Development of a Fire Modeling Study for the Chuquicamata Underground Mine

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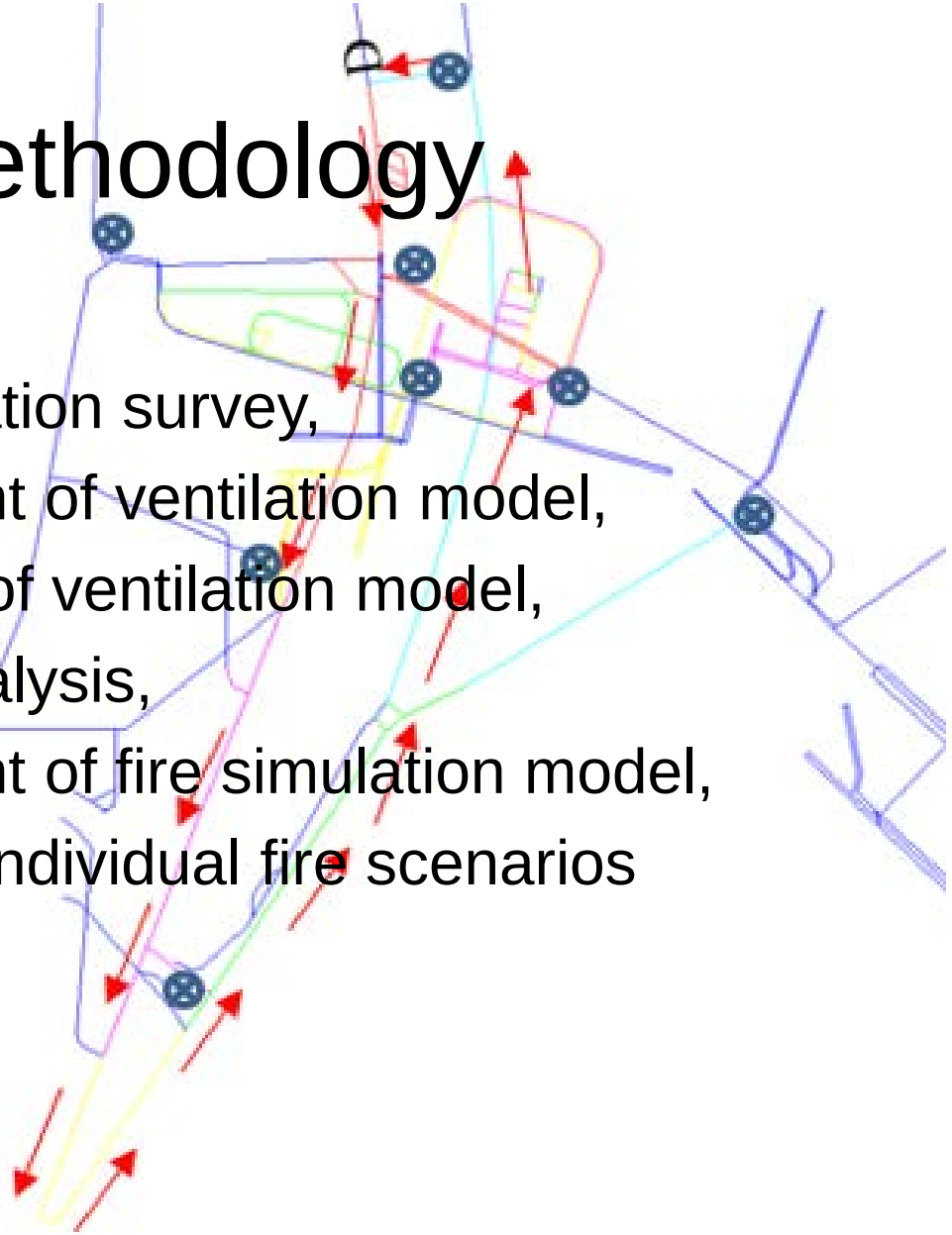
Why take the time to do this study

- Developing a ventilation system to provide fresh air to the workers is a primary goal of the ventilation system.
- But we must know how the ventilation system will react during an emergency
- By understanding how the ventilation system will react we can elevate the level of safety in the mine and help ensure safety during an emergency.

