9th Chemical Process Safety Sharing (CPSS)

Facility Siting Study of Ethylene Plant

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IRPC

Contents

Introduction

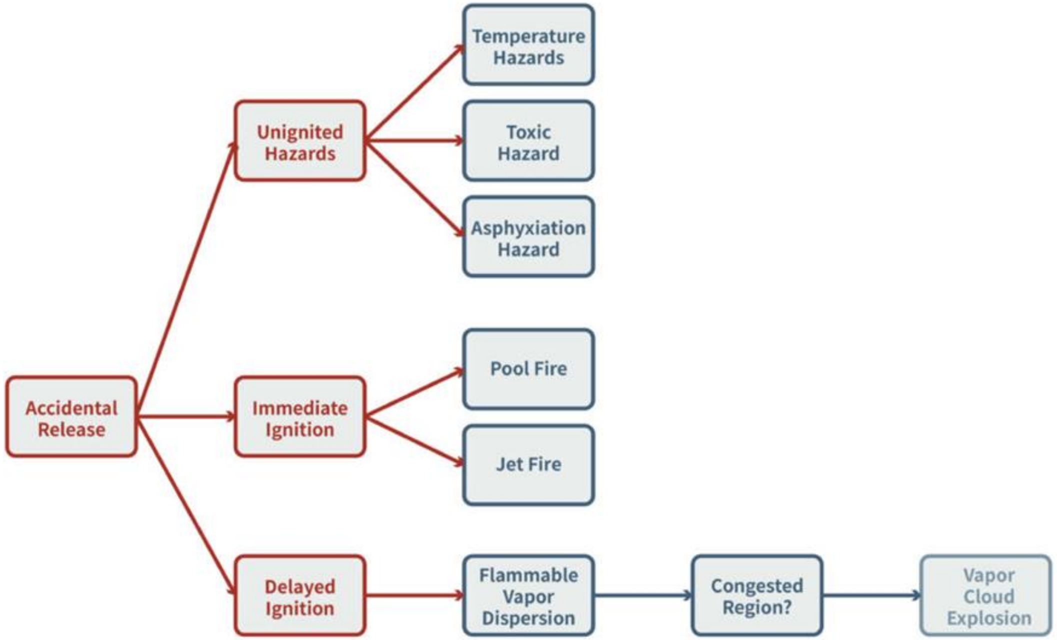
Study Intention

Fire Risk Analysis (FRA) to cover facility siting study posed by the ETP.

To assess the consequences of fires and explosions on the facility in terms of:

- Immediate fatalities
- Damage to structures
- Damage to safety critical systems
- Damage to other hydrocarbon inventory holders

To identify potential hazard protection measures



Study Scope

Scopes and Objectives

To carry out Facility Siting Study or Fire and Explosion Consequence Analysis (consequence-based approach) for all flammable inventories from process units within Ethylene Plant Facilities (ETP).

The facilities comprise of the process units as follows

- ❑ Pyrolysis Gasoline Hydrogeneration Unit (PGH)
- ❑ Butadiene Plant Unit (BD)
- ❑ Tank Farm Area (TF)
- ❑ Propylene Plant Unit (PRP)
- ❑ Furnace Unit (FUR)
- ❑ Compressor Area Unit (COM)
- ❑ Demethanizer Unit(C1)
- ❑ C3 Splitter Unit (C3)

Process units and occupied buildings of interest for the study

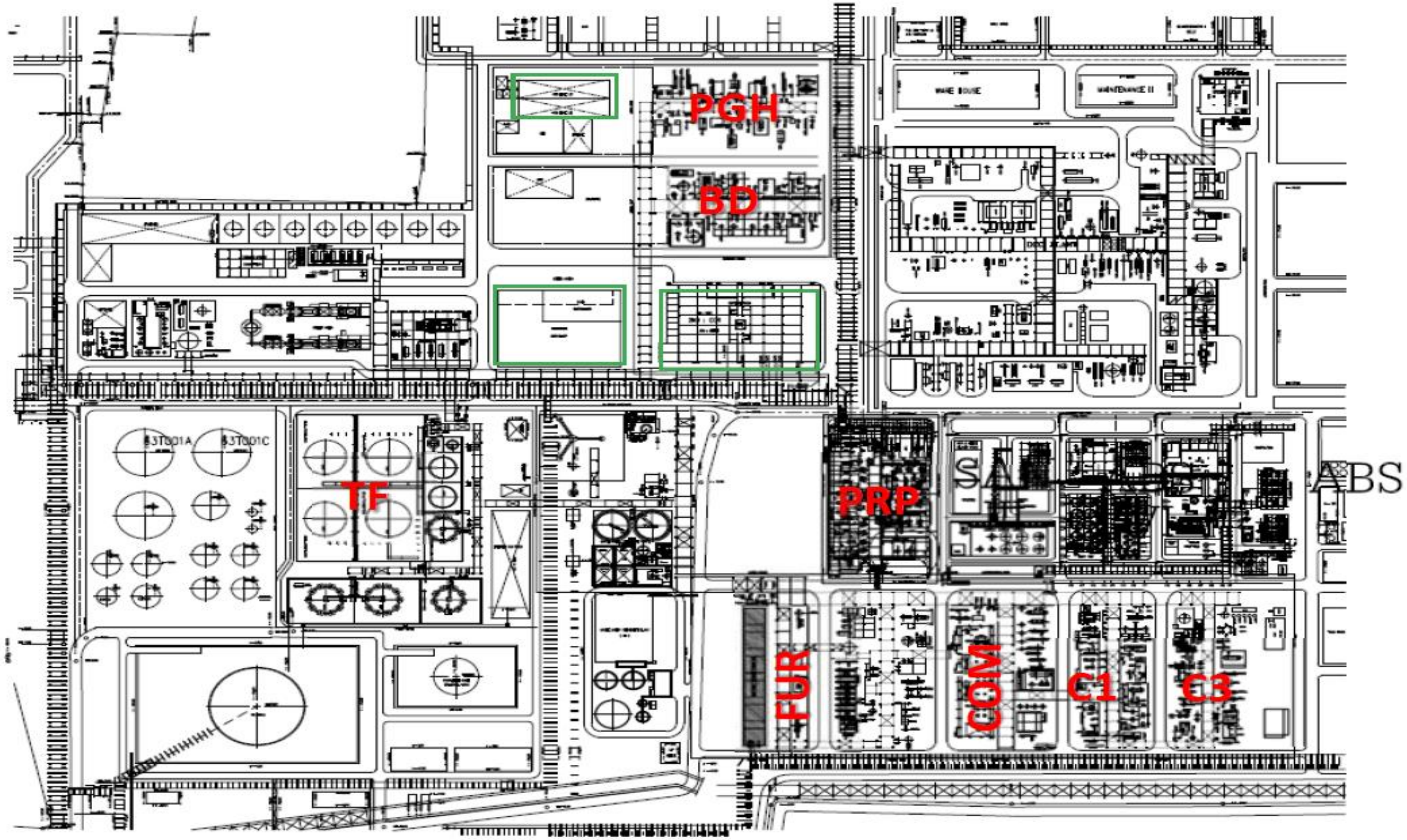


Figure 1.1: Process units of interest for the study.

Study Process

Identify Accident Scenarios and Inventories

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Calculate

- release rates
- fire characteristics
- dispersion characteristics
- explosion characteristics

↓

Assess survivability of target

- impact on people
- impact on piping & structures

Identification of Accident Scenarios

Loss of containment from process equipment releases(Process Hazards), resulting in the following:

- **Jet fires;**
- **Pool fires (i.e., if the release is liquid phase or two-phase);**
- **Vapor Cloud Explosions**
- **Flash fires;**
- **Unignited gas releases**

Fireball | Jet fire | Pool fire | Flash fire / VCE

Effects of Chemical Release (Process Hazards)

- Explosions
  - Overpressure generation & effects
- Fires
  - Momentum (jet) / Low momentum (pool)
  - Thermal radiation effects
- Gas dispersion
  - Dispersion of vapour and flash fires
  - Toxic effects
- Smoke
  - Asphyxiation
  - Visibility

HAZARDOUS EVENT TYPES AND IMPAIRMENT CRITERIA

EVENT TYPES

- ❑ Jet Fires
- ❑ Pool Fire
- ❑ Flash Fires
- ❑ Vapor Cloud Explosion (VCE)

Overpressure (bar)	Effects within Zone
0.02	10% window glass broken
0.05	Window glass damage causing injury
0.1	Repairable damage buildings and house facades
0.35	Heavy damage to building and process equipment

Human Impact Criteria & Explosion Overpressure Impact Criteria

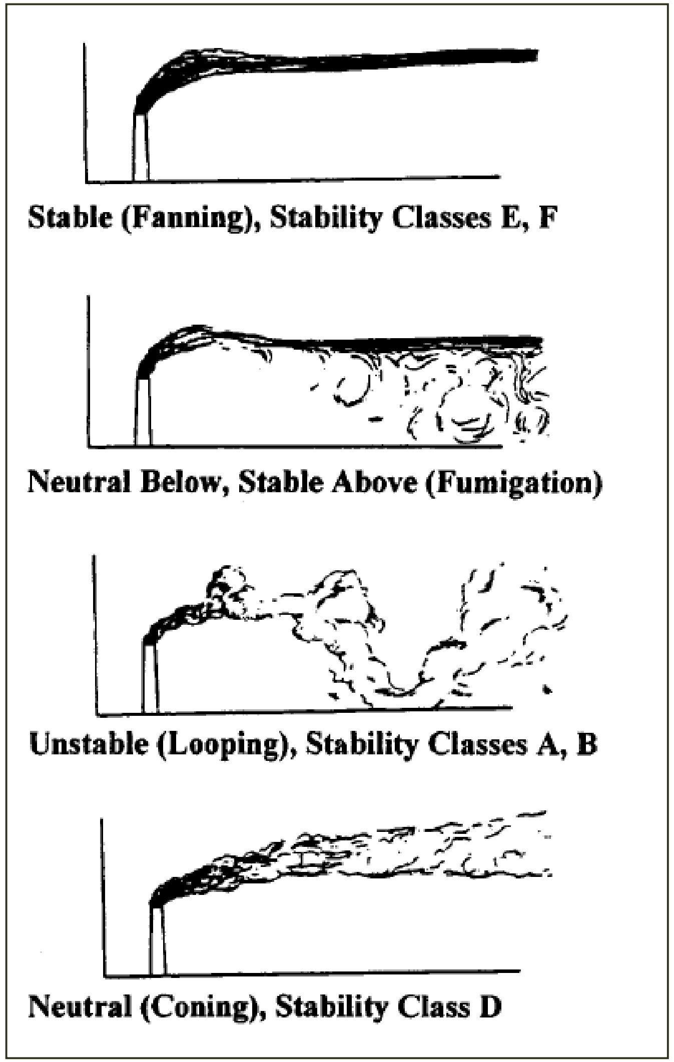
Event Effect	Distances to	Effect within Zone
Flash fire	100 % LFL	Potential fatalities for people in the flammable cloud
Jet fire	4.0 kW/m2	Will cause pain in 15 to 20 seconds and injury after 30 seconds' exposure
	12.5 kW/m2	Extreme pain within 20 s; movement to shelter is instinctive; fatality if escape is not possible. Outdoors: 70% lethality /Indoors: 30% lethality
	37.5 kW/m 2	Immediate fatality (100% lethality)
Overpressure bar (psi)	0.02 (0.3)	10% window glass broken
	0.05 (0.73)	Window glass damage causing injury
	0.1 (1.45)	Repairable damage buildings and house facades
	0.35 (5)	Heavy damage to building and process equipment, 50% lethality for people outdoors, in the open

Modelled Wind Speed & Stability Class

The dispersion calculations shall take into account the most unfavorable, yet realistic, weather conditions. Typical weather conditions for based on the Wind Rose data include.

- 5 m/s wind speed with atmospheric stability of "D", per the Pasquill – Gifford Stability Category (5/D)
- 1.5 m/s wind speed with atmospheric stability of "F", per the Pasquill – Gifford Stability Category (2/F)

These two representative weather conditions will be considered in the PHAST modelling. The wind rose data has been analyzed and split into these two categories as shown below. Wind speeds in the range 0 – 3 m/s will be represented by the 2/F category, and wind speeds >3 m/s will be modelled using the 5/D category. PHAST is unable to model calm weather conditions, therefore the proportion of calm weather has been equally distributed across all wind direction.

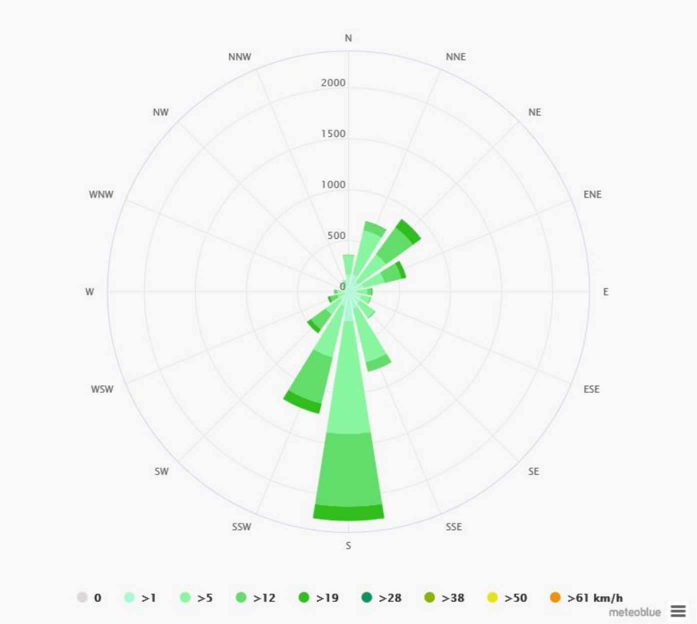


Base Weather Conditions

Base Weather Conditions

- Ambient temperature: annual average of 28.4 deg C
- Humidity: annual average of 74%
- Natural solar radiation: 1 kW/m2
- Surface roughness: 0.25m (a consideration of the local topography and a sensitivity analysis which was carried out to investigate the effect on dispersion modelling led to value adopted).

