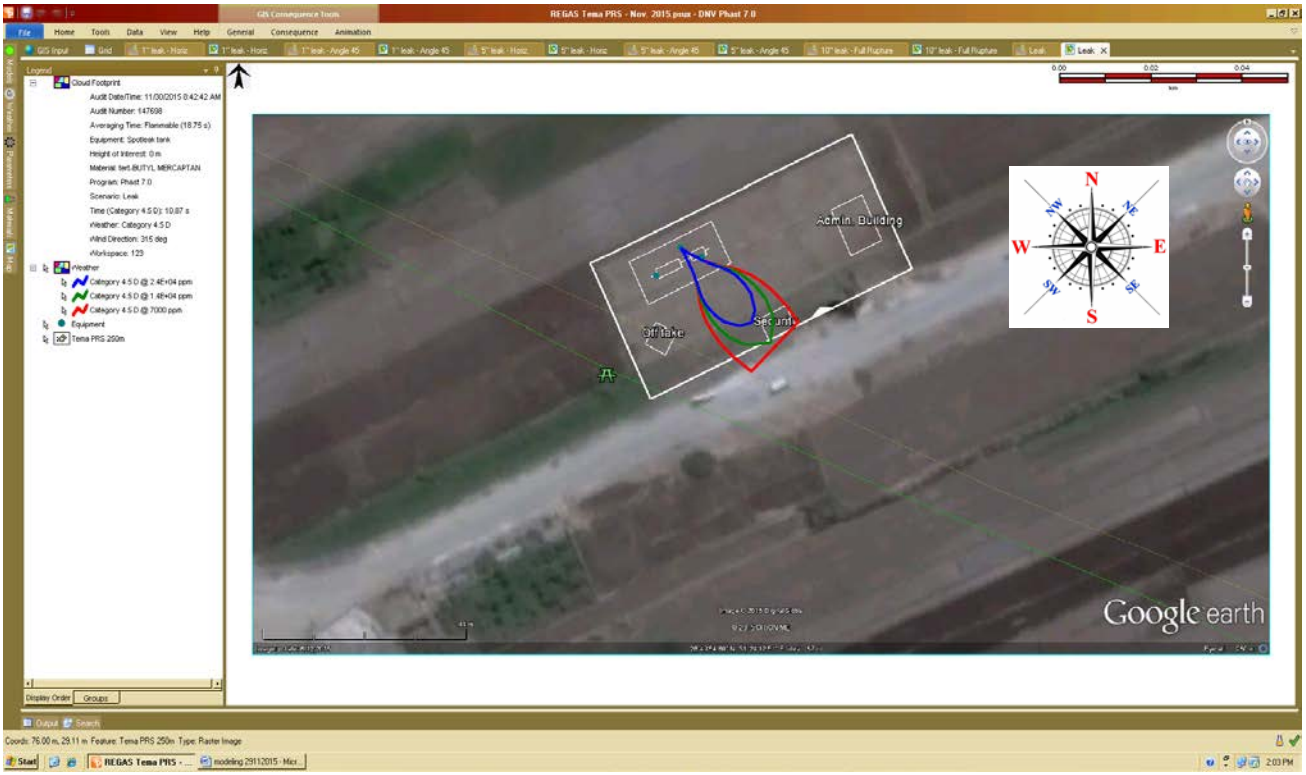


Figure (50) Vapor Cloud (UFL/LFL) Footprint on Site Map (Odorant leak)

- The previous figures show that if there is a leak from odorant container without ignition, the flammable vapors will reach a distance more than 39 m downwind and from 0 to 0.72 m height (the vapors heavier than air).

- The UFL (2.1E+04 ppm) will reach a distance of about 21.72 m downwind and the cloud large width will be 0.34 m crosswind at a distance of 14.80 m from the source.

- The LFL (1.4E+04 ppm) will reach a distance of about 27.74 m downwind and the cloud large width will be 0.46 m crosswind at a distance of 20 m from the source.

- The 50 % LFL (7000 ppm) will reach a distance of about 38.38 m downwind and the large width will be 0.72 m crosswind at a distance of 24.40 m from the source.

The modeling show that the gas cloud effects will be limited inside the PRS boundary but reaching the security office downwind (SE side).

Consideration should be taken when deal with liquid, vapors and smokes according to the MSDS for the material.