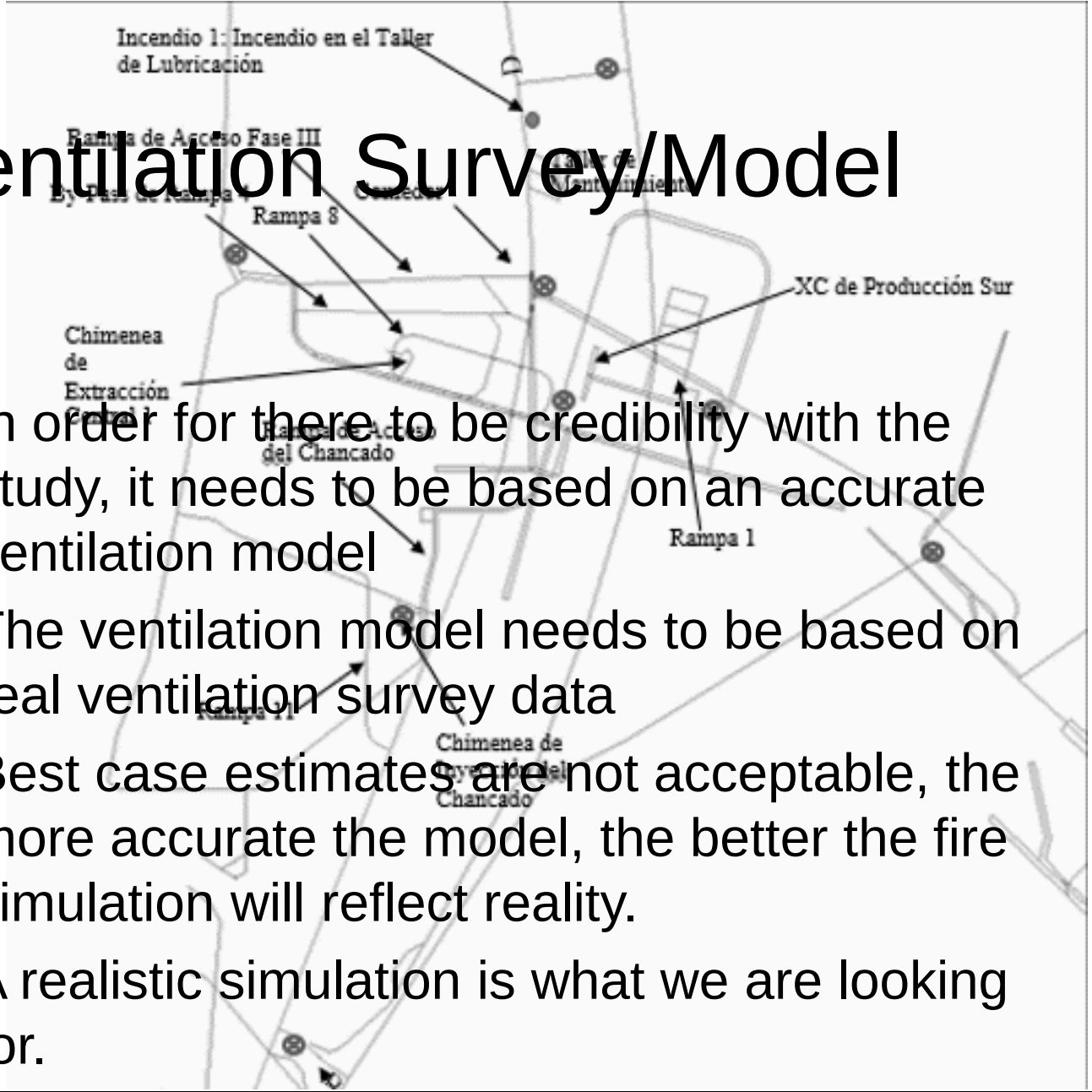
Study Methodology



- Initial ventilation survey,
- Development of ventilation model,
- Correlation of ventilation model,
- Hazards analysis,
- Development of fire simulation model,
- Analysis of individual fire scenarios

Ventilation Survey/Model

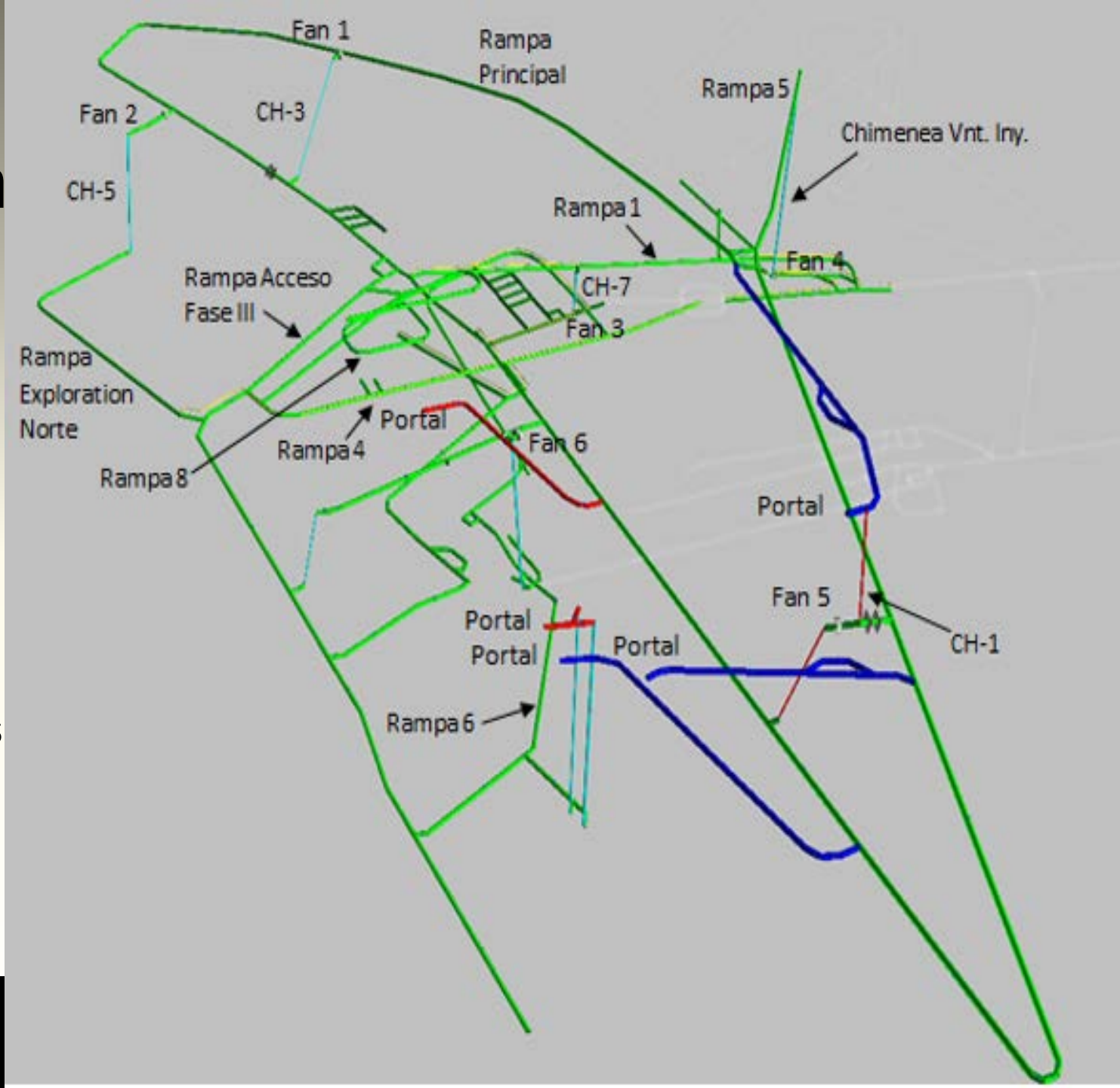
Full P/Q Survey, All Measurements Properly Balanced, And The Model Correlated To Establish A Level Of Accuracy



- In order for there to be credibility with the study, it needs to be based on an accurate ventilation model
- The ventilation model needs to be based on real ventilation survey data
- Best case estimates are not acceptable, the more accurate the model, the better the fire simulation will reflect reality.
- A realistic simulation is what we are looking for.

The Ventilation Model

- The model correlation error was calculated at 4.6%
- Simulation Software was VnetPC Pro+



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Development of the Fire Model

Start with the ventilation model and add additional parameters to describe thermal conditions.

- Conductivity
- Diffusivity
- Rock Temperature
- Fan Curve Performance Operation
- System Inlet Atmospheric Conditions

Hazards Analysis

Hazards analysis provides focus for the study

- The process starts with a hazards analysis
- You can model a fire in any branch of a system, but is it realistic? Fire modeling takes a considerable amount of time, the fire types and locations need to be pared down.
- Hazards analysis identifies probable locations, fire types, and basic mitigation strategies already in existence.
- Hazards analysis is a basic ranking and consequence quantification study. This type of study is commonly used throughout the industry.