Wind Rose- Ban Prakong (for example)
30-year global history with hourly weather data



Maximum Credible Events (MCEs), Isolable Section (ISs) and Hydrocarbon Inventories


General

To estimate isolatable process hydrocarbon inventories from the process units within Ethylene Plant Facilities (ETP) have been identified from the most potential severity in the process areas.

Automatically operated shut down valves define the boundary of each of the isolatable sections is assumed so that the process may be quickly isolated on detection of a leak or fire.

In cases where the stream composition changes within the isolatable section, a representative composition is assumed for the purpose of modelling. An estimate has been made of the mass of hydrocarbon material within each of these inventory sections based upon the sizes of vessels and approximate size of compressor.

Maximum Credible Events (MCEs) & Isolable Section (ISs)

20 MM. from assigned leak scenarios including fluid compositions and conditions. Summary of Maximum Credible Events (MCEs) and Isolable Sections of the hydrocarbon inventories which have been used for fire and explosion consequence analysis modelling.

- Columns / Vessels / Drums
- Reactors
- Furnace
- Compressor

Maximum Credible Events (MCEs), Isolable Section (ISs)

MCE & IS	Hazard Source	Composition (%Mole)	Isolable Inventory (m3)	Temperature (° C)	Pressure (Barg)
PGH-IS-1.1	R6101 & 6101R	n-Pentane (29.7) Benzene (44.8) Toluene (13.8) n-Octane (4.1) n-Nonane (7.6)	15	170	25
PGH-IS-1.2	R6401	Benzene (48.80) n-Pentane (20.40) Toluene (17.80) n-Octane (5.20) n-Nonane (4.80) H2 (3.00)	4	330	24
PGH-IS-1.3	C6401&6401R	Hydrogen (97.7) n-Pentane (1.3) Benzene (1.0)	1.4	65	23

Maximum Credible Events (MCEs), Isolable Section (ISs)

MCE & IS	Hazard Source	Composition (%Mole)	Isolable Inventory (m3)	Temperature (° C)	Pressure (Barg)
BD-IS-2.1	T6801	Butadiene (97.51) Butene (2.5)	32	41.9	4.4
TF-IS-3.1	D9505	n-Pentane (89.5) Benzene (9.5) 1-Butene (1.0)	2124	42	2
TF-IS-3.2	D9501B	Butadiene (48.7) 1-Butene (40.9) Ethane (5.0) n-Butane (5.4)	3563	42	3.9
PRP-IS-4.1	K7401&7402	Propylene (99.99) Ethane (0.01)	1007	-25.9	1.47
PRP-IS-4.2	T7201	1-Butene (90.1) n-Butane (9.9)	100	53-70	5.9-6.9
PRP-IS-4.3	R7101A&B	1-Butene (72.0) n-Butane (28.0)	17.6	50-87	26
PRP-IS-4.4	R7301A&B	Ethylene (61.1) 1-Butene (23.8) n-Butane (15.1)	22.52	304	29
FUR-IS-5.1	Furnace	N-nonane (25.8) Ethylene (12.4) Methane (11.1) Hydrogen (7.2) Propylene (5.0) Ethane (2.0) Propane (0.5) Benzene (1.0) H20 (35.0)	1357	420	0.6
COM-IS-6.1	C3101	Ethylene (31.2) Methane (25.8) H2 (15.5) Propylene (9.9) Ethane (7.0) Butadiene (2.8) 1-Butene (2.3) n-Butane (2.0) H2O (1.5) Acetylene (1.0) Propane (1.0)	169	80	35
COM-IS-6.2	C4401	Ethylene (99.5) Ethane (0.5)	25.2	54.3	27
COM-IS-6.3	C4601	Propylene (99.6) Propane (0.4)	91.1	67	16.5

MCE & IS	Hazard Source	Composition (%Mole)	Isolable Inventory (m3)	Temperature (° C)	Pressure (Barg)
C1-IS-7.1	T3802	Propylene (55.4) Butadiene (17.5) 1-Butene (13.5) n-Pentane (9.2) Propane (3.4) n-Butane (1.0)	267.3	86.5	25.3
C3-IS-8.1	A4801	Hydrogen (100)	19	15	31
C3-IS-8.2	T5701	n-Pentane (87.0) Benzene (11.8) n-Butane (0.7) Toluene (0.5)	68.7	100	4.3
C3-IS-8.3	D5501&T5501	Propene (99.60) Propane (0.37)	68.2	47.5	18.5
C3-IS-8.4	T4301	Ethylene (99.9) Methane (0.05) Ethane (0.05)	396.5	-58	7.38
C3-IS-8.5	R201&5201B	Propylene (97.1) Propane (2.9)	5	56	25

Release Rate

Release Rate

The release rates will be determined based on the release size and the process conditions i.e., temperature and pressure. Depending on the operating conditions, the release state of the fluid could be liquid, gas or two-phase. The release rates will be estimated using the latest PHAST software. The release rates and the phase would give an indication of severity of the leak and influence the flammable impact.

Release Direction

The direction of release will be considered based on target criteria (i.e., evaluation of impact on target equipment/personnel at risk). e.g., jet fires will be modeled as un-impeded horizontal jets. The results will illustrate the maximum extent of the release without obstructions.

The release elevation is set at 1m above ground for the equipment located at grade level. For the leak source located at a higher elevation, the release elevation will be calculated based on the height of equipment above the grade level.

For above ground installation horizontal release will be considered.

Outputs & Results

Hazard footprints are evaluated to qualify fatal and damage effects as follows,

- Flammable gas dispersion
- Blast pressure contour
- Heat flux contour

Fire and Explosion Effect Zone from the assigned MCEs

Table 5.1: Fire and Explosion Effect Zone from the assigned MCEs

MCE & IS	Hazard Source	Fire & Explosion Event Type	Impact Criteria	Effect Zone Distance (m)
PGH-IS-1.1	R6101 & 6101R	Flash Fire	100%LEL	30.98
		Jet Fire	4 kW/m2	35.9
			12.5 kW/m2	28.2
			37.5 kW/m2	23.7
		Vapor Cloud Explosion	0.7 psig	16.3
			1.4 psig	19.0
			5.0 psig	13.8
PGH-IS-1.2	R6401	Flash Fire	100%LEL	9.1
		Jet Fire	4 kW/m2	21.9
			12.5 kW/m2	18.2
			37.5 kW/m2	15.3
		Vapor Cloud Explosion	0.7 psig	23.9
			1.4 psig	17.7
			5.0 psig	13.2
PGH-IS-1.3	C6401&6401R	Flash Fire	100%LEL	19.1
		Jet Fire	4 kW/m2	16.2
			12.5 kW/m2	13.3
			37.5 kW/m2	11.0
		Vapor Cloud Explosion	0.7 psig	26.1
			1.4 psig	19.0

MCE & IS	Hazard Source	Fire & Explosion Event Type	Impact Criteria	Effect Zone Distance (m)
			5.0 psig	13.7
BD-IS-2.1	T6801	Flash Fire	100%LEL	11.9
		Jet Fire	4 kW/m2	28.3
			12.5 kW/m2	22.5
			37.5 kW/m2	18.9
		Vapor Cloud Explosion	0.7 psig	24.4
			1.4 psig	18.0
			5.0 psig	13.4
TF-IS-3.1	D9505	Flash Fire	100%LEL	59.5
		Jet Fire	4 kW/m2	52.3
			12.5 kW/m2	40.8
			37.5 kW/m2	33.5
		Pool Fire	4 kW/m2	91.4
			12.5 kW/m2	39.4
			37.5 kW/m2	36.2
		Vapor Cloud Explosion	0.7 psig	119.5
			1.4 psig	88.5
			5.0 psig	66.2
TF-IS-3.2	D9501B	Flash Fire	100%LEL	13.0
		Jet Fire	4 kW/m2	28.2
			12.5 kW/m2	22.1
			37.5 kW/m2	17.1
		Vapor Cloud Explosion	0.7 psig	24.6
			1.4 psig	18.1
			5.0 psig	13.4
PRP-IS-4.1	K7401/7402	Flash Fire	100%LEL	15.2
		Jet Fire	4 kW/m2	24.0
			12.5 kW/m2	19.2
			37.5 kW/m2	16.3
		Pool Fire	4 kW/m2	11.9

Fire and Explosion Effect Zone from the assigned MCEs

MCE & IS	Hazard Source	Fire & Explosion Event Type	Impact Criteria	Effect Zone Distance (m)
		Vapor Cloud Explosion	0.7 psig	26.7
			1.4 psig	19.3
			5.0 psig	13.9
COM-IS-6.1	C3101	Flash Fire	100%LEL	12.9
		Jet Fire	4 kW/m2	23.4
			12.5 kW/m2	18.9
			37.5 kW/m2	15.1
		Vapor Cloud Explosion	0.7 psig	23.6
			1.4 psig	17.5
			5.0 psig	13.2
COM-IS-6.2	C4401	Flash Fire	100%LEL	13.1
		Jet Fire	4 kW/m2	21.8
			12.5 kW/m2	17.6
			37.5 kW/m2	14.0
		Vapor Cloud Explosion	0.7 psig	23.3
			1.4 psig	17.4
			5.0 psig	13.1
COM-IS-6.3	C4601	Flash Fire	100%LEL	9.36
		Jet Fire	4 kW/m2	20.4
			12.5 kW/m2	16.2
			37.5 kW/m2	11.5
		Vapor Cloud Explosion	0.7 psig	23.7
			1.4 psig	17.6
			5.0 psig	13.2
C1-IS-7.1	T3802	Flash Fire	100%LEL	12.3
		Jet Fire	4 kW/m2	26.0
			12.5 kW/m2	21.1
			37.5 kW/m2	17.4
		Vapor Cloud Explosion	0.7 psig	23.9
			1.4 psig	17.7

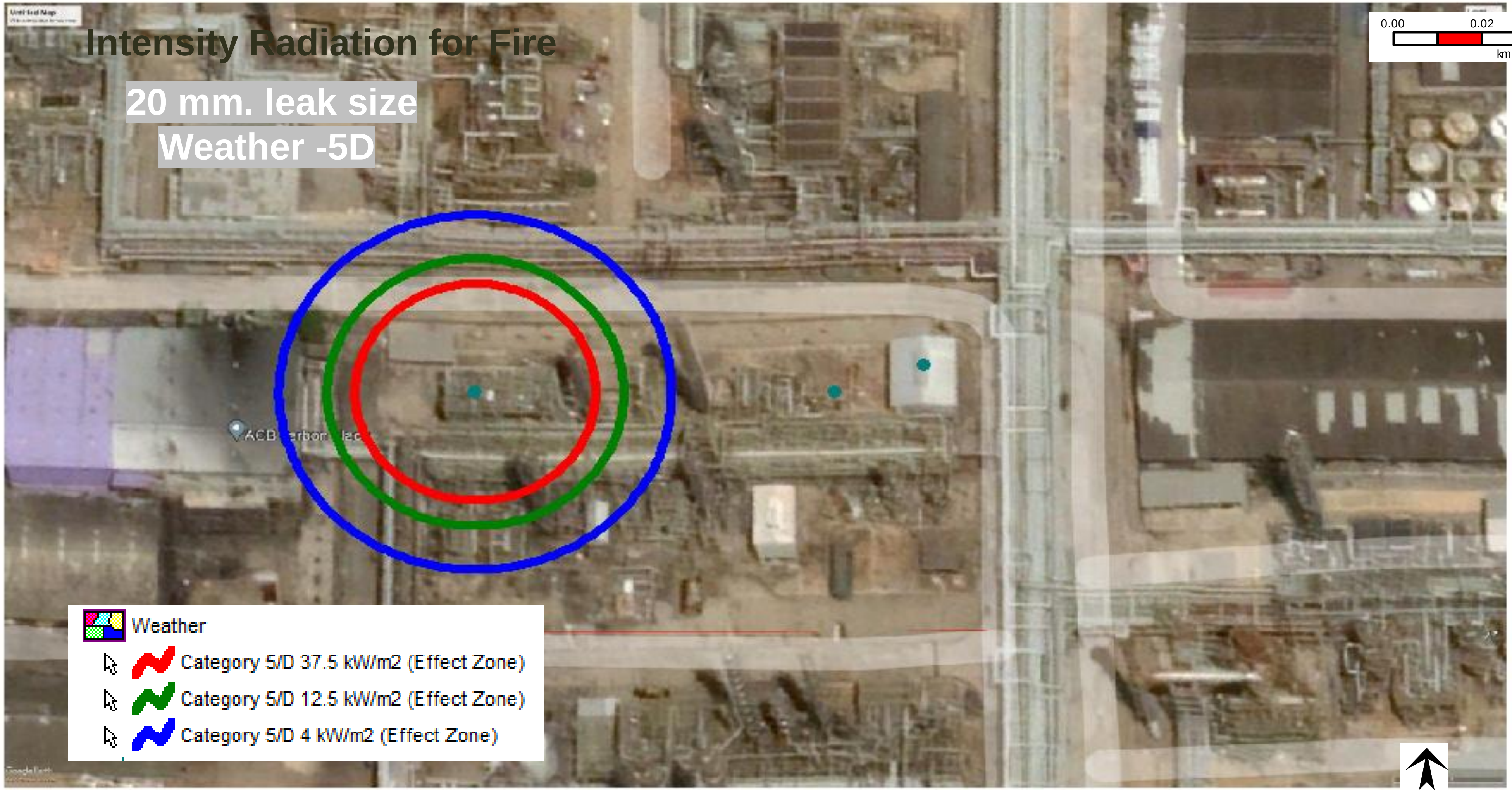
MCE & IS	Hazard Source	Fire & Explosion Event Type	Impact Criteria	Effect Zone Distance (m)
			5.0 psig	13.2
C3-IS-8.1	A4801	Flash Fire	100%LEL	23.3
		Jet Fire	4 kW/m2	25.5
			12.5 kW/m2	19.3
			37.5 kW/m2	11.9
		Vapor Cloud Explosion	0.7 psig	47.5
			1.4 psig	35.2
			5.0 psig	26.4
C3-IS-8.2	T5701	Flash Fire	100%LEL	15.1
		Jet Fire	4 kW/m2	30.5
			12.5 kW/m2	23.8
			37.5 kW/m2	18.4
		Vapor Cloud Explosion	0.7 psig	25.6
			1.4 psig	18.6
			5.0 psig	13.6
C3-IS-8.3	D5501&T5501	Flash Fire	100%LEL	10.2
		Jet Fire	4 kW/m2	21.1
			12.5 kW/m2	16.9
			37.5 kW/m2	12.6
		Vapor Cloud Explosion	0.7 psig	22.0
			1.4 psig	16.6
			5.0 psig	12.8
C3-IS-8.4	T4301	Flash Fire	100%LEL	8.26
		Jet Fire	4 kW/m2	17.4
			12.5 kW/m2	14.2
			37.5 kW/m2	12.2
		Vapor Cloud Explosion	0.7 psig	21.6
			1.4 psig	16.4
			5.0 psig	12.7
C3-IS-8.5	R5201&5201B	Flash Fire	100%LEL	15.8