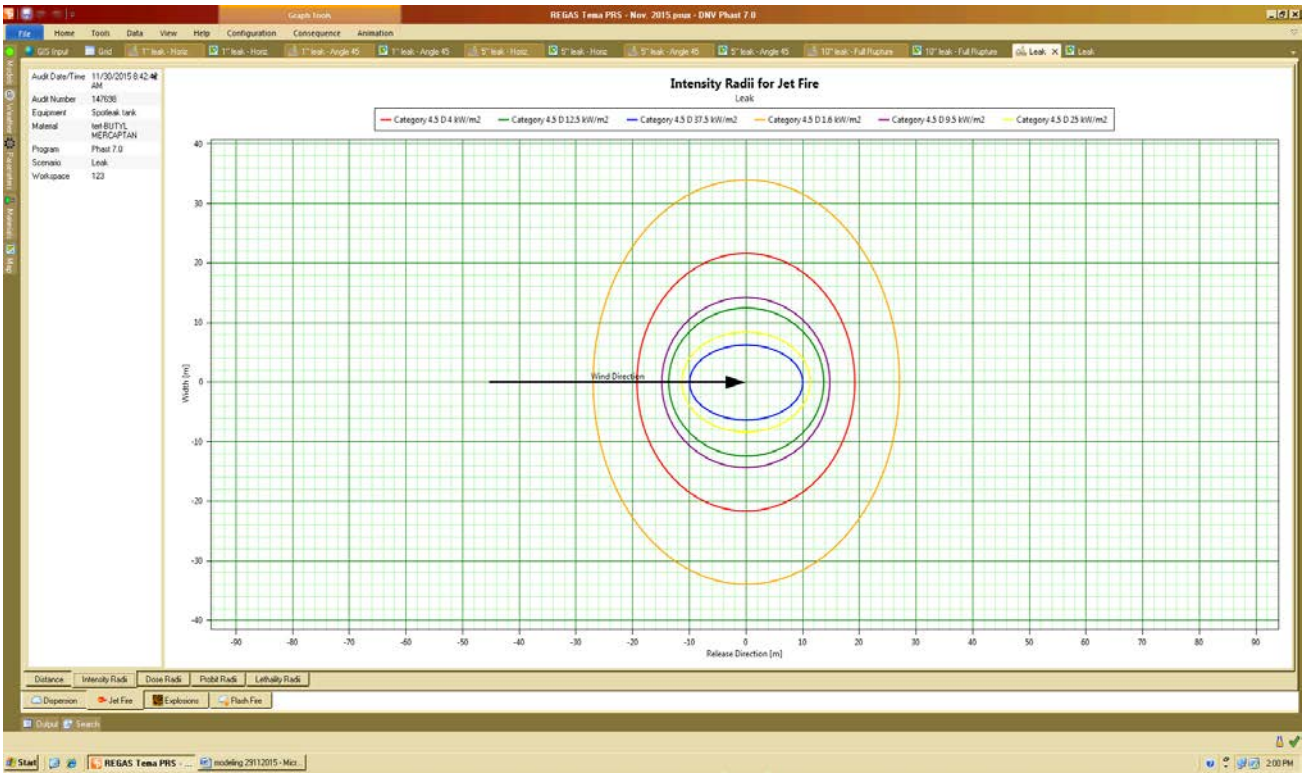


Figure (51) Heat Radiation Contours - Jet Fire Graph (Odorant Leak)

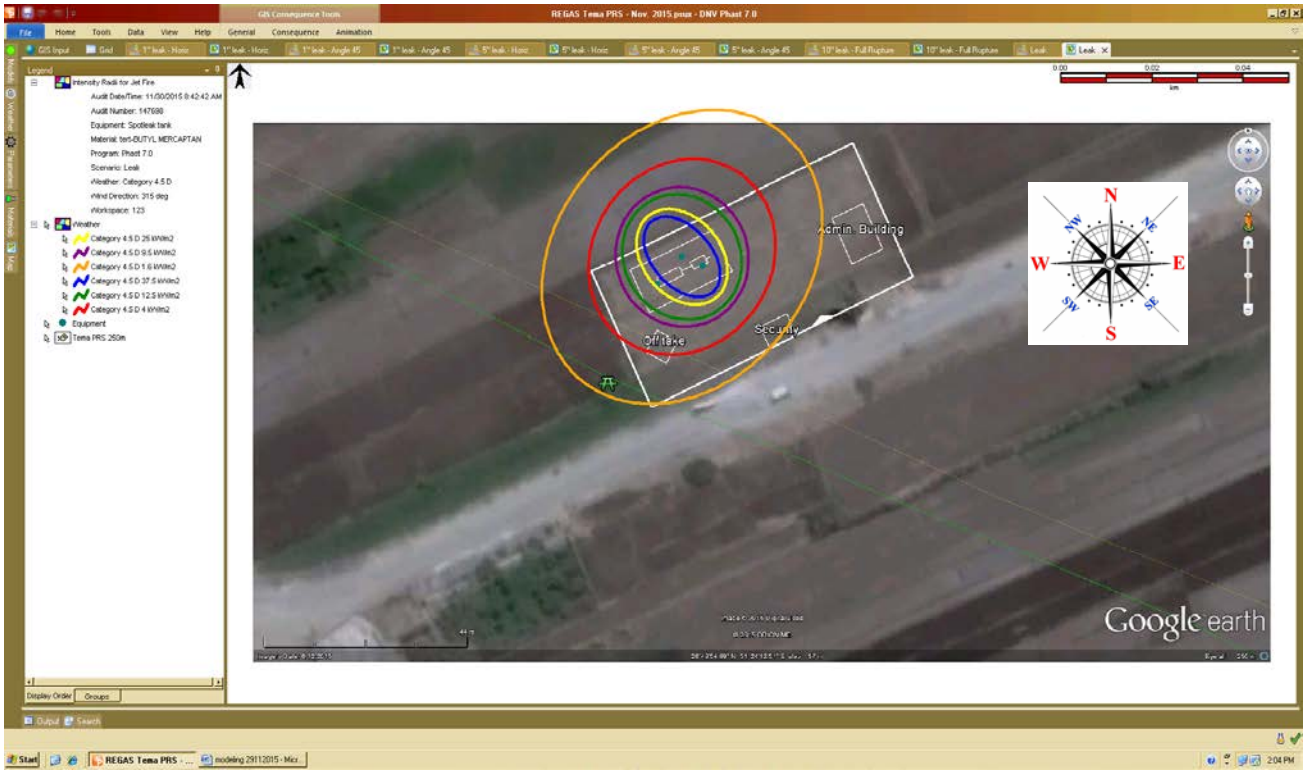


Figure (52) Heat Radiation Contours - Jet Fire on Site (Odorant Leak)

- The previous figure show that if there is a leak from the odorant tank and ignited, the expected flame length is about 17.81 meters downwind.
- The 9.5 kW/m^2 heat radiation contours extend about 14.82 meters downwind and 14.29 meters crosswind.
- The 12.5 kW/m^2 heat radiation contours extend about 13.67 meters downwind and 12.45 meters crosswind.
- The 25 kW/m^2 heat radiation contours extend about 11.32 meters downwind and 8.40 meters crosswind.
- The 37.5 kW/m^2 heat radiation contours extend about 9.98 meters downwind and 6.29 meters crosswind.

The modeling show that the heat radiation effects will be limited inside the PRS boundary from three sides (NE / SE / SW), but will extended beyond the NW fence with some of 5 to 10 meters (upwind).