Basic Hazards Analysis

	CRITERIA TO ESTIMATE PROBABILITY	VALUE
Probability (P)	Probability that a danger becomes an incident more than 8 times per year	**HIGH 8**
	Probability that a danger becomes an incident between 2 and 8 times per year	**MEDIUM 4**
	Probability that the danger becomes an incident once per year	**LOW 2**
	Probability that a danger DOES NOT become an incident during the year	**INSIGNIFICANT 1**

	INJURIES – DAMAGES CRITERIA	VALUE
Consequence (C)	▪ Death of one or more people ▪ Permanent disability ▪ Irreparable and extensive damage to materials ▪ Production losses that affect forecasted results ▪ Stop operations affecting the Company's image	**HIGH 8**
	▪ Injuries with temporary disability on one or more person ▪ Reparable and partial damage to materials ▪ Production losses requiring special plans to recover	**MEDIUM 4**
	▪ Non-disabling injuries ▪ Damage to materials not affecting production process ▪ Minimum production losses. May be recovered within a short time	**LOW 2**
	▪ Almost losses	**INSIGNIFICANT 1**

		CONSEQUENCE (C)			
		1	2	4	8
PROBABILITY (P)	1	1	2	4	8
	2	2	4	8	16
	4	4	8	16	32
	8	8	16	32	64

CLASSIFICATION	MR = P x C
INTOLERABLE	32 a 64
MODERATE	8 a 16
TOLERABLE	1 a 4

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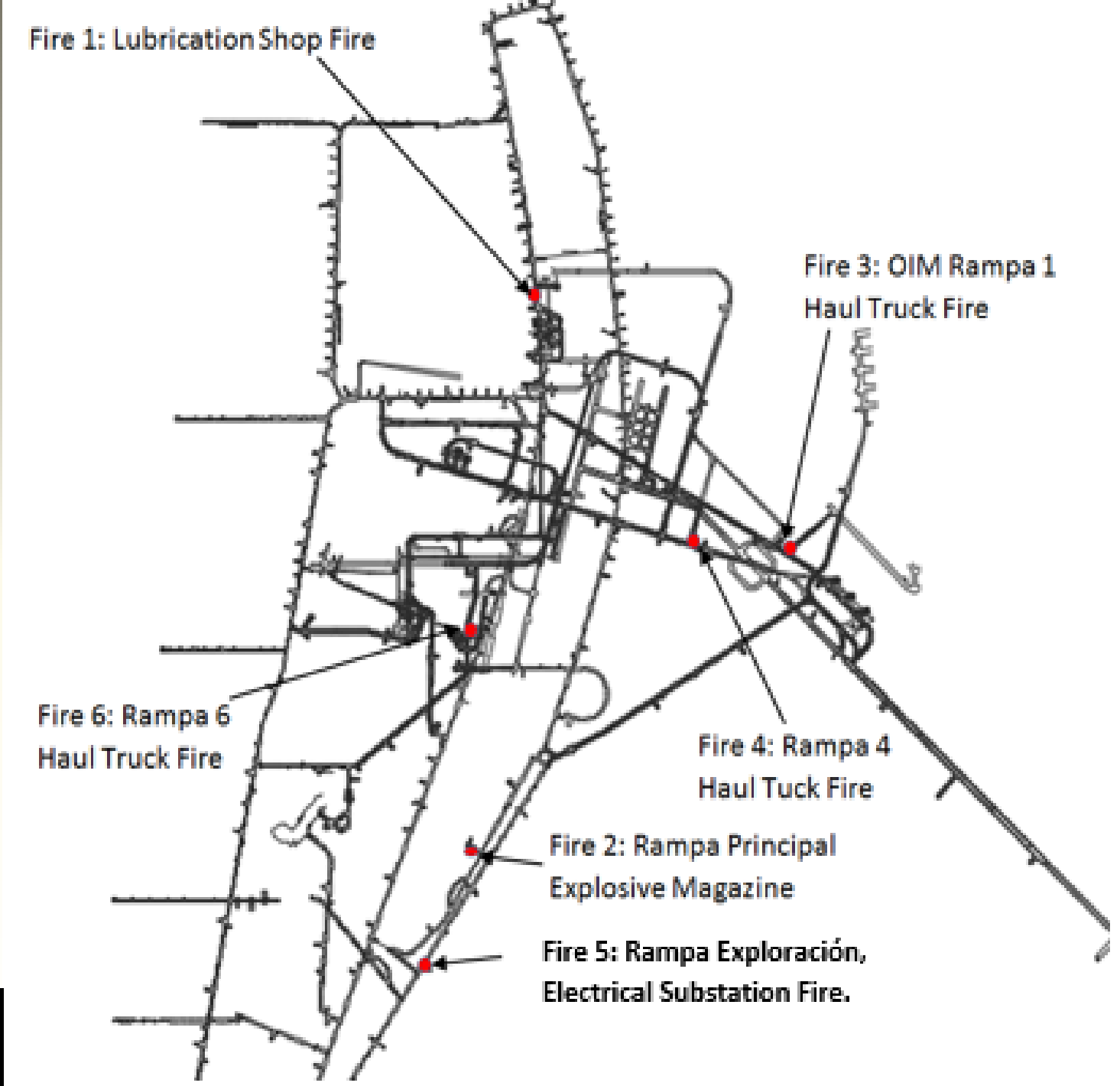
Results of Basic Hazards Analysis

Six different fire locations and types; lubrication shop, explosives magazine, electrical substation and haul trucks

Fire No.	Location	Fire Source
1	Rampa 10	Lubrication Shop
2	Rampa Principal	Explosives Magazine
3	Rampa 1	Haul Truck
4	Rampa 4	Haul Truck
5	Rampa Exploracion	Electrical Substation
6	Rampa 6	Haul Truck