PSG

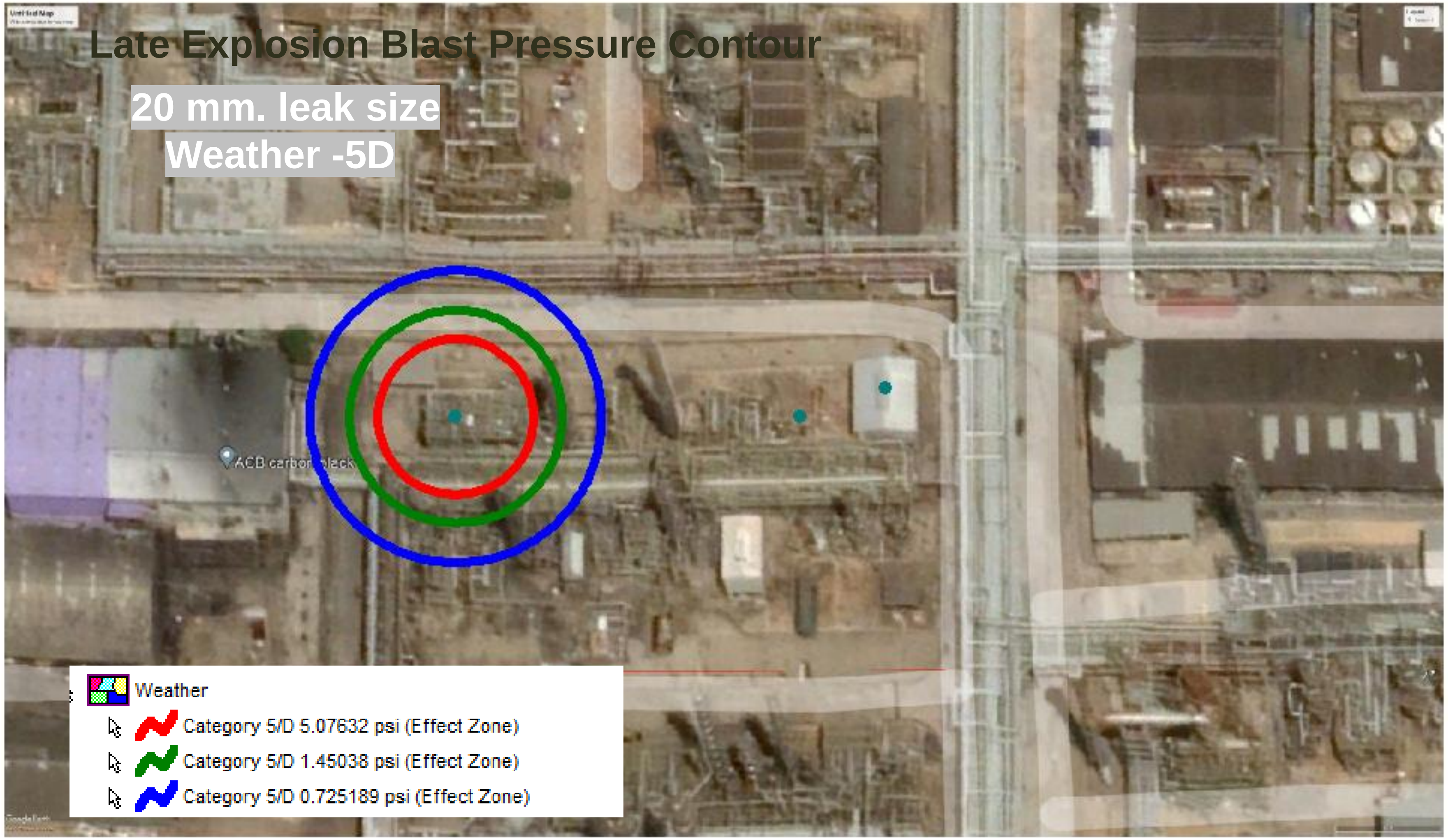
PGH-IS-1.1-R6101 & 6101R

PGH-IS-1.1-R6101 & 6101R

PGH-IS-1.1-R6101 & 6101R



PGH-IS-1.1-R6101 & 6101R

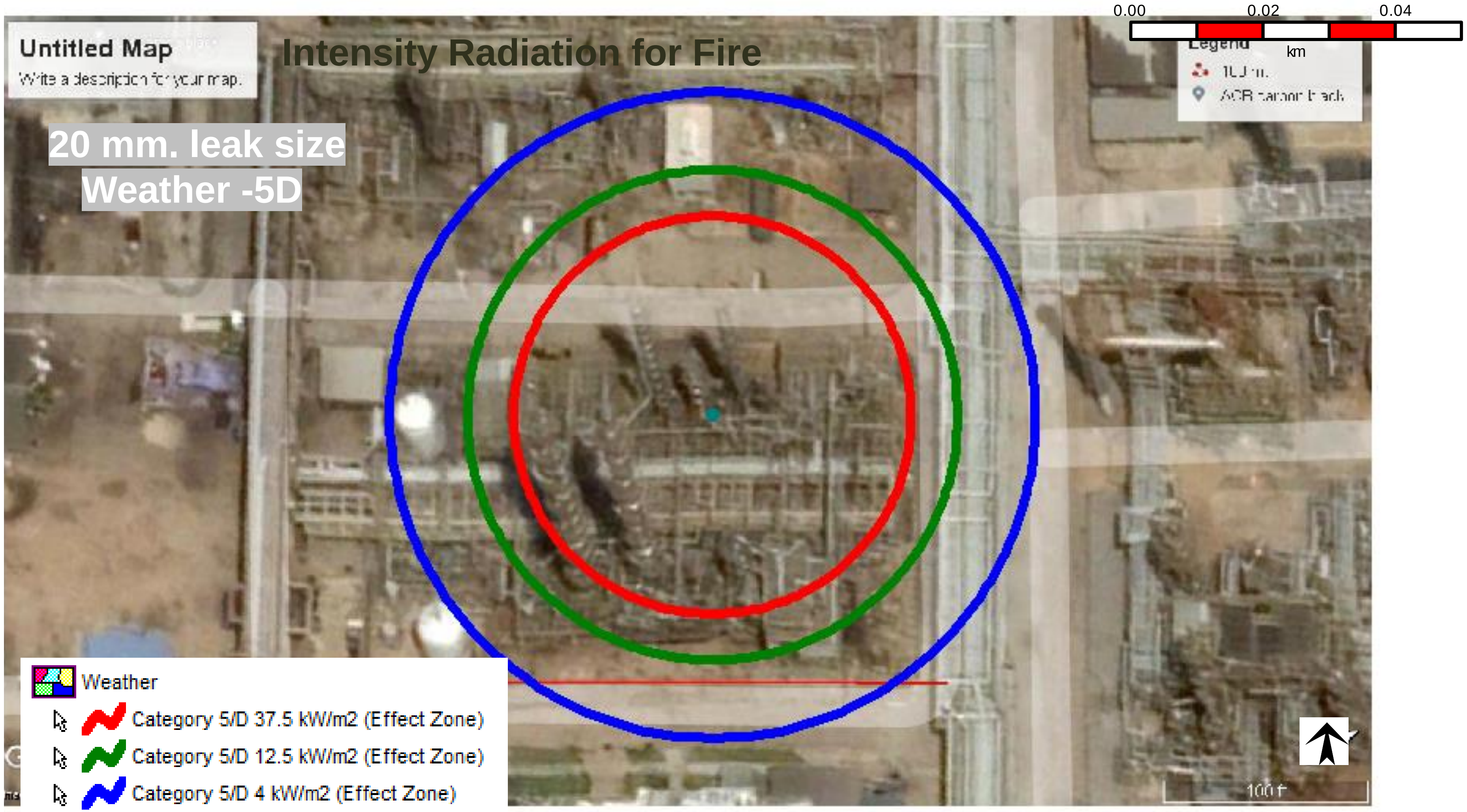


0.00 0.02 0.04
km

BD

BD-IS-2.1-T6801

BD-IS-2.1-T6801



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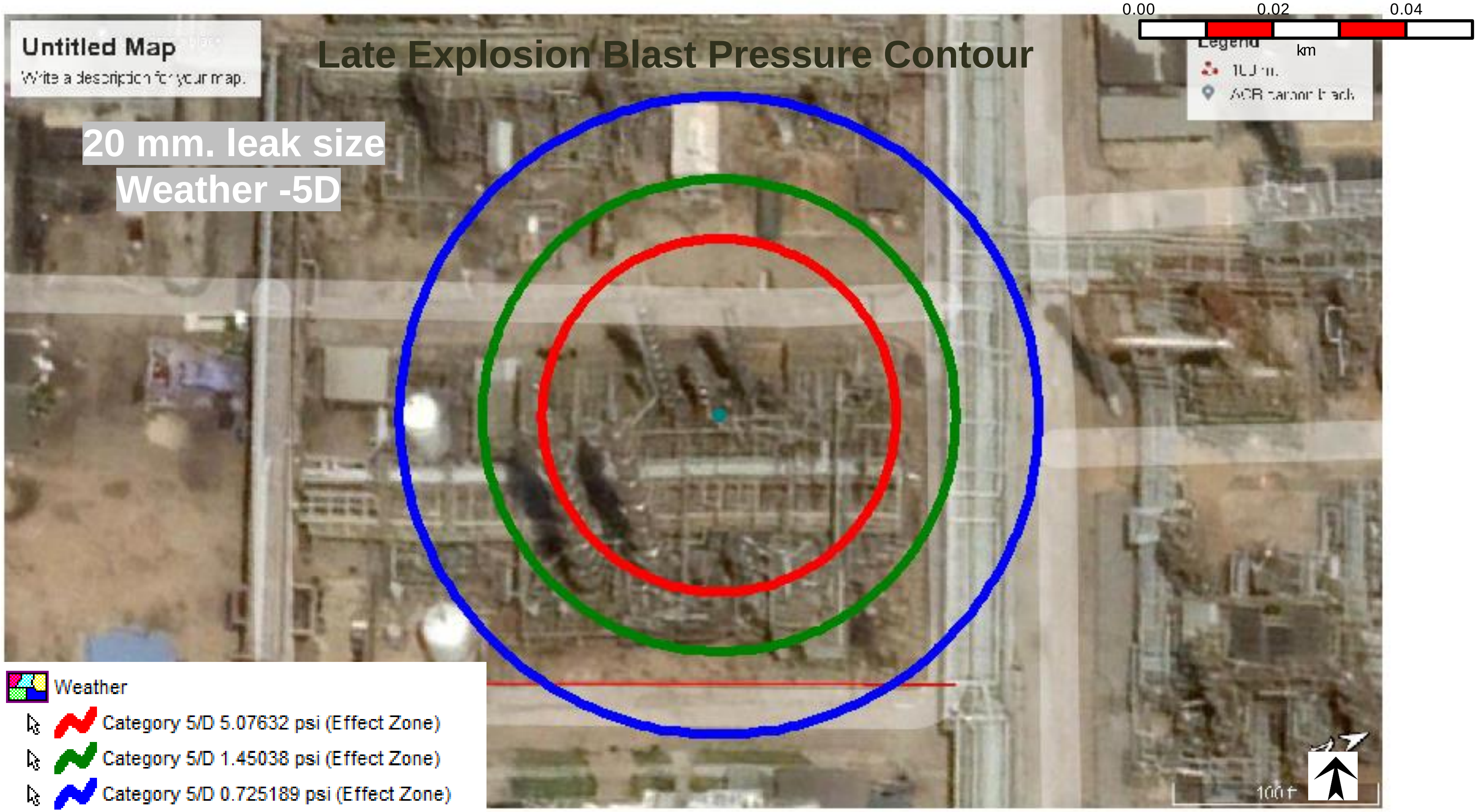