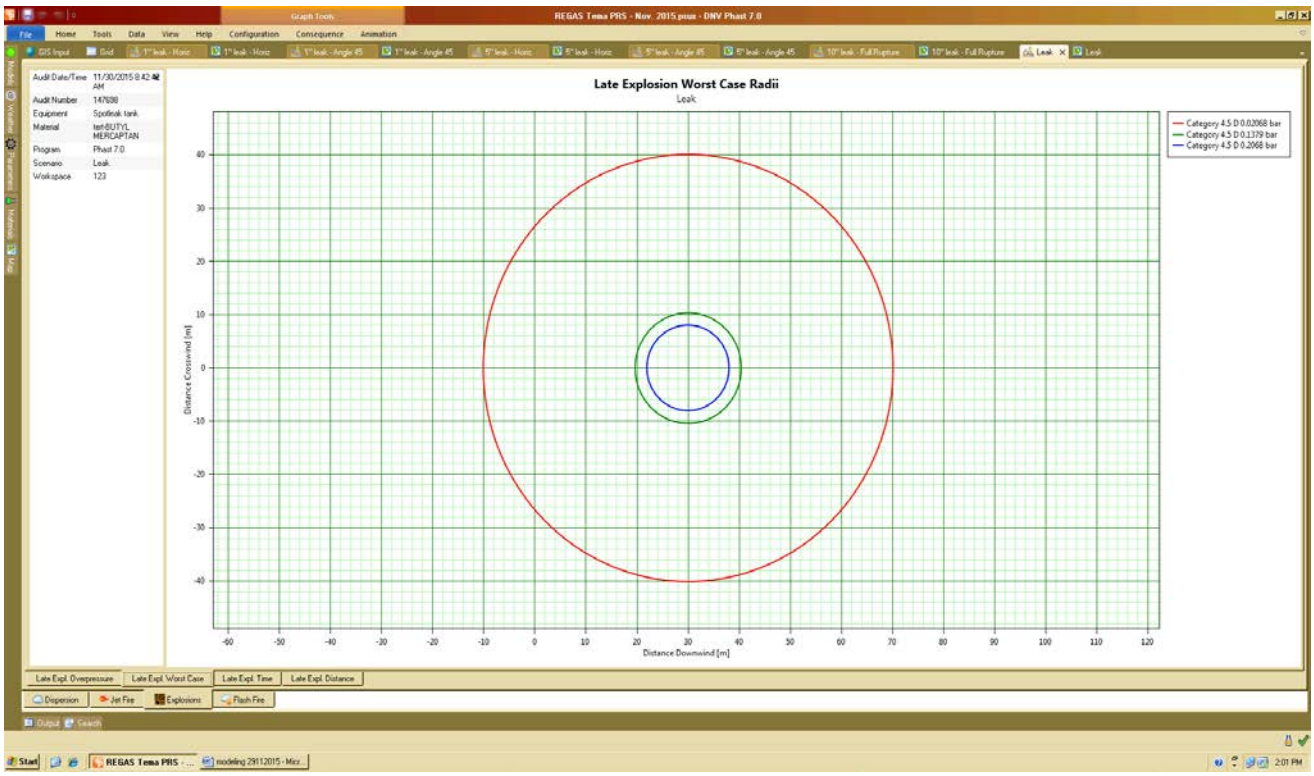


Figure (53) Late Explosion Overpressure Waves Graph (Odorant Leak)

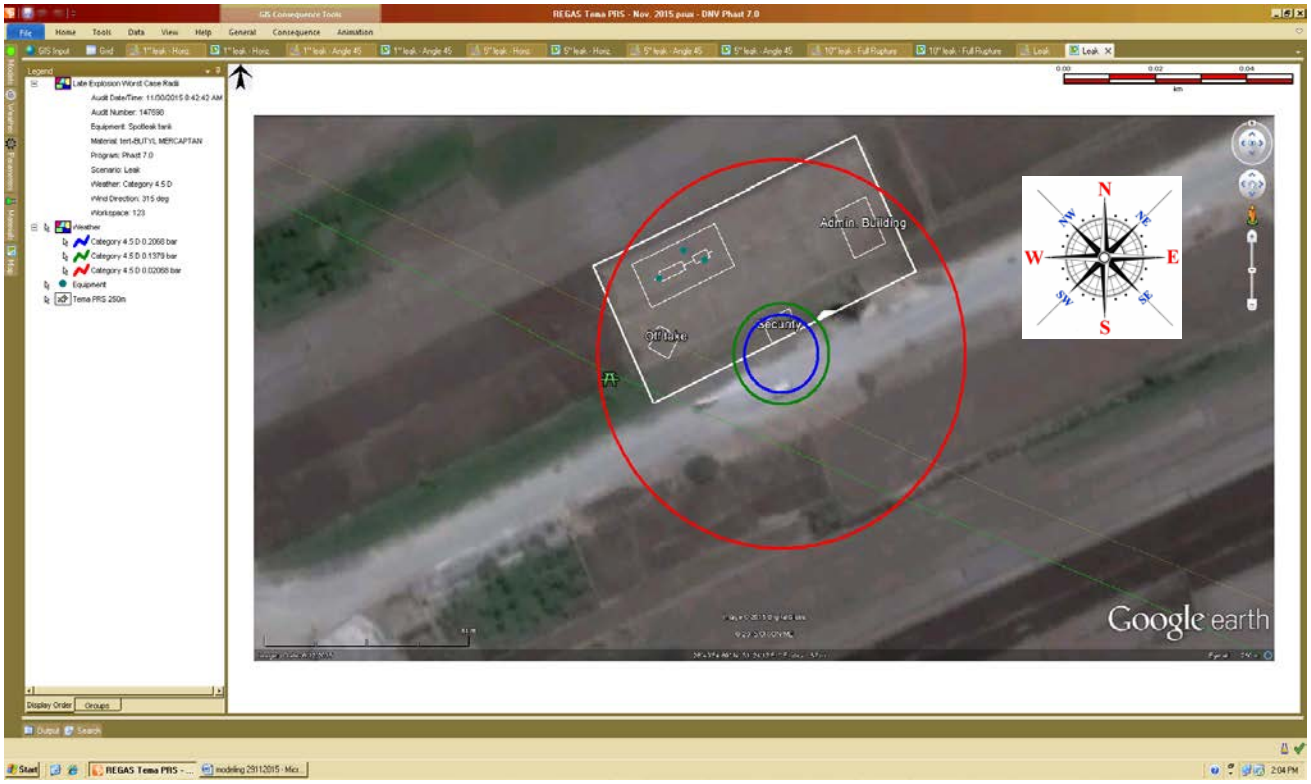


Figure (54) Late Explosion Overpressure Waves on Site (Odorant Leak)

- The previous figure show that if there is a leak from the odorant tank and late ignited, this will give an explosion with different values of overpressure waves.
- The 0.020 bar overpressure waves will extend about 70.09 meters radius.
- The 0.137 bar overpressure waves will extend about 40.38 meters radius.
- The 0.206 bar overpressure waves will extend about 38.38 meters radius.