Results of Basic Hazards Analysis



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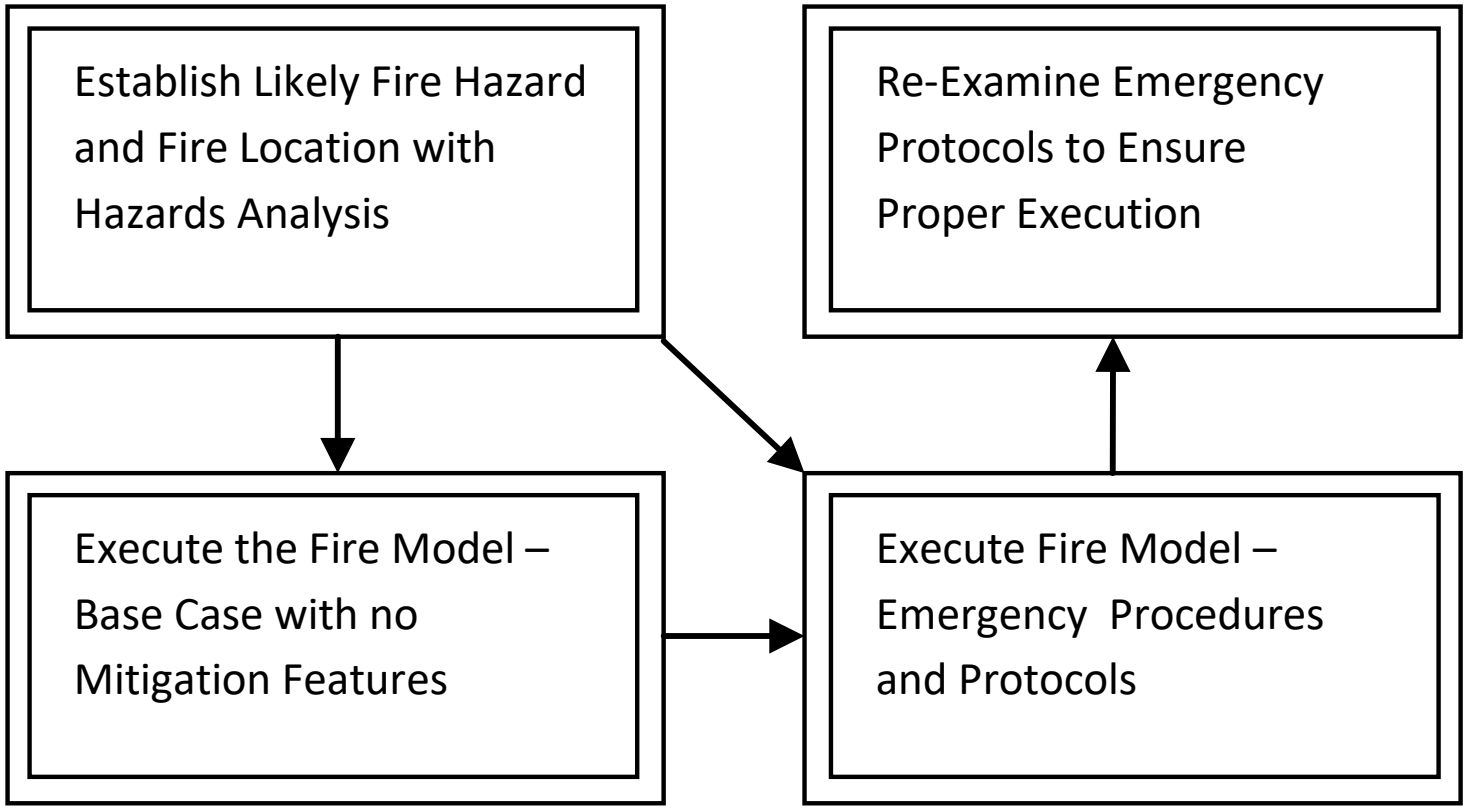
Fire Modeling Flow Chart

Models are set up to simulate hazards/fires and alternative mitigation procedures.



Two Modeled Scenarios (Focus)

Training Example
Test and Visually Demonstrate Current Procedures

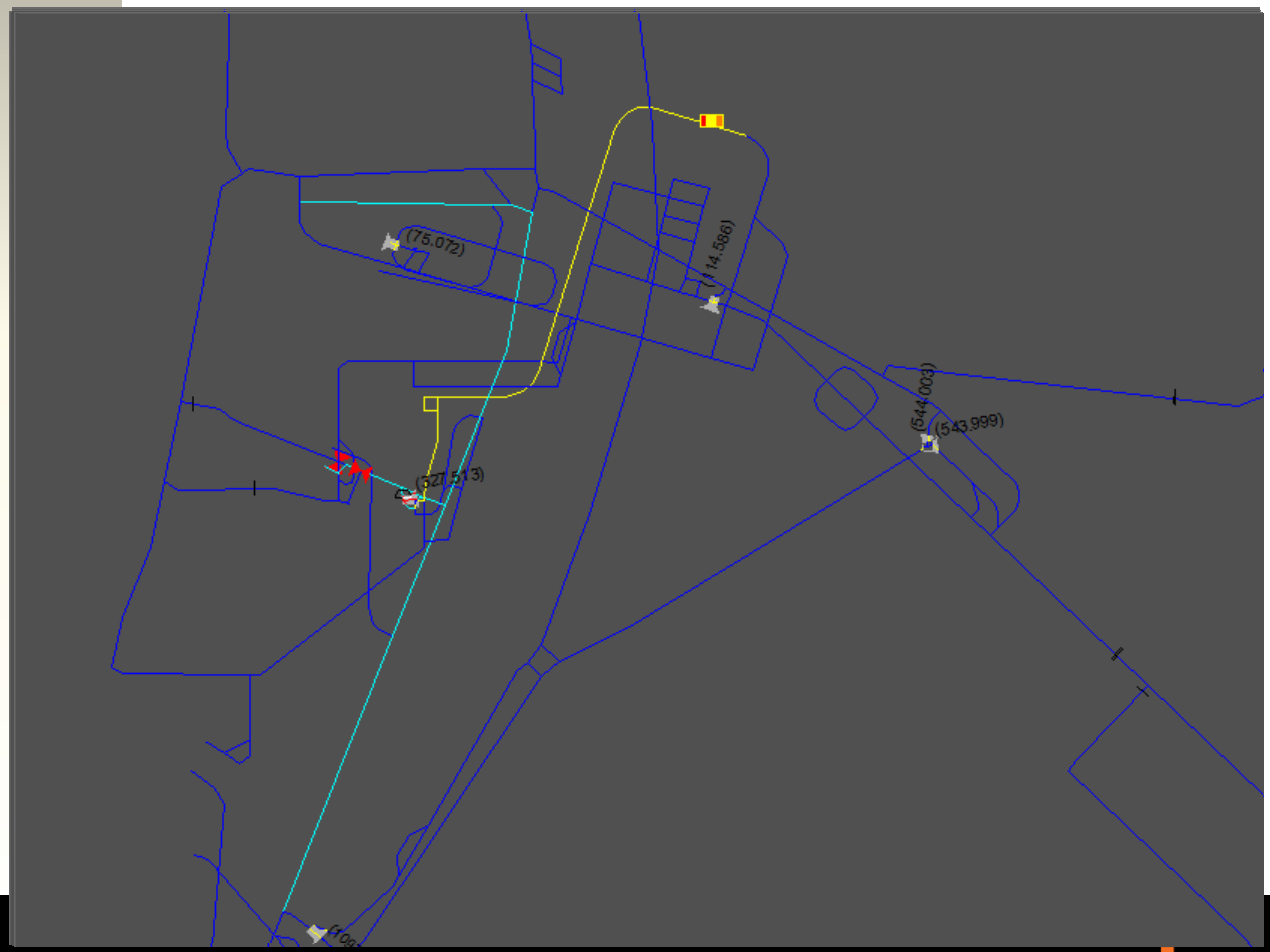
Mitigation Strategy
Identify design options to enhance emergency response