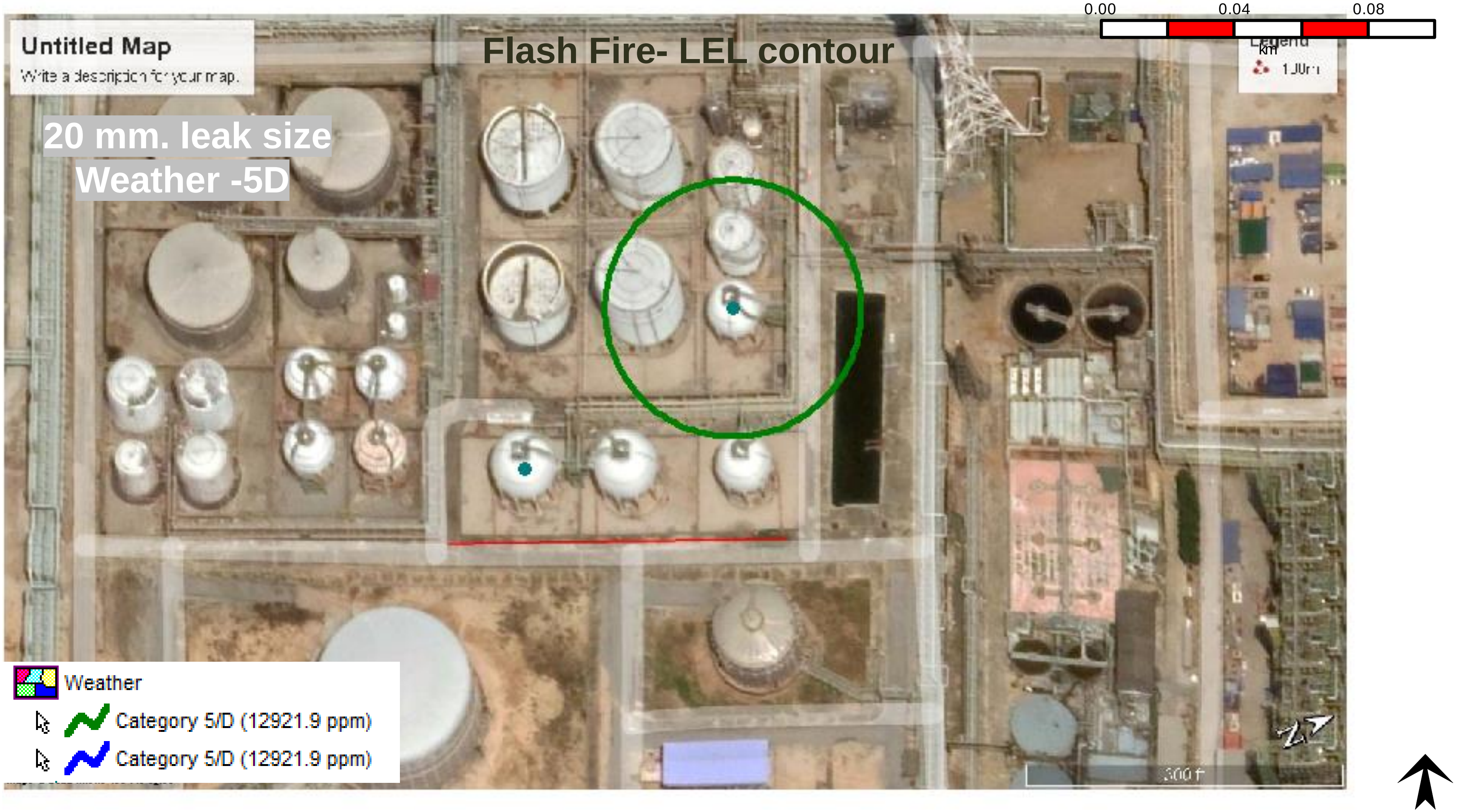


Storage Tank

TF-IS-3.1-D9505



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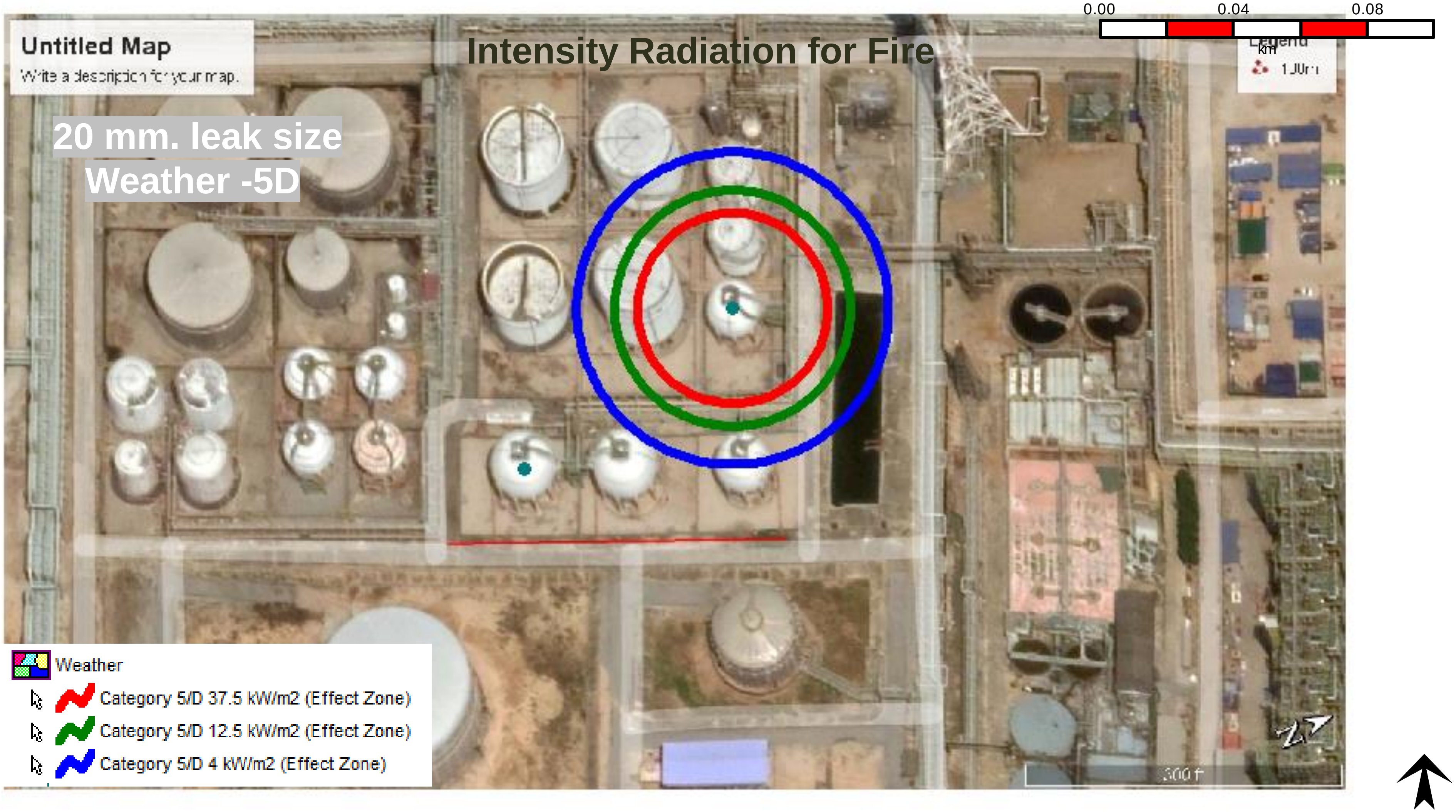

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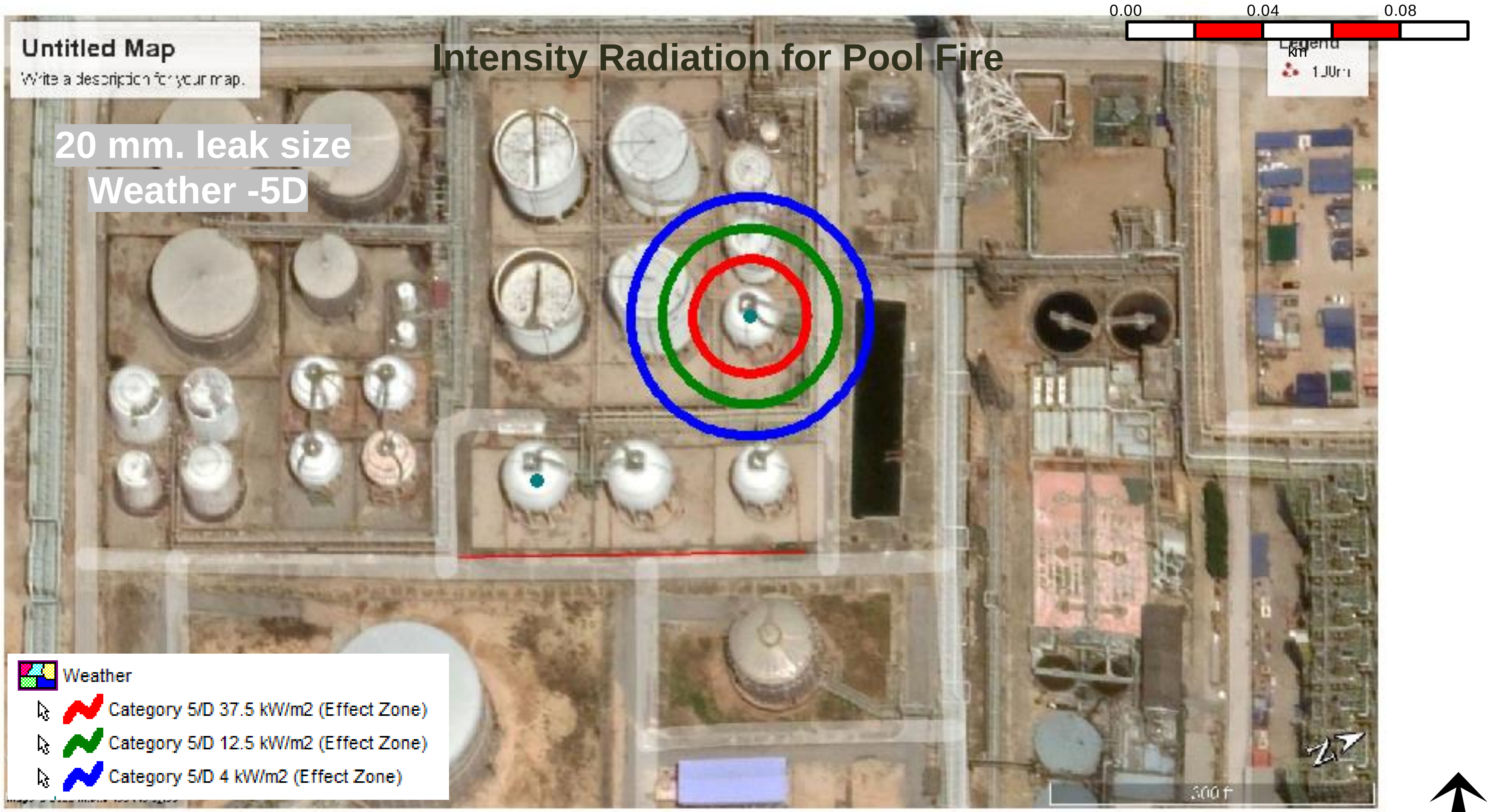