The modeling show that the value of 0.137 bar and 0.206 bar will be extended the PRS SE fence affecting the security building and reaching the road at a distance of 12 and 10 m.

The value of 0.020 bar will extend outside with a distances of about 5 m NE, 9 m SW, 41 m SE and 6 m NW.

Individual Risk Evaluation

- **Risk Calculation**

All identified hazards should be subject to an evaluation for risk potential. This means analyzing the hazard for its probability to actually progress to loss event, as well as likely consequences of this event.

There are four steps to calculate risk which determined as follows:

1- *Identify failure frequency (International Data Base)*

2- *Calculating the frequency against control measures at site by using Event Tree Analysis "ETA".*

3- *Identify scenarios probability.*

4- *Calculated risk to people regarding to the vulnerability of life loses.*

Basically, risk will be calculated as presented in the following equation:

Risk to people (Individual Risk – IR) =

Total Risk (Σ Frequency of fire/explosion) x Occupancy x Vulnerability

Where:

- *Total risk* — *Is the sum of contributions from all hazards exposed to (fire / explosion).*
- *Occupancy* — *Is the proportion of time exposed to work hazards. (Expected that x man the most exposed person to fire/explosion hazards on site. He works 8 hours shift/day)*
- *Vulnerability* — *Is the probability that exposure to the hazard will result in fatality.*

As shown in table (5) – (Page: 37) *the vulnerability of people to heat radiation starting from 12 kW/m^2 will lead to fatality accident for 60 sec. Exposure.* The modeling of the different scenarios show that the heat radiation of 12.5 kW/m^2 that would be a result from release scenarios for

all sizes of crack and according to the space size for the PRS, all of the sequence will be calculated for three values, and will be classified to small, medium and large release.

Calculating frequencies needs a very comprehensive calculations which needs a lot of data collecting related to failure of equipment's and accident reporting with detailed investigation to know the failure frequency rates in order to calculate risks from scenarios.

In this study it decided that to use an international data bank for major hazardous incident data.

The following table (27) show frequency for each failure can be raised in pressure reduction station operations:

Table (27) Failure Frequency for Each Scenario

Scenario	Release Size	Failure Cause	Failure Rate
Gas Release from 1" / 4" Pipeline	***Small***		
Gas Release from 1" / 10" Pipeline		Internal Corrosion	*1.19E-05*
		External Corrosion	*3.55E-06*
		Maintenance Error	*2.28E-05*
		Corrosive Liquid or Gas	*4.84E-04*
		Total	*5.22E-04*
Gas Release from 2" / 4" Pipeline	***Medium***		
Gas Release from 5" / 10" Pipeline		**Failure Cause**	**Failure Rate**
		Internal Corrosion	*2.71E-05*
		External Corrosion	*8.24E-06*
		Erosion	*4.85E-04*
		Total	*5.20E-04*
Gas Release from 4" Pipeline Full Rupture	***Large***		
Gas Release from 10" Pipeline Full Rupture		**Failure Cause**	**Failure Rate**
		Internal Corrosion	*5.53E-06*
		External Corrosion	*1.61E-06*
		Weld Crack	*4.34E-06*
		Earthquake	*1.33E-07*
		Total	*1.16E-05*
Spotleak (Odorant Tank)	***Medium***	***As a package***	**Failure Rate**
			1.25E-05

- **Event Tree Analysis**

  An event tree is a graphical way of showing the possible outcomes of a hazardous event, such as a failure of equipment or human error.

  An ETA involves determining the responses of systems and operators to the hazardous event in order to determine all possible alternative outcomes.

  The result of the ETA is a series of scenarios arising from different sets of failures or errors.

  These scenarios describe the possible accident outcomes in terms of the sequence of events (successes or failures of safety functions) that follow the initial hazardous event.

  Event trees shall be used to identify the various escalation paths that can occur in the process. After these escalation paths are identified, the specific combinations of failures that can lead to defined outcomes can then be determined.

  This allows identification of additional barriers to reduce the likelihood of such escalation.

  The results of an ETA are the event tree models and the safety system successes or failures that lead to each defined outcome.

  Accident sequences represents in an event tree represent logical and combinations of events; thus, these sequences can be put into the form of a fault tree model for further qualitative analysis.

  These results may be used to identify design and procedural weaknesses, and normally to provide recommendations for reducing the likelihood and/or consequences of the analyzed potential accidents.

  Using ETA requires knowledge of potential initiating events (that is, equipment failures or system upsets that can potentially cause an accident), and knowledge of safety system functions or emergency procedures that potentially mitigate the effects of each initiating event.

The equipment failures, system upsets and safety system functions shall be extracted from the likelihood data presented before.

In the case of hydrocarbon release, the event tree first branch is typically represents "Early Ignition". These events are represented in the risk analysis as jet fire events.

This is because sufficient time is unlikely to elapse before ignition for a gas/air mixture to accumulate and cause either a flash fire or a gas hazard.

Subsequent branches for these events represent gas detection, fire detection, inventory isolation (or ESD) or deluge activation.

Delayed ignitions are typically represented by the fifth branch event. This is because, in the time taken for an ignition to occur, sufficient time is more likely to elapse for gas detection and inventory isolation.