- Scenario to examine what happens if the fans are turned off (training, mitigation strategy)

  It was standard practice to drop the power to the mine in the event of a fire.
- Scenario with fire in lubrication shop (system design, mitigation strategy)

Training Example
Test and Visually Demonstrate Current Procedures

Current Layout – No Change to Fans



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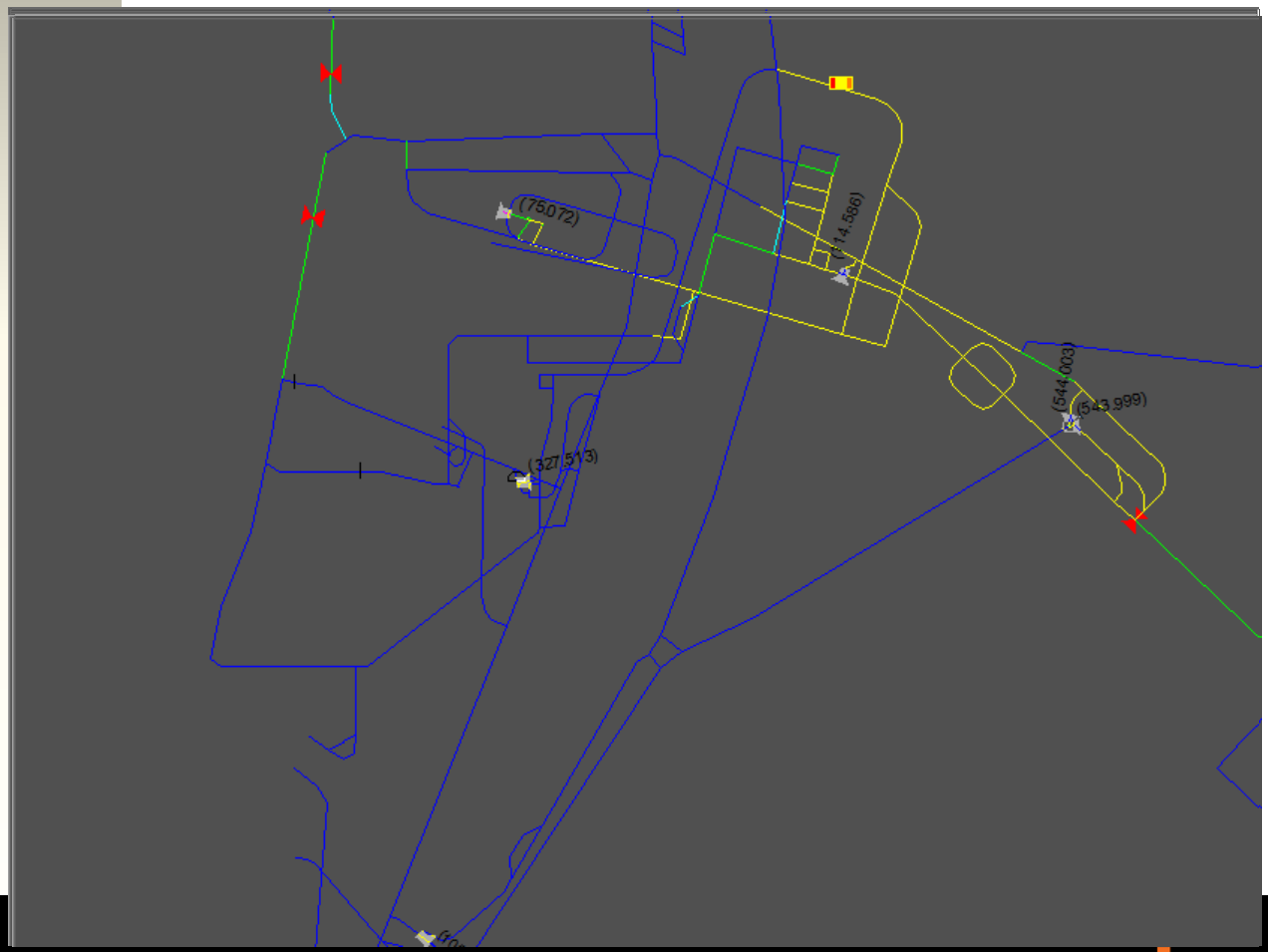
The Existing Procedure Shut Down the Power to the Underground in the Event of a Fire.

Current Layout – All Fans Turned Off at 5 Minutes



Training Example
Test and Visually Demonstrate Current Procedures

The Existing Procedure Shut Down the Power to the Underground in the Event of a Fire.

These models can be shown to management and emergency personnel to more easily/visually identify how a system may react during a fire.

Example - Why Leave Main Fans Operating

Do we know where the fire is at an instant

- The exact location of a fire is often difficult to determine during the initial stages of an emergency

Which fan should be turned off?

- The existing fans in the OIM and Tunnels are not equipped with individual shut-offs. New fan installations could be equipped
- Currently the fans are controlled by turning off all of the power in the underground. Power is used for items other than the fans that could be important during an emergency

Should all fans be turned off at the first indication of a fire?