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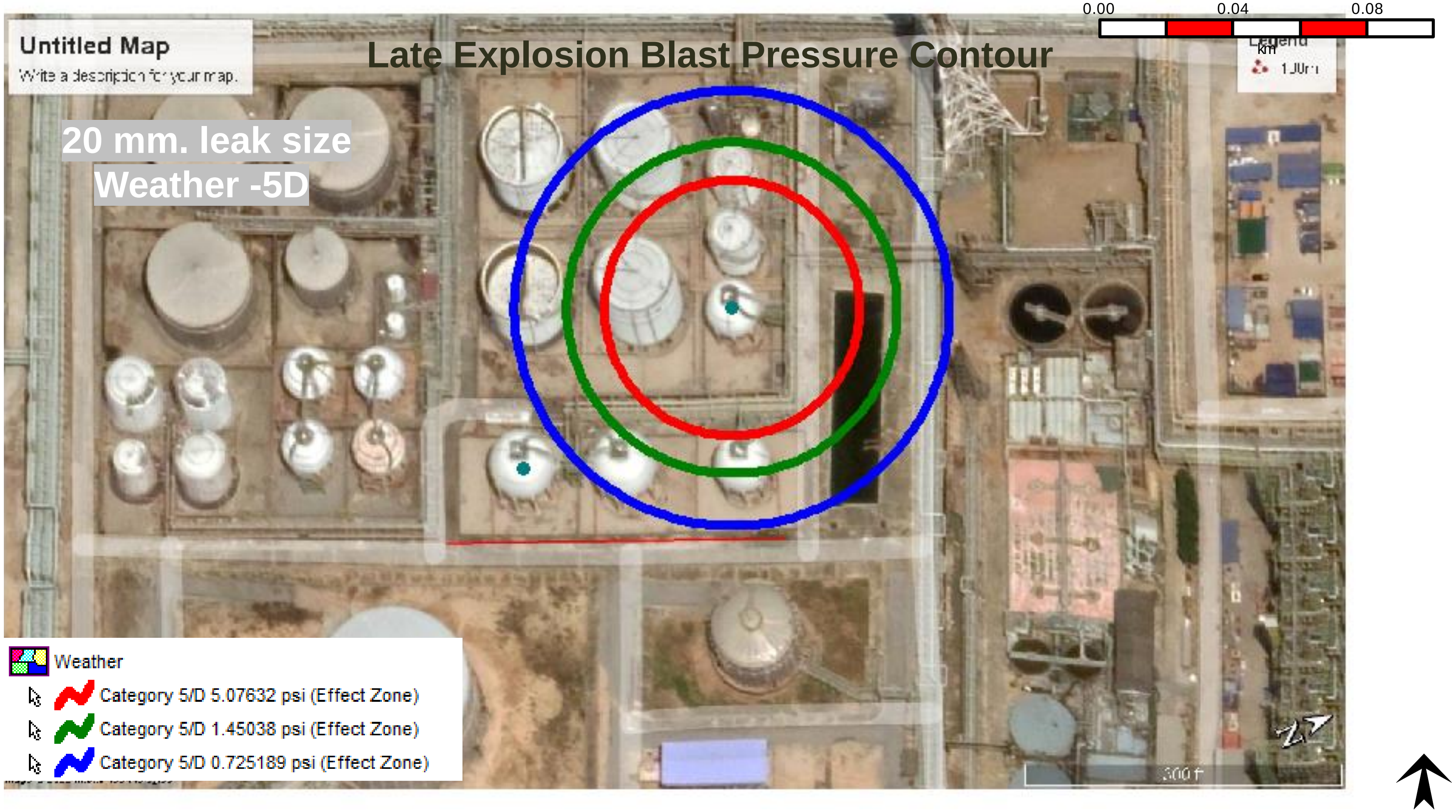
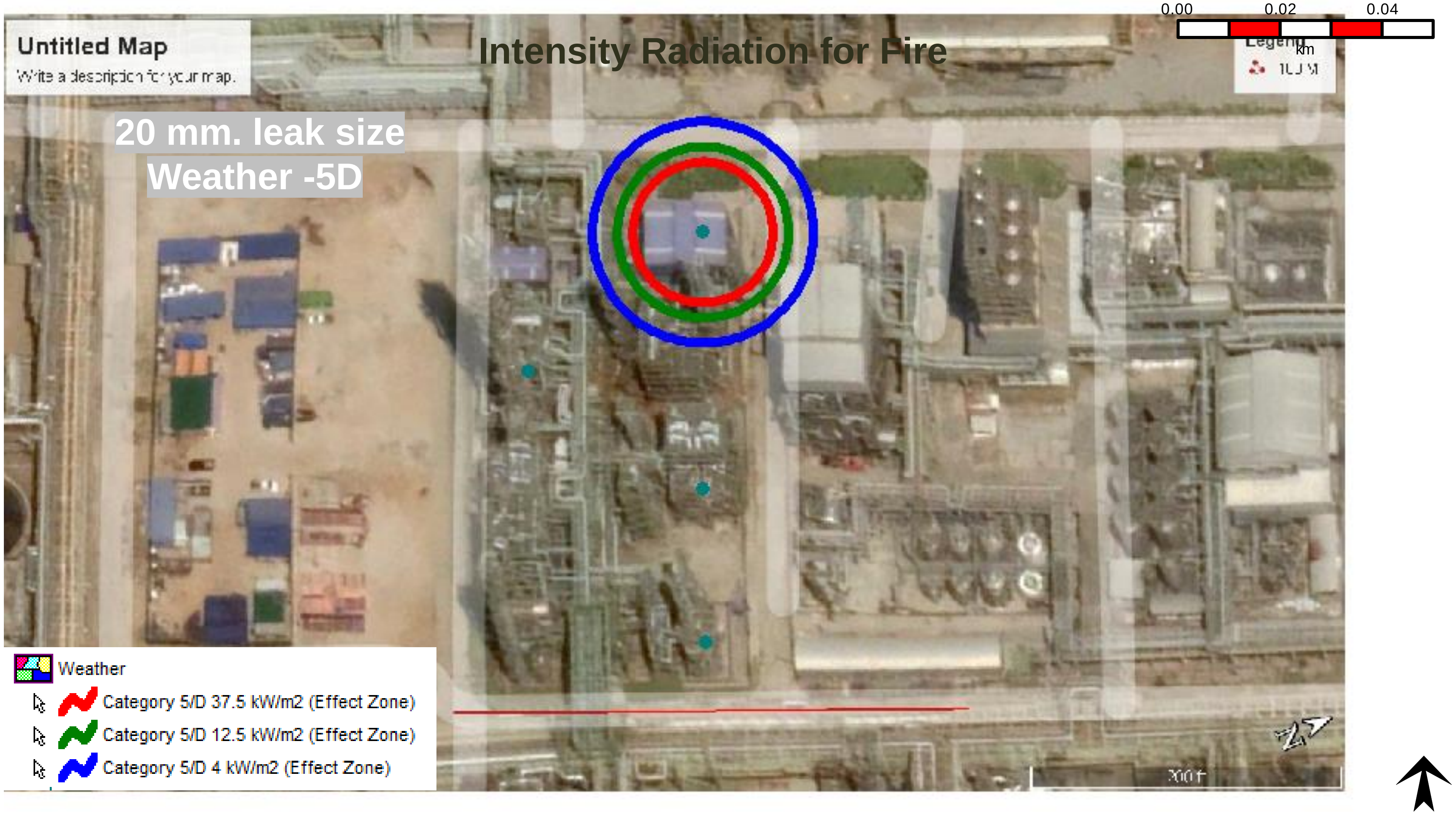


PRP

PRP-IS-4.1-K7401/7402

PRP-IS-4.1-K7401/7402



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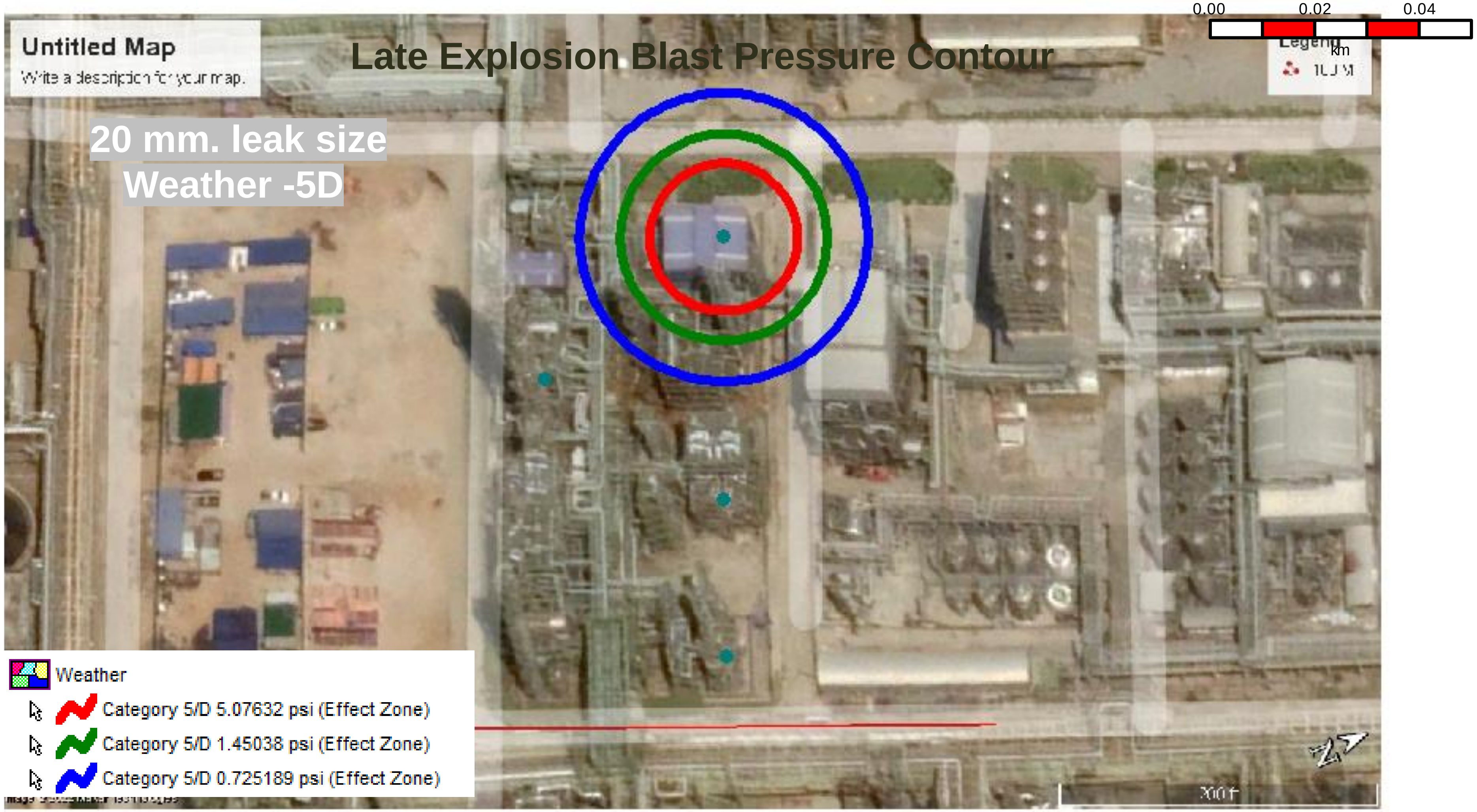
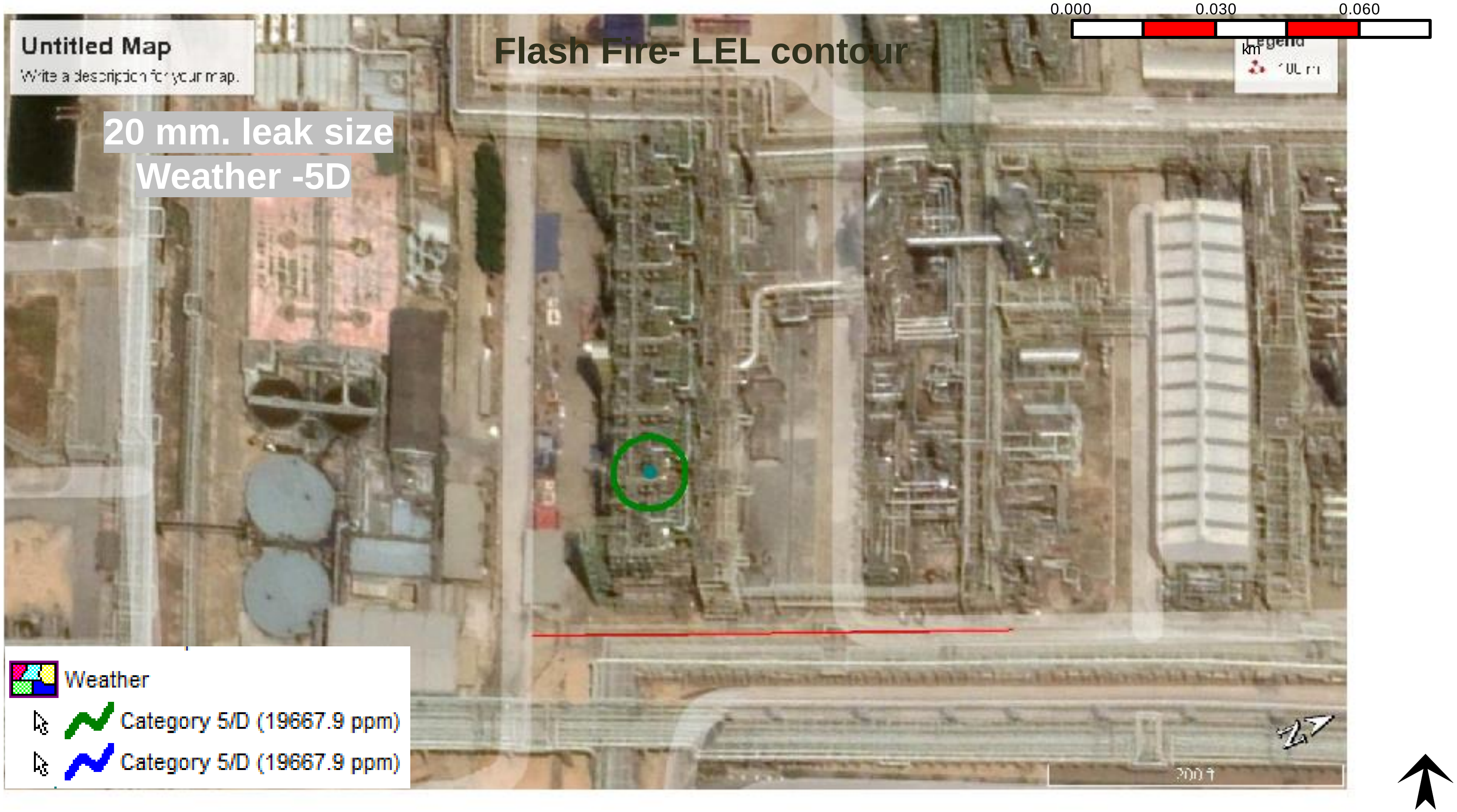
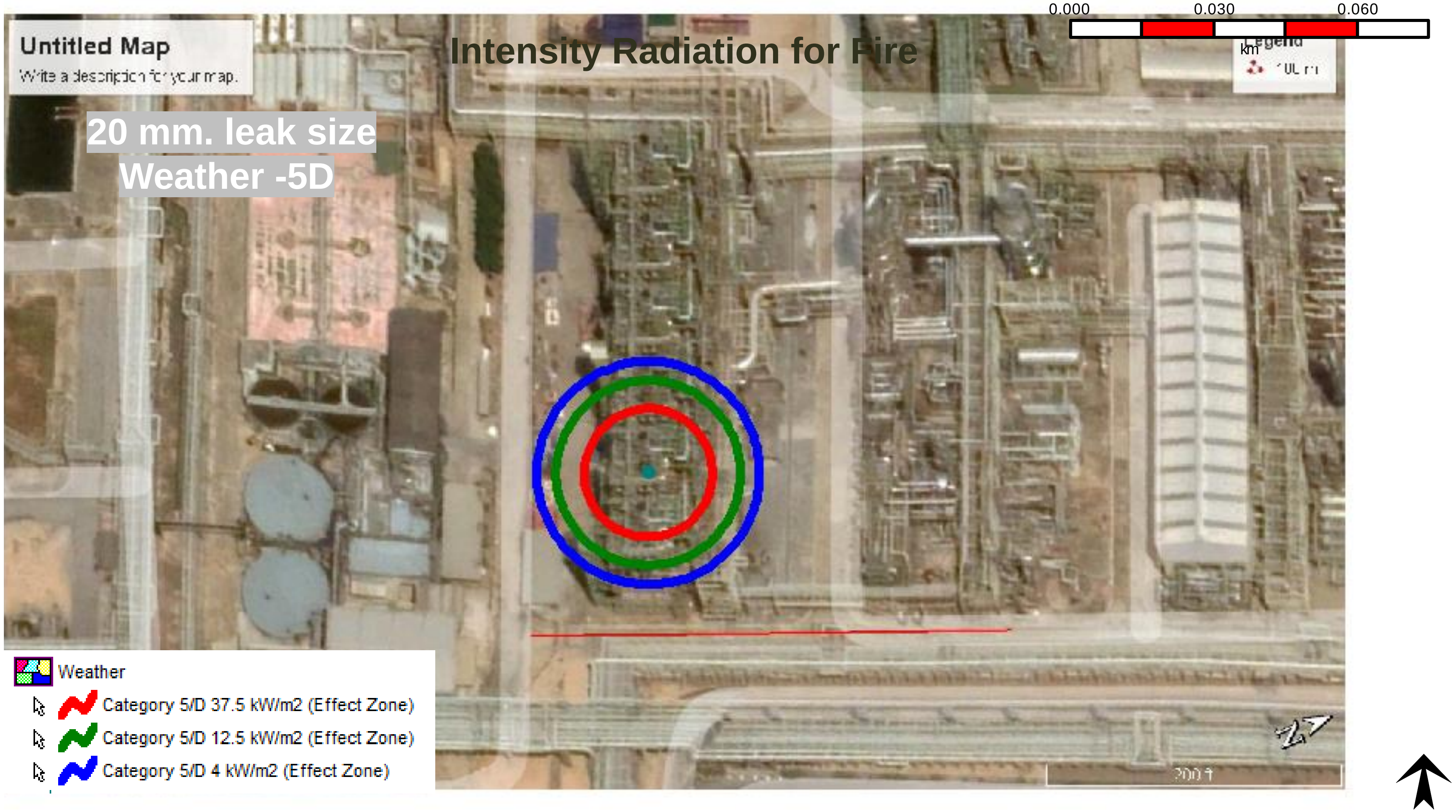