The scenario development shall be performed for the following cases**:**

- Without any control measures
- With control measures

The event tree analysis outcomes can be classified into three main categories as follows:

"Limited Consequence"	*Indicates that the release has been detected and the inventory source has been isolated automatically.*
"Controlled Consequence"	*Indicates that the release has been detected but the source has not been isolated automatically. [Needs human intervention].*
"Escalated Consequence"	*Indicates that the release has not been detected and consequently the source has not been isolated.*

The event trees analysis for each scenario are presented in the below pages:

Table (28) PRS Inlet 4" and Outleut 10" Pipeline Scenrios (Pin Hole Crack – 1" Release) – Event Tree Analysis

Release of Flammable Materials (1)	Immediate Ignition (2)	Fire Detection (3)	ESD System (3)	Fire Protec. (3)	Delayed Ignition (2)	Outcomes	Frequency
5.22E-04	**0.2**	**0.6**	**0.978**	**0.97**	**0.06**		
5.22E-04	Yes 0.2	Yes 0.6	Yes 0.978	Yes 0.97	Yes 0.06	Controled Jet fire	----------
					No 0.94	Escaleted release	***3.93E-04***
				No 0.03		Not controled jet fire	***3.13E-06***
			No 0.022			Large release	***9.18E-06***
		No 0.4				Escaleted jet fire	***4.18E-05***
	No 0.8					Limited release	----------
						TOTAL	***7.0E-05***

(1) Refere to QRA Study Page 129.
(2) Ref. Handbook Failure Frequencies 2009.
(3) Ref. OGP – Report No. 434 – A1 / 2010.

Table (29) PRS Inlet 4" and Outleut 10" Pipeline Scenrios (Half Dia. Release) – Event Tree Analysis

Release of Flammable Materials (1)	Immediate Ignition (2)	Fire Detection (3)	ESD System (3)	Fire Protec. (3)	Delayed Ignition (2)	Outcomes	Frequency
5.22E-04	**0.2**	**0.6**	**0.978**	**0.97**	**0.06**		
5.2E-04	Yes 0.2	Yes 0.6	Yes 0.978	Yes 0.97	Yes 0.06	Controlled jet fire	----------
					No 0.94	Escaleted release	***3.91E-04***
				No 0.03		Large jet fire	***3.12E-06***
			No 0.022			Large release	***9.15E-06***
		No 0.4				Escaleted jet fire	***4.16E-05***
	No 0.8					Limited release	----------
						TOTAL	***2.94E-04***

(1) Refere to QRA Study Page 129.
(2) Ref. Handbook Failure Frequencies 2009.
(3) Ref. OGP – Report No. 434 – A1 / 2010.

Table (30) PRS Inlet 4" and Outleut 10" Pipeline Scenrios (Full Rupture Release) – Event Tree Analysis

Release of Flammable Materials (1)	Immediate Ignition (2)	Fire Detection (3)	ESD System (3)	Fire Protec. (3)	Delayed Ignition (2)	Outcomes	Frequency
1.16E-05	**0.2**	**0.6**	**0.978**	**0.97**	**0.06**		
1.16E-05	Yes 0.2	Yes 0.6		Yes 0.97		Controlled jet fire	----------
				No 0.03		Large jet fire	***6.96E-08***
		No 0.4				Escaleted jet fire	***9.28E-07***
	No 0.8		Yes 0.978			Limited release	----------
			No 0.022			Large release	***2.04E-07***
					Yes 0.06	Escaleted jet fire	***5.56E-07***
					No 0.94	Escaleted release	***8.72E-06***
						TOTAL	***1.55E-06***

(1) Refere to QRA Study Page 129.
(2) Ref. Handbook Failure Frequencies 2009.
(3) Ref. OGP – Report No. 434 – A1 / 2010.

Table (31) Odorant Tank Release – Event Tree Analysis

Release of Flammable Materials (1)	Immediate Ignition (2)	Fire Detection (3)	ESD System (3)	Fire Protec. (3)	Delayed Ignition (2)	Outcomes	Frequency
1.25E-05	**0.2**	**0.6**	**0.978**	**0.97**	**0.06**		
1.25E-05	Yes 0.2	Yes 0.6	Yes 0.978	Yes 0.97	Yes 0.06	Controlled fire	----------
					No 0.94	Escaleted leak	*9.4E-06*
				No 0.03		Large fire	*7.5E-08*
			No 0.022			Large leak	*2.2E-07*
		No 0.4				Escaleted fire	*1.0E-06*
	No 0.8					Limited leak	----------
					Yes 0.06	Escaleted fire	*6.0E-07*
					No 0.94	Escaleted leak	*9.4E-06*
						TOTAL	***2.40E-05***

(1) Refere to QRA Study Page 129.
(2) Ref. Handbook Failure Frequencies 2009.
(3) Ref. OGP – Report No. 434 – A1 / 2010.

The following table (32) show the total frequency for each scenario from ETA - Tables (28 to 31):

Table (32) Total Frequencies for Each Scenario

Source of Release	Total Frequency (ETA)
Gas Release from 1" / 4" Pipeline	**7.0E-05**
Gas Release from 1" / 10" Pipeline	
Gas Release from 2" / 4" Pipeline	**2.94E-04**
Gas Release from 5" / 10" Pipeline	
Gas Release from 4" Pipeline Full Rupture	**1.55E-06**
Gas Release from 10" Pipeline Full Rupture	
Odorant Tank 1" Leak	**2.40E-05**

The modeling show that the most effective scenarios on ReGas employees and public is the heat radiations from jet fire in case of half and full rupture of 4" & 10" pipelines (Inlet/Outlet) which effects employees, and full rupture of 4" (Inlet) which effects the public, so the risk calculation will depend on total risk from these scenarios.

As per equation at page (109):

Risk to people (Individual Risk – IR) =
Total Risk (Σ Frequency of fire/explosion) x Occupancy x Vulnerability

Where:

- Total risk - is the sum of contributions from all hazards exposed to (fire / explosion).

(Scenarios from Table-36)

- Occupancy - is the proportion of time exposed to work hazards. (Expected that x man the most exposed person to fire/explosion hazards on site. He works 8 hours shift/day).