- No, once the fans are turned off all control is lost
- All contamination/fumes will be trapped and will not be able to be flushed out of the ventilation system

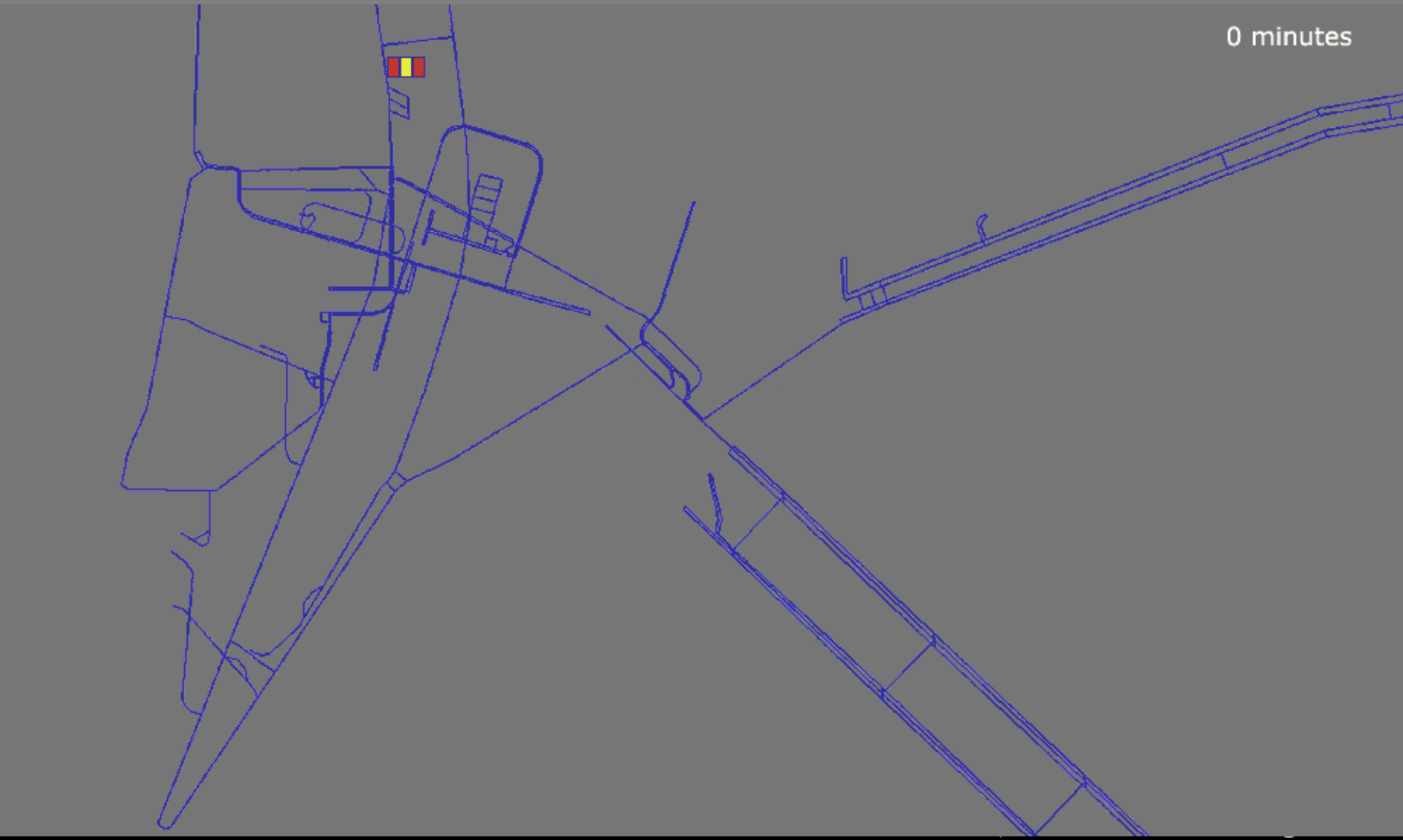
There is a lot of potential variance in determining what and how much of a combustible is burning and at what rate, this is why a bracketing or sensitivity study is important.

Fire Model 1: Low Intensity

Lubrication Shop – Lubrication Storage Fire

- Fires can be modeled with a high intensity or a low/medium intensity.
- Not all fires are going to be raging infernos
- The ventilation system will perform differently depending upon the magnitude of the fire
- This example shows the effects of a low intensity fire in a fuel storage area.

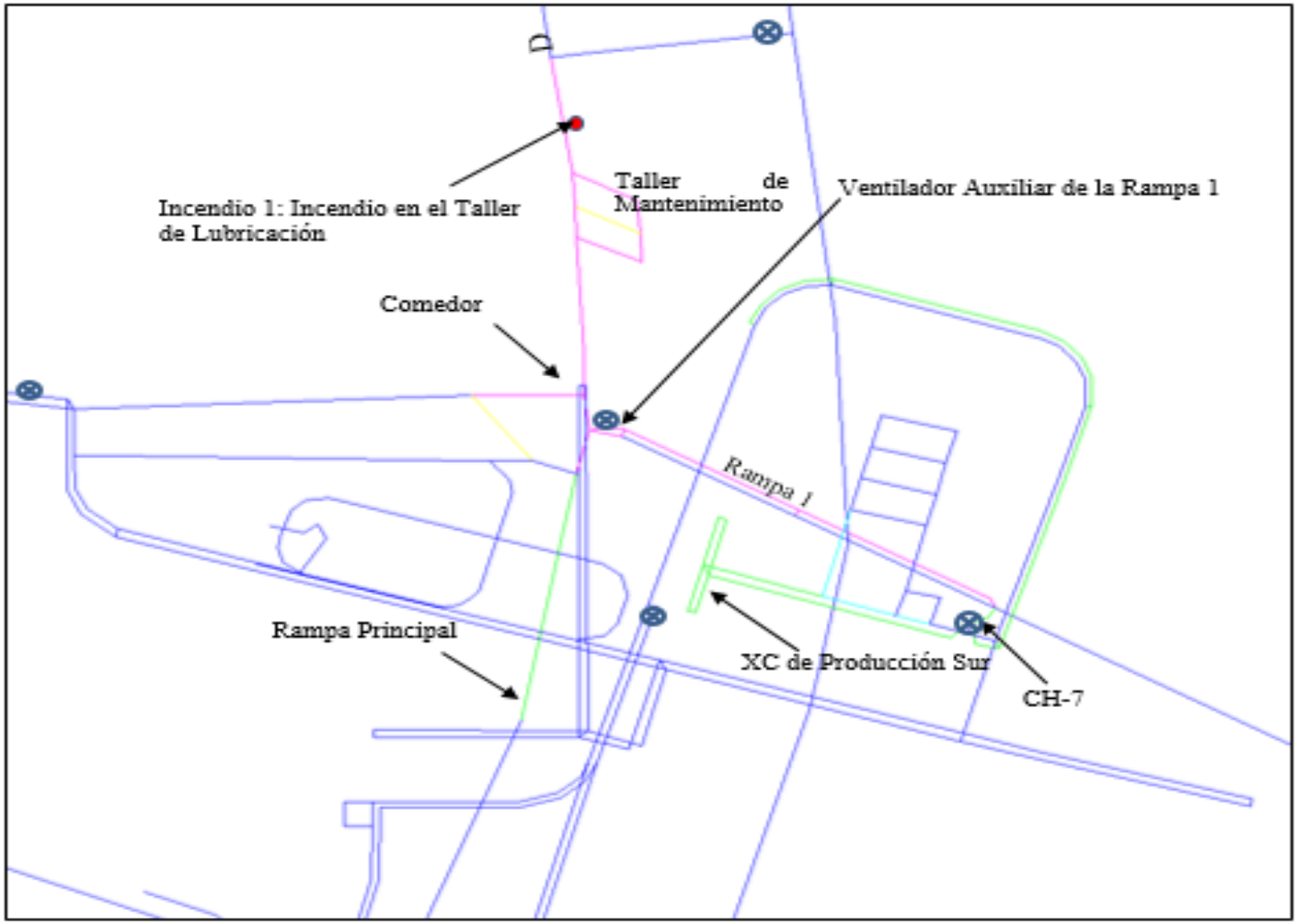
Fire Model 1: Animation of Low Intensity Fire Lubrication Shop/Lubricants Storage Area