Furnace

Furnace-IS-5.1-Furnace



Furnace-IS-5.1-Furnace



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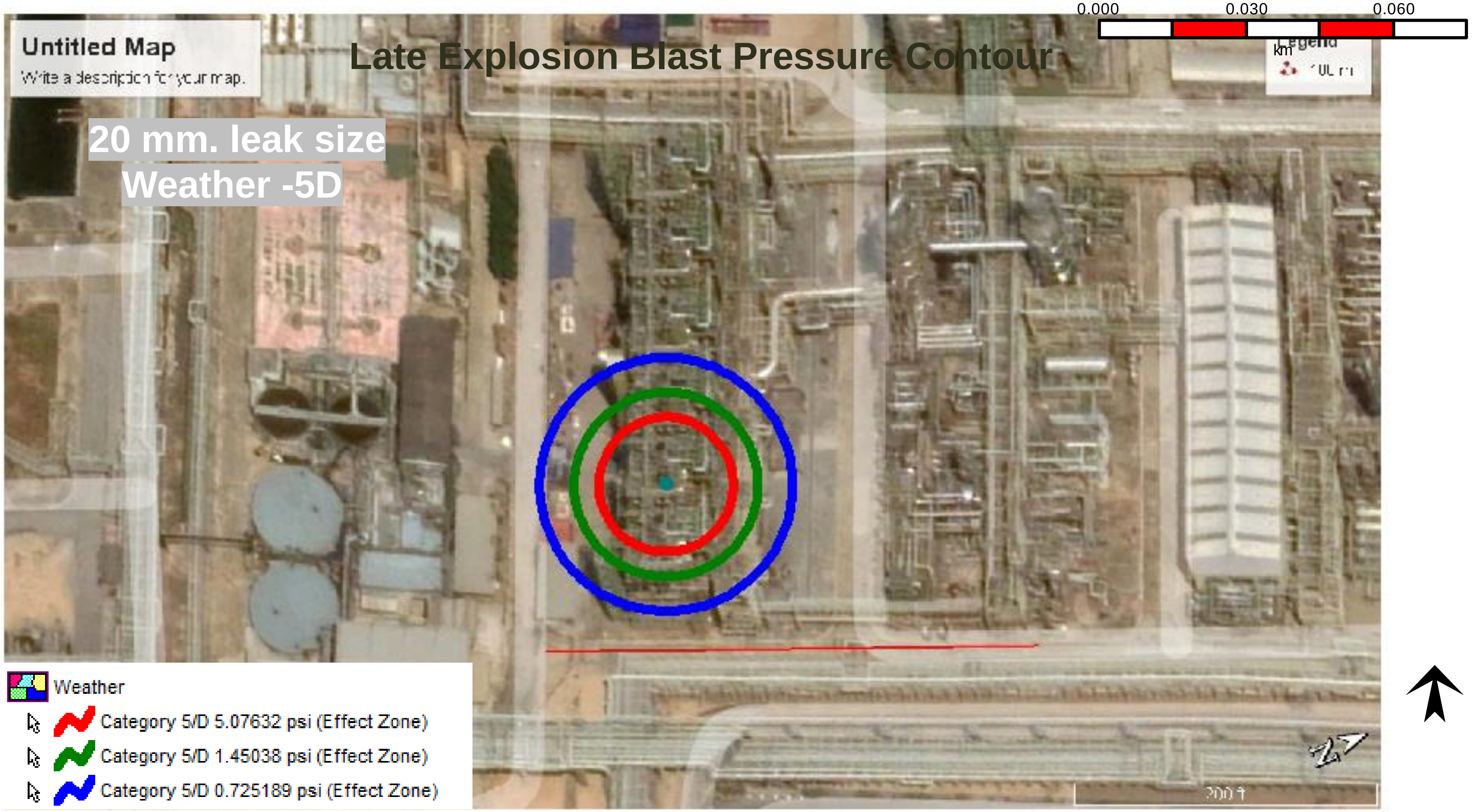
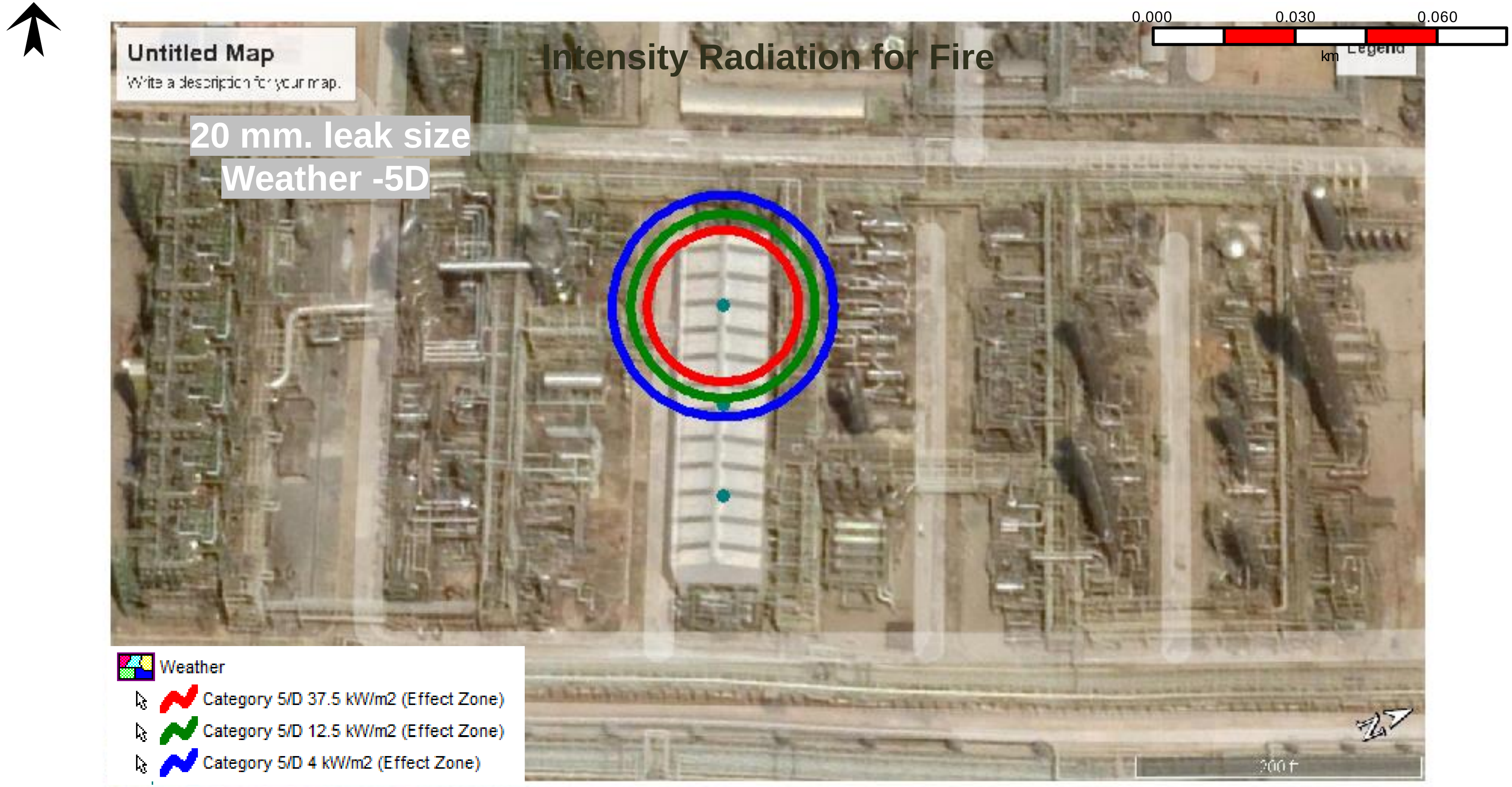