(As per ReGas data Tema PRS Occupancy is 3 persons 24 hour until)

- Vulnerability - is the probability that exposure to the hazard will result in fatality.

(Reference: Report No./DNV Reg. No.: 2013-4091/1/17 TLT 29-6 – Rev. 1)

The following table (33) show the Individual Risk (IR) calculation for the workers and the public:

Table (33) Individual Risk (IR) Calculation

Source of Event	Frequency 1	Heat Radiation kW/m^2 & Overpressure	Vulnerability (Indoor) 2	Time Exposed 3	IR = 1 x 2 x 3
Gas Release from 1" / 4" Pipeline	7.0E-05	Jet Fire 12.5	Not Reached	N/R	----------
Gas Release from 1" / 10" Pipeline					
Gas Release from 2" / 4" Pipeline	2.94E-04	Jet Fire 12.5	0.1	3.0 3 Person	***8.82E-05***
Gas Release from 5" / 10" Pipeline		Explosion 0.137	0.3	1.0 1 Person	***8.82E-06***
Gas Release from 4" Pipeline Full Rupture	1.55E-06	Jet Fire 12.5	0.1	3.0 3 Person	***4.65E-07***
Gas Release from 10" Pipeline Full Rupture		Explosion 0.137	0.3	1.0 1 Person	***4.65E-08***
Odorant Tank 1" Leak	2.40E-05	Explosion 0.137	0.3	1.0 1 Person	***7.2E-07***
				TOTAL Risk for Workers	***9.82E-05***

Source of Event	Frequency 1	Heat Radiation kW/m^2 & Overpressure	Vulnerability (Indoor) 2	Time Exposed 3	IR = 1 x 2 x 3
Gas Release from 2" / 4" Pipeline	2.94E-04	Jet Fire 12.5 Explosion 0.137	0.7 (Outdoor) 0.1 (Outdoor)	0.033	***6.79E-06*** ***9.70E-07***
Gas Release from 5" / 10" Pipeline		Jet Fire 12.5	0.7 (Outdoor)	0.033	***6.79E-06***
Gas Release from 4" Pipeline Full Rupture	1.55E-06	Jet Fire 12.5	0.7 (Outdoor)	0.033	***3.58E-08***
Gas Release from 10" Pipeline Full Rupture					
Odorant Tank 1" Leak	2.40E-05	Explosion 0.137	0.1 (Outdoor)	0.033	***7.92E-08***
				TOTAL Risk for Public	***1.47E-05***

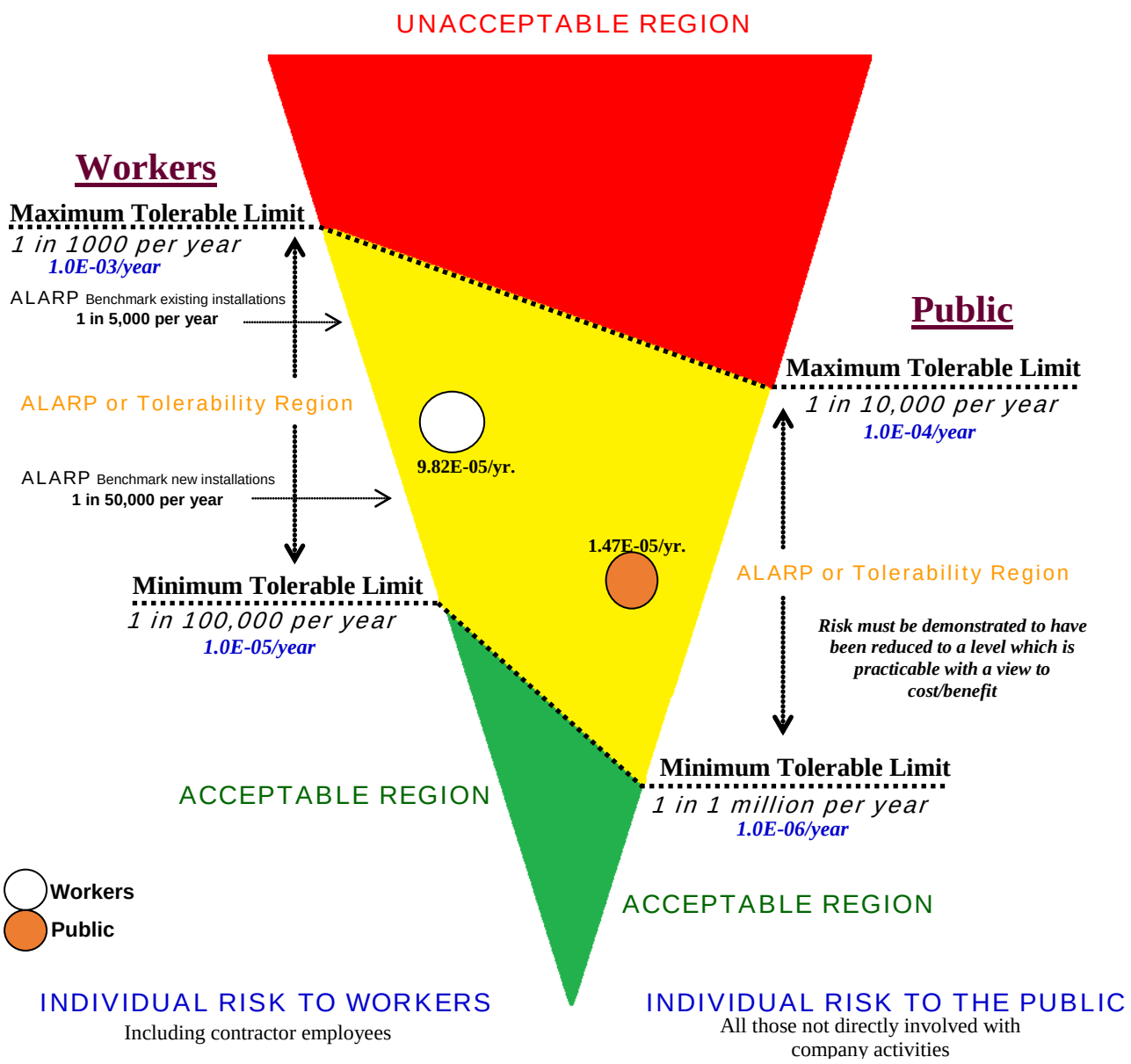


Figure (55) Evaluation of Individual Risk

The level of Individual Risk to the most exposed worker at Tema PRS, based on the risk tolerability criterion used, is ALARP.