Fire Model 1: Low Intensity

Lubrication Shop – Lubrication Storage Fire

(ppm)	%	Color
9-50	0.0009-0.005	
50-200	0.005-0.02	
200-400	0.02-0.04	
400-800	0.04-0.08	
800-1600	0.08-0.16	
1600-3200	0.16-0.32	
3200-6400	0.32-0.64	
6400-12,800	0.64-1.28	
>12,800	>1.28	



Propagation of fumes from the lubrication shop after approximately 5 minutes.

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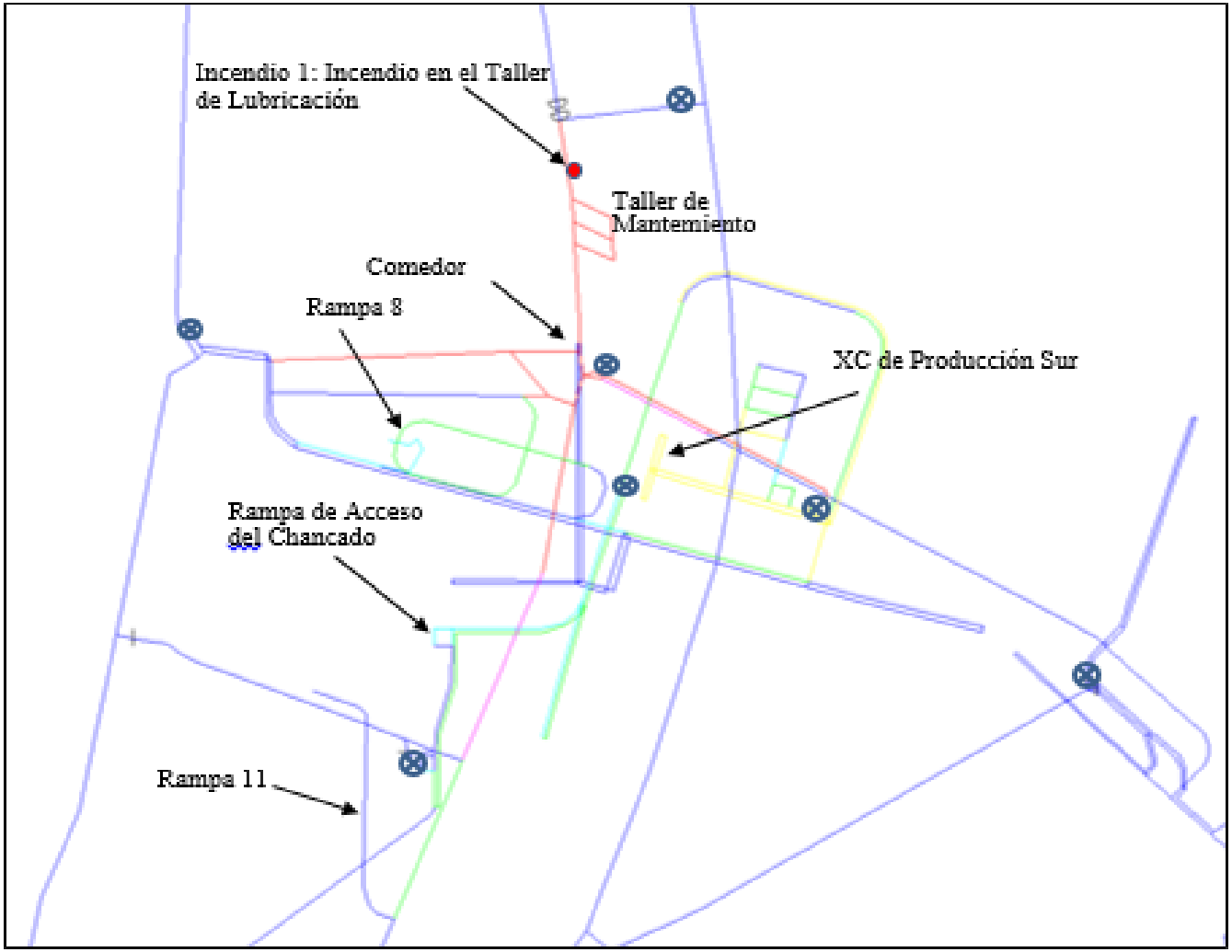

Propagation of fumes from the lubrication shop after approximately 10 minutes.