Compressor

Comp-IS-6.1-C3101

Comp-IS-6.1-C3101



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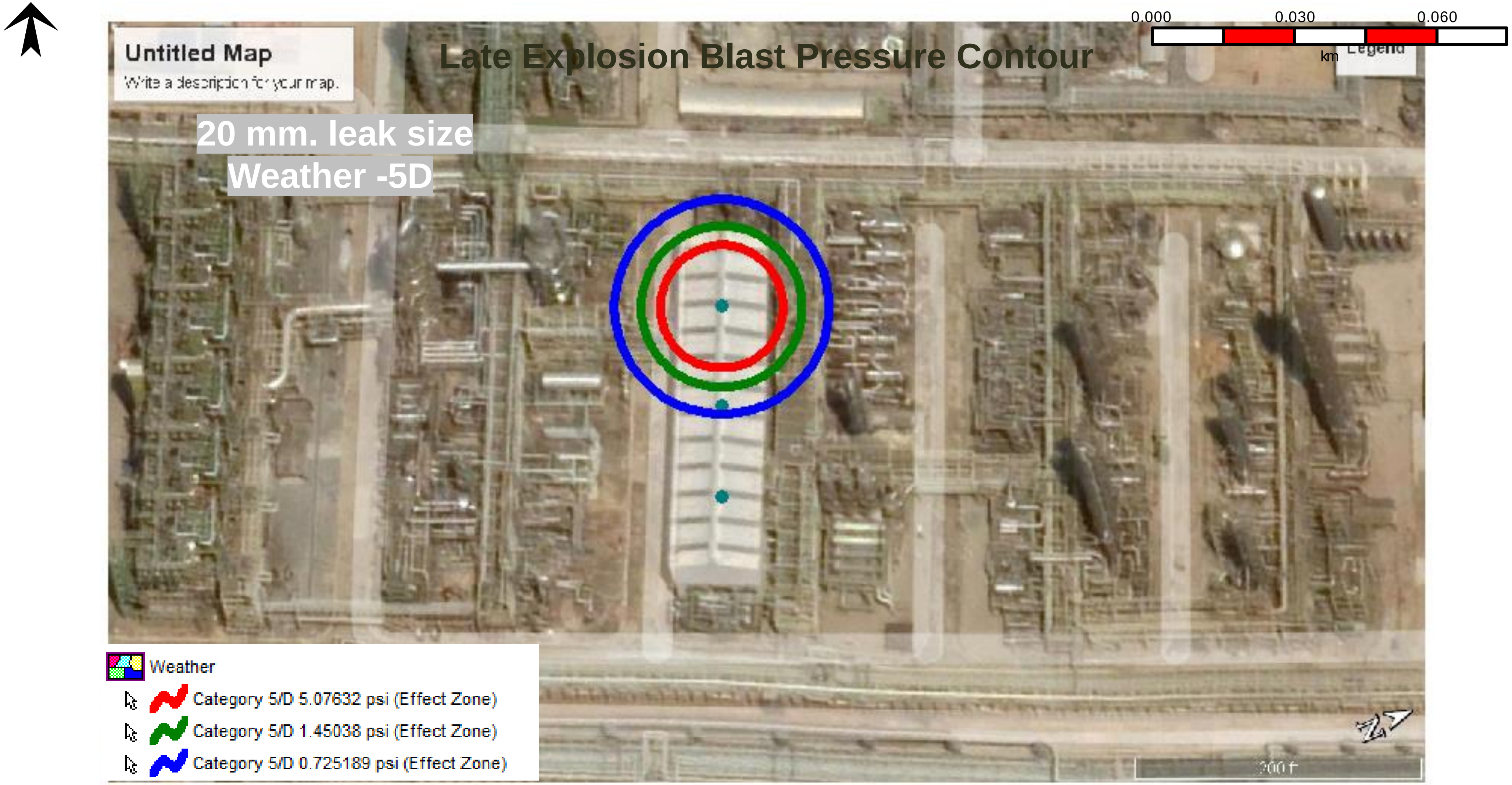
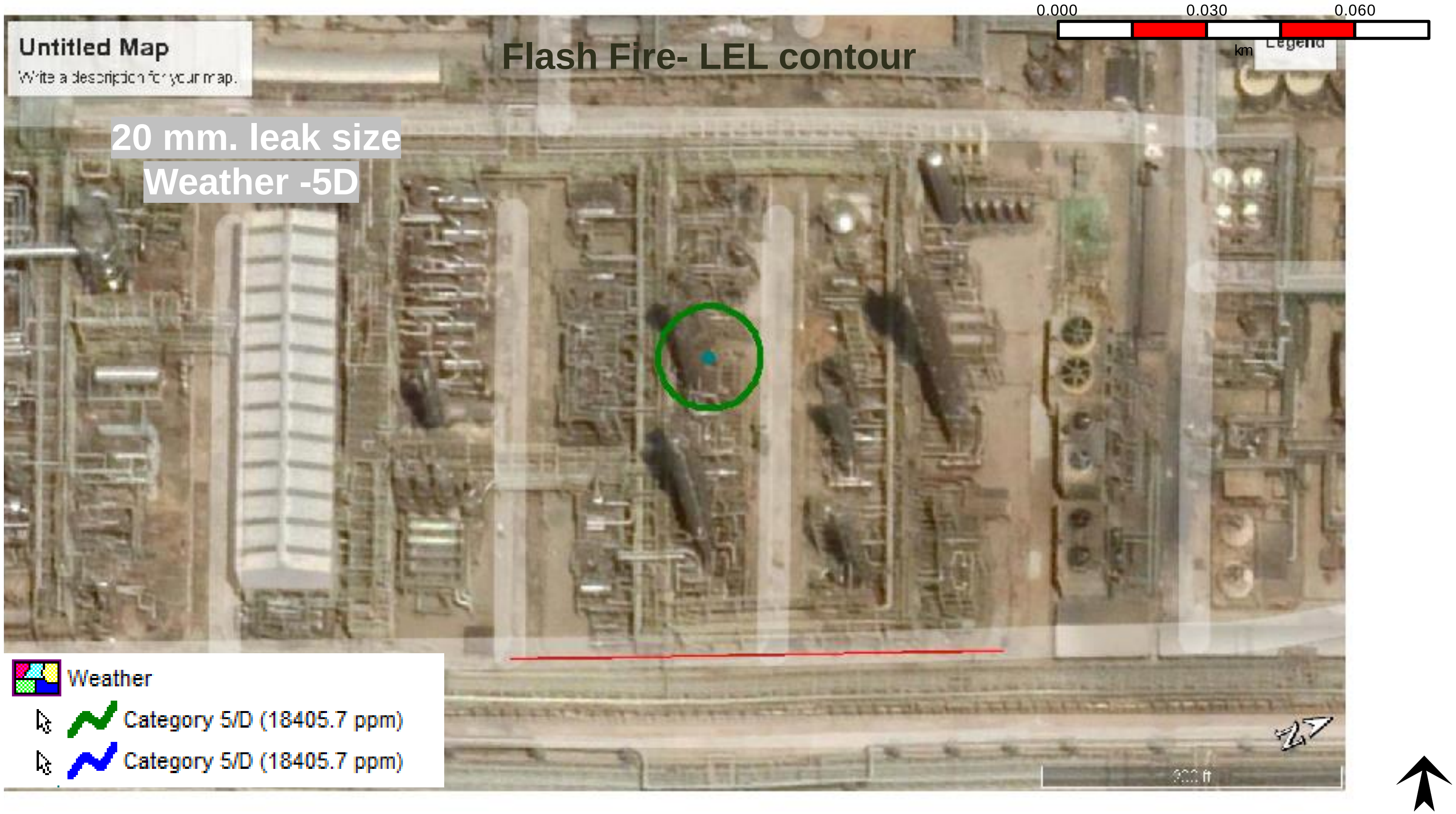


C1

C1-IS-7.1-T3802



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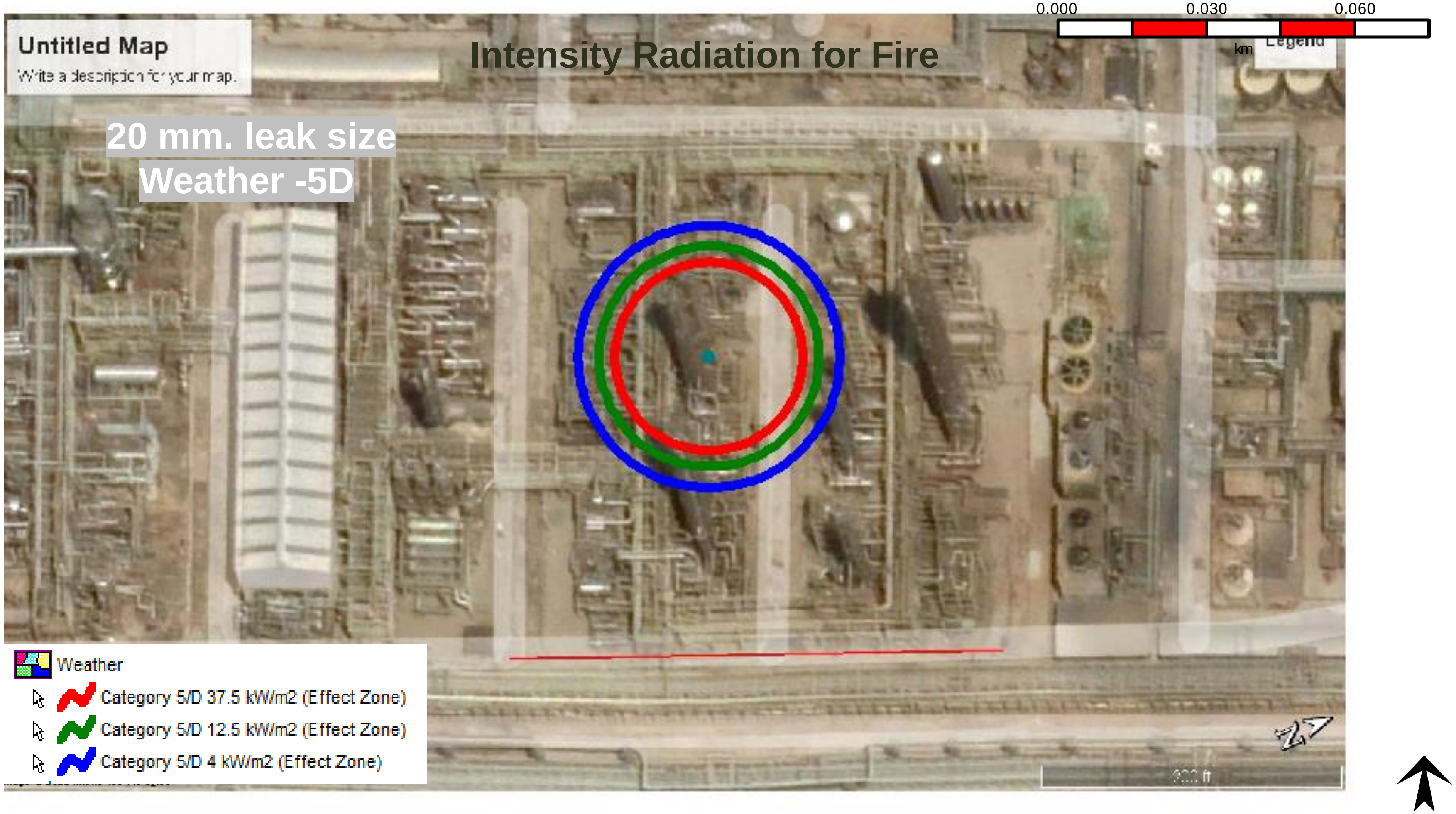