The level of Individual Risk to the exposed Public at Tema PRS area, based on the risk tolerability criterion used, is ALARP.

Conclusion

As per results from modeling the consequences of each scenario the following table summarize the study, and as follows:

Event	Scenario	Effects
Pin hole (1") gas release 0º 4" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects will be limited inside the PRS area.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation value (9.5 kW/m^2 and 12.5 kW/m^2) effects will be limited inside the PRS boundary.* *The heat radiation value (4 kW/m^2) effects will be near the security office from the SW side.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extend outside the PRS fence with a distances of about 45 m NW, 48 SW and 29 m SE reaching the security office and extending the road.* *The value of 0.137 bar and 0.206 bar will be limited inside from NE, SW and SE, but extended from 2 to 5 meters out from NW side.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the 0.020 bar will reach a distance of 32 m SE covering the security office, at NE fence covering the office building, 48 m NW and 40 SW.* *The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary from NE, SE and NW, with extending of about 2 m for 0.137 bar from NW side.*
Pin hole (1") gas release 45º 4" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects will be limited inside the PRS area.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation value (9.5 kW/m^2 & 12.5 kW/m^2) effects will be limited inside the PRS boundary.*

Event	Scenario	Effects
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extend outside the PRS fence with a distances of about 47 m NW, 38 SW and 30 m SE and reaching the security office and the road direction.* *The value of 0.137 bar and 0.206 bar will be limited inside from NE and SE, but extended from 2 to 5 meters out from NW side.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	N/D
Half Rupture (2") gas release 0º 4" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects will be limited inside the PRS area.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation value of (9.5, 12.5, 25 & 37.5 kW/m^2) effects will extended the SE fence downwind, effecting the security office and the public road with different distances as per table (18).*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extend outside PRS fence with a distances of about 47 m NW, 29.5 m NE and 39.5 SE reaching the security office and the road.* *The value of 0.137 bar and 0.206 bar will be limited inside from NE, SW and SE, but extended from 2 & 4 meters outside from NW side.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extended the PRS NW fence to a distance of 15 m, SW fence 22 m and SE fence 40 m covering the security office the road.* *The value of 0.137 bar and 0.206 bar will be extended outside the PRS from the SE side to a distance of 10 & 12 m.*

Event	Scenario	Effects
Half Rupture (2") gas release 45º 4" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects will be limited inside the PRS boundary.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation of 9.5 kW/m^2 will effects the security office and extended the PRS SE fence with about 10 m reaching the road.* *The heat radiation of 12.5 kW/m^2 will be near the SW side of the security office and will extended the PRS SE fence with about 5 m.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extended outside the PRS fences with a distances of about 42 m NW, 38 SW and 29 m SE covering the security office and the road. This value will limited inside the PRS NE fence (at fence) and covering the office building.* *The value of 0.137 bar and 0.206 bar will be limited inside from NE, SW and SE, but extended from 5 & 2 meters outside from NW side.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extend outside the PRS fences with a distance of about 25 m SW, 24 NW and 29 m SE effecting the security office and the road. This value will reach the administration building at the NE side, but not extending the fence.* *The value of 0.137 bar and 0.206 bar will be limited inside PRS boundary and covering the off-take point.*
Full Rupture (4") gas release 4" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects (LFL and 50 % LFL) will extend outside the PRS boundary about 76.92 m.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation values (9.5 & 12.5 kW/m^2) will cover the security office and administration building down & crosswind, and extended outside the PRS SE fence to the road.*

Event	Scenario	Effects
		The heat radiation values of 25 & 37.5 kW/m^2 will cover security office, off-take surface point and extended the PRS SE fence to the road.
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extend outside the PRS fences with a distance of about 42 m NW, 36 SW and 27 m SE covering the security office and reaching the road, and at NE fence covering the office building.* *The value of 0.137 bar and 0.206 bar will be limited inside PRS boundary from NE & SE, but extended from 5 & 2 meters out from NW side and 1 m SW effecting the off-take surface.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extended outside the PRS fence SE with a distance of 48 m effecting the security office and the road.* *The overpressure wave values of 0.137 bar and 0.206 bar will be outside the PRS boundary (SE fence) with a distance from 20 to 22 m downwind.*
	Heat radiation / Fireball 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation value of:* *9.5 kW/m^2 will be limited from NE & SE and extended 7 m SW & 10 m NW.* *12.5 kW/m^2 will be limited from NE & SE and extended 3 m SW & 9m NW.* *25 kW/m^2 will be limited from NE, SE & SW and extended 1 m NW.* *37.5 kW/m^2 will be limited inside the PRS boundary.*
Pin hole (1") gas release 0^o 10" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects will be limited inside the PRS boundary.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation value (9.5 kW/m^2 & 12.5 kW/m^2) effects will be limited inside the PRS boundary.*

Event	Scenario	Effects
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extend outside the PRS boundary with a distances of about 8 m SE effecting the security office, 7 m SW and 22 m NW.* *The value of 0.137 bar and 0.206 bar will be limited inside PRS boundary.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	N/D
Pin hole (1") gas release 45º 10" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects will be limited inside the PRS area.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation value (9.5 kW/m^2 & 12.5 kW/m^2) effects will be limited inside the PRS boundary.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extend outside the PRS boundary with a distances of about 22 m NW, 8 m SW and 9 SE effecting the security office and reaching the road, also will be very close to the administration building from the NE side.* *The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	N/D
Half Rupture (5") gas release 0º 10" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud (UFL & LFL) will be limited inside the PRS boundary and the 50 % LFL may extended outside with about 3 m SE direction.*