Fire Model 1: Low Intensity

Lubrication Shop – Lubrication Storage Fire

(ppm)	%	Color
9-50	0.0009-0.005	
50-200	0.005-0.02	
200-400	0.02-0.04	
400-800	0.04-0.08	
800-1600	0.08-0.16	
1600-3200	0.16-0.32	
3200-6400	0.32-0.64	
6400-12,800	0.64-1.28	
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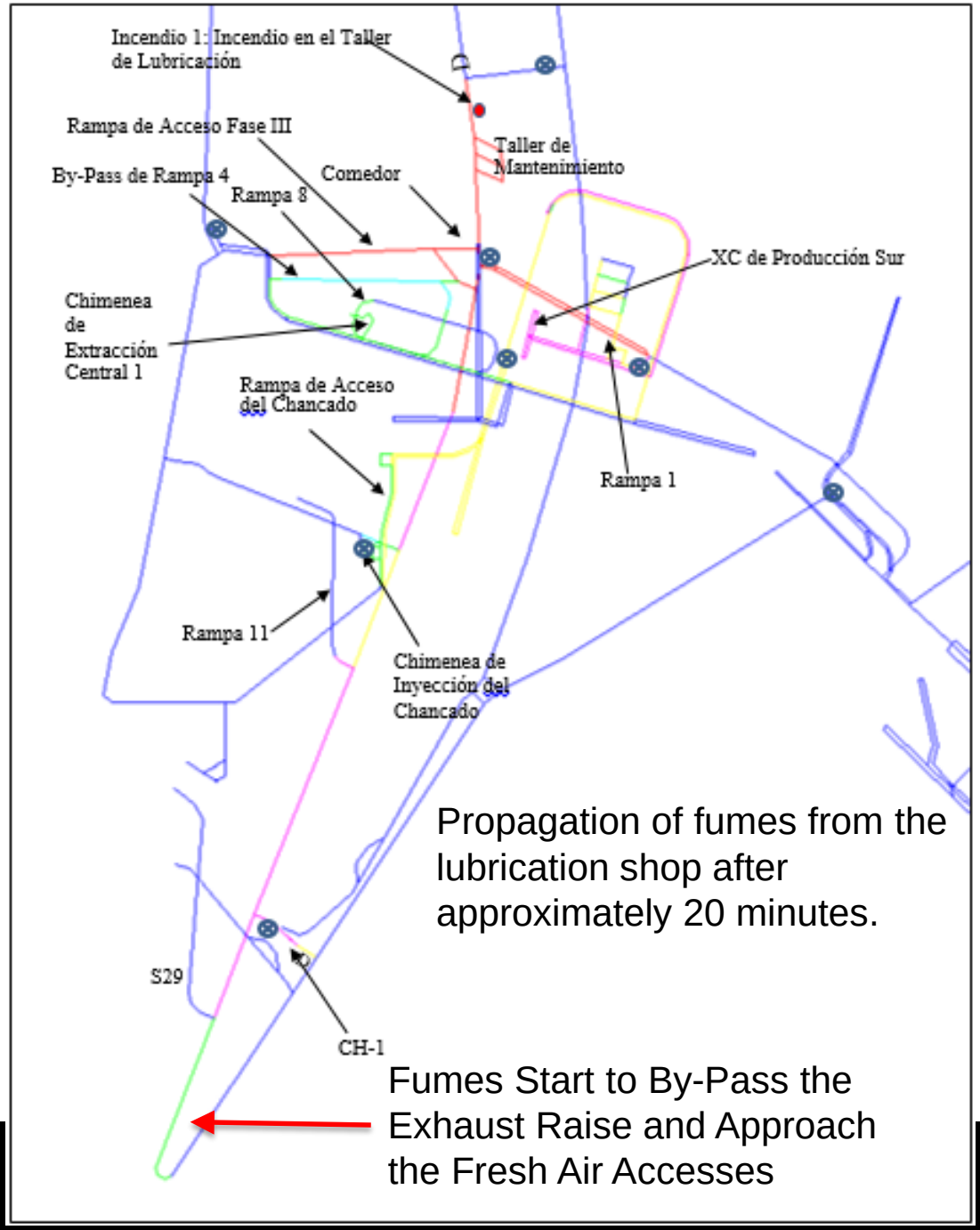

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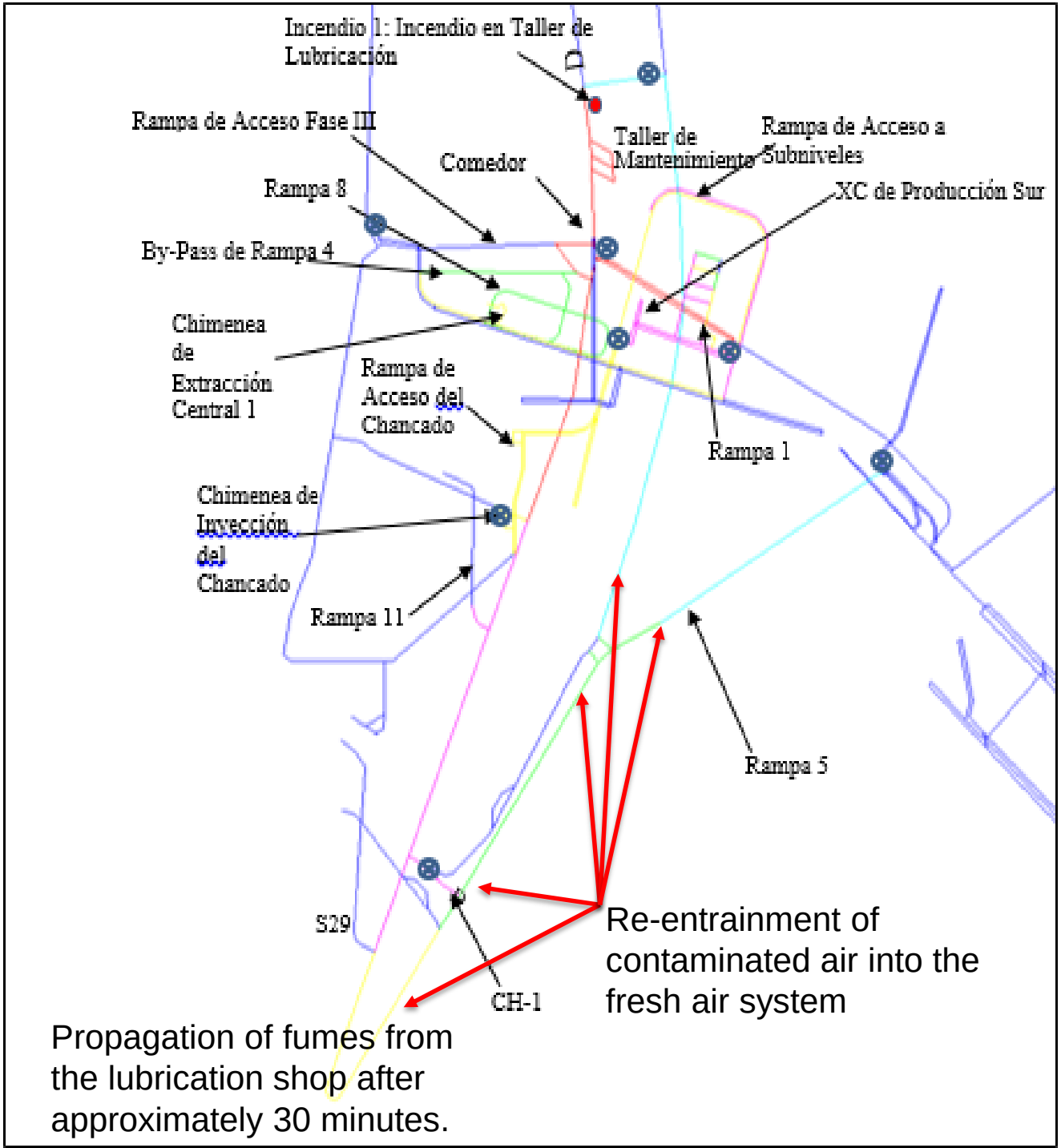