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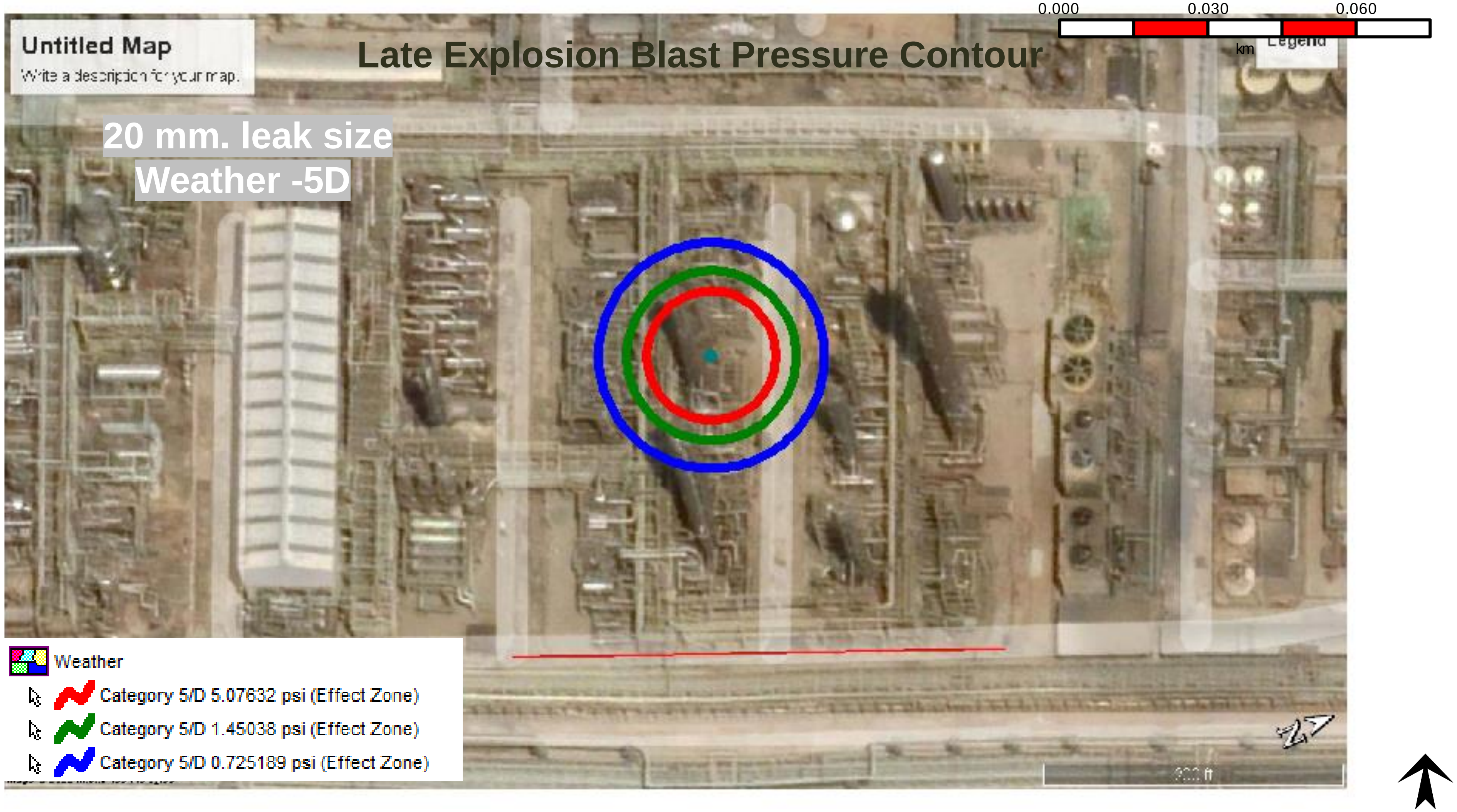
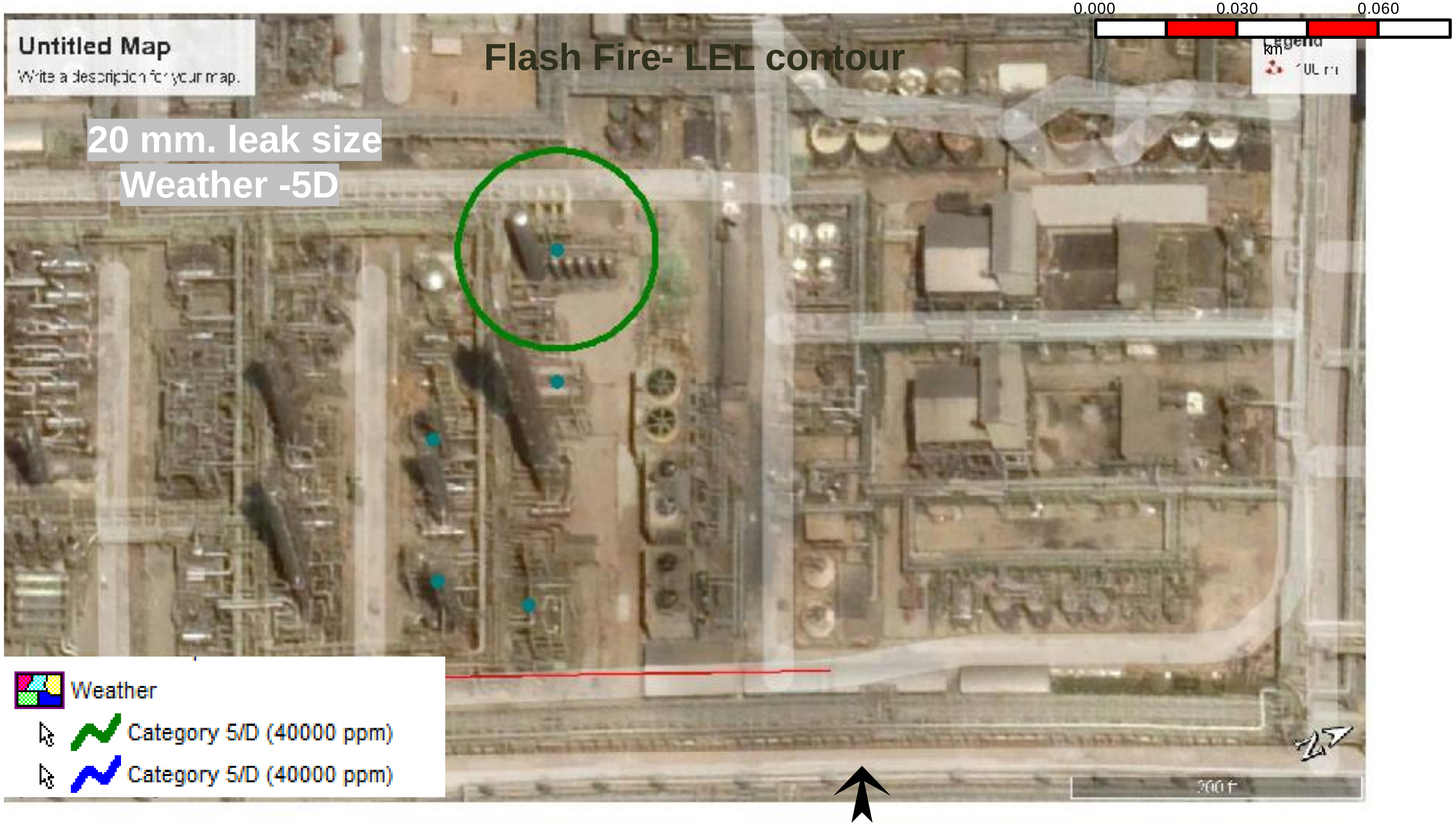


C3

C3-IS-8.1-A4801



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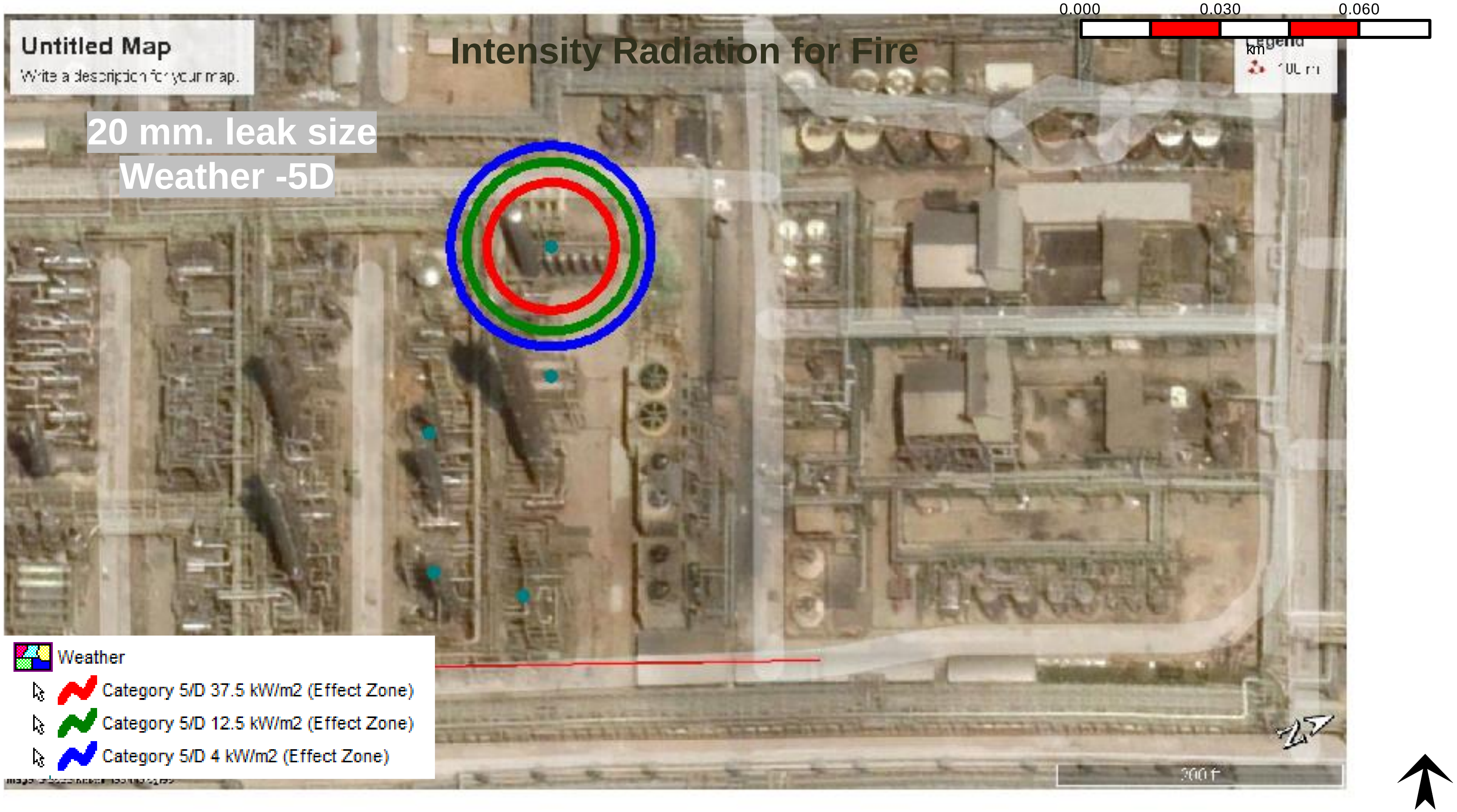

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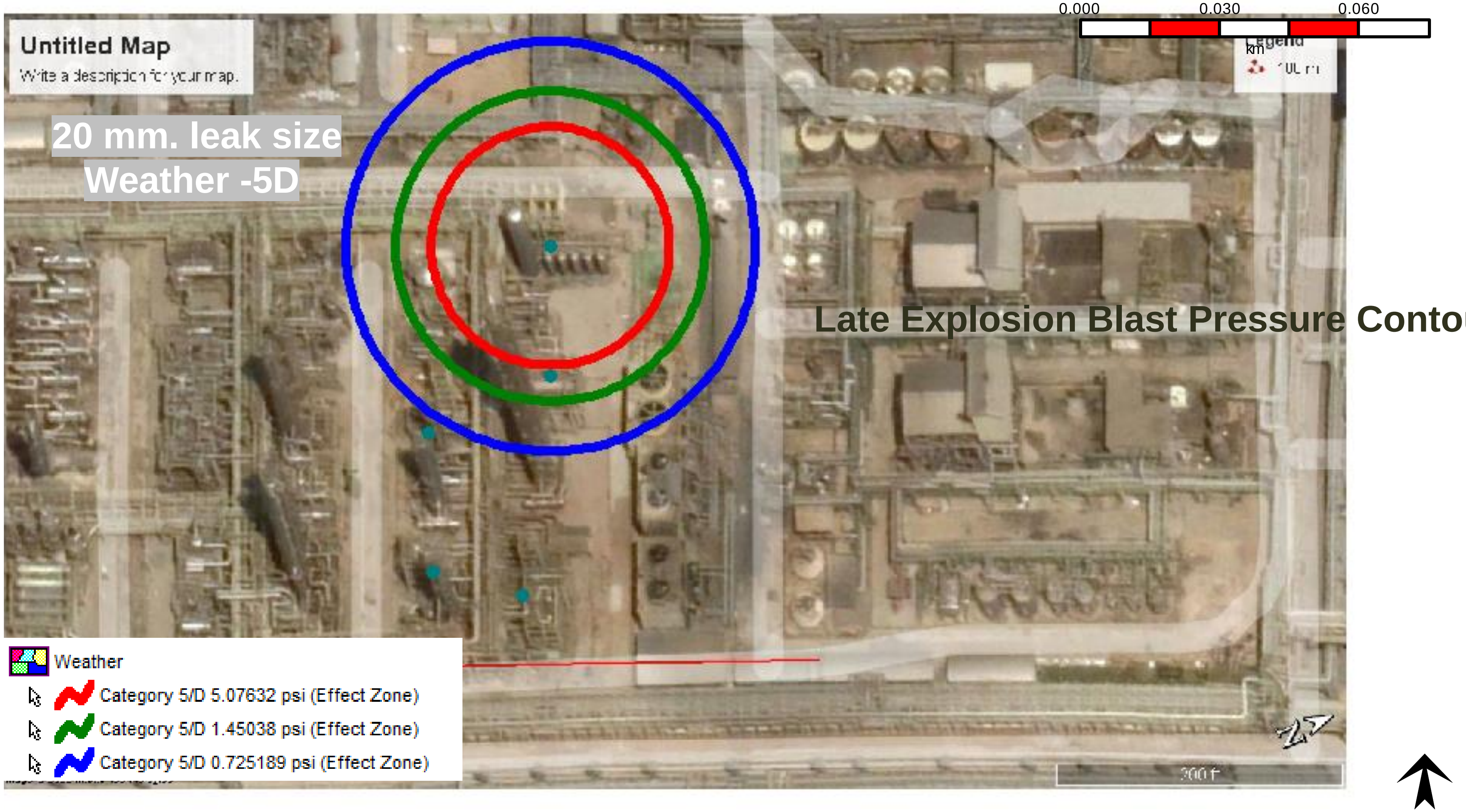


CONCLUSION AND RECOMMENDATIONS

- In vapor cloud explosion outcome results, potential for direct vapour cloud explosion event impact on the distance indicated occupied buildings, does not occur, is even unlikely and the pressure blast contours do not have a disastrous effect on such areas.

- In jet fire outcome results, the high temperatures pose a hazard not only from direct effects of heat on humans, but also from the possibility of escalation. If a jet flame impinges upon a target such as a vessel, pipe, or structural member, it can cause the item to fail within a few minutes. Unobstructed jet fires can cover significant areas and can cause damage and escalation at large distances from the source of the leak.

- It is therefore crucial that the precise inherently safer design practices, effective process safety management, and integrity protective/ mitigative protection are implemented to prevent and stop escalation of the consequences. However, the active and passive fire protection system for the facility assets and SCEs in the process area within Ethylene Plant Facilities should be revisited and implemented following prescript based designed in following to good engineer practices.

Chemical
Process Safety Sharing

Thank you for your attention