Event	Scenario	Effects
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation value of 9.5, 12.5 kW/m^2 will effects the security and administration buildings down and crosswind (NE/SE).* *The values of 25 & 37.5 kW/m^2 effects the security office and extended outside the PRS SE fence to the road.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extended outside the PRS fences with a distance of about 21 m NW, 7 SW and 9 m SE effecting the security office and the road.* *The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extended the PRS fence from SE side with a distance of 14 m reaching the road, and limited inside the boundary from NE, NW & SW sides.* *The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary reaching the security office.*
Half Rupture (5") gas release 45º 10" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects will be limited inside the PRS area.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation value of 9.5 kW/m^2 & 12.5 kW/m^2 will extended outside the PRS fence from the SE side with a distance of 15 & 20 m covering the security office and reaching the road.* *The value of 9.5 kW/m^2 will be close to the administration building from the NE side.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extended outside the PRS fence with a distance of about 21 m NW, 8 m SW*

Event	Scenario	Effects
		and 8 SE effecting the security office and reaching the road. This value will be close to the administration building from the NE side. *The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary.*
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will be limited inside the PRS fence from NE, SW and NW, but extended outside from the SE side covering the security office and reaching the road.* *The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary and may be close to the security office.*
Full Rupture (10") gas release 10" pipeline		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects will be limited inside the PRS boundary for the (LFL & UFL) but may extended outside from SE side with a distance of about 6 m.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation of:* *9.5 kW/m^2 will extend to 40 m SE / 13 m NE / 5 m SW / at fence NW.* *12.5 kW/m^2 will extend to 38 m SE / 10 m NE / 1 m SW.* *25 kW/m^2 will extend to 30 m SE / 2 m NE.* *37.5 kW/m^2 will extend to 25 m SE.* *The heat radiations of 9.5, 12.5 and 25 kW/m^2 will affect the administration and security buildings, reaching the road.* *The heat radiation of 37.5 kW/m^2 will affect the security office and reaching the road, also close to the admin building.*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extended outside the PRS boundary with a distances of about 21 m NW, 8 m SW and 8 SE covering the security office and reach the road. This value will be close to administration building from the NE side.*

Event	Scenario	Effects
		The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary.
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.020 bar will extended outside the PRS fence from SE side with a distance of 26 m covering the security office and reaching the road, and limited inside the boundary from NE, NW & SW sides.* *The value of 0.137 bar and 0.206 bar will be limited inside the PRS boundary covering the security office.*
	Heat radiation / Fireball 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation value (9.5 kW/m^2 and 12.5 kW/m^2) will be limited inside the PRS boundary.*
Odorant tank 1" leak		
	Gas cloud UFL LFL 50 % LFL	*The modeling show that the gas cloud effects will be limited inside the PRS boundary but reaching the security office downwind (SE side).* *Consideration should be taken when deal with liquid, vapors and smokes according to the MSDS for the material.*
	Heat radiation / Jet fire 9.5 kW/m^2 12.5 kW/m^2	*The modeling show that the heat radiation effects will be limited inside the PRS boundary from three sides (NE / SE / SW), but will extended beyond the NW fence with some of 5 to 10 meters (upwind).*
	Early explosion *0.020 bar* *0.137 bar* *0.206 bar*	N/D
	Late explosion *0.020 bar* *0.137 bar* *0.206 bar*	*The modeling show that the value of 0.137 bar and 0.206 bar will be extended the PRS SE fence affecting the security building and reaching the road at a distance of 12 and 10 m.* *The value of 0.020 bar will extend outside with a distances of about 5 m NE, 9 m SW, 41 m SE and 6 m NW.*

The previous table show that there are some potential hazards with heat radiation resulting from jet fire, and explosion overpressure waves in case of gas release and early or late ignited.

These hazards will affect the office and security buildings, also some scenarios will extend over the site boundary like heat radiation of 12.5 kW/m^2 and explosion overpressure waves reaching the main road (Tall Ezzawaky Road) or other PRS sides.

Regarding to the risk calculations the risk to *public which is in ALARP*, and also the risk for the *workers is in ALARP region*, but there are some points need to be considered to maintain the risk tolerability and this will be describe in the study recommendations.

Recommendations

As per results from modeling the consequences of each scenario and risk calculations it is recommended to:

- Ensure that all facility specifications referred to the national and international codes and standards.
- Ensure that the inspection and maintenance plans and programs are according to the manufacturers guidelines to keep all facility parts in a good conditions.
- Ensure that all operation is according to standard operating procedure for the PRS operations and training programs in-place for operators.
- Review the emergency response plan for Sohag Area and prepare a plan for Tema PRS including all scenarios in this study and other needs including:
    - Fire fighting brigades, mutual aids, emergency communications and fire detection / protection systems.
    - Dealing with the external road in case of major fires.
    - First aid including dealing with the odorant according to the MSDS for it, with respect of means of water supply for emergency showers, eye washers and cleaning.
    - Emergency shut-down detailed procedure including shut-off points at the PRS and GASCO main line.
    - Safe exits in building according to the modeling in this study, and also to the PRS from other side beside the designed exit in lay-out provided.
- Provide the site with SCBA "Self-Contained Breathing Apparatus (at least two sets) and arrange training programs for operators.
- Arrange for relocate the security office, according to the modeling consequences, which show that the heat radiations and the explosion overpressure waves will affect this building.
- Ensure that the office and security buildings are designed according to the accepted standard technical specifications.

- Protecting the off-take by a concrete fence with a height of about 3 m from the inlet side, fro protection from heat radiaton and explosion overpressure waves.
- Considering that all electrical equipment, facilities and connections are according to the hazardous area classification for the PRS.
- Ensure that the surface drainage system is suitable for contaminating any odorant spills and rainwater.
- Provide a suitable tool for wind direction (Windsock) to be installed at a suitable place to determine the wind direction.
- Cooperation should be done with the concerned parties before planning for housing projects around the PRS area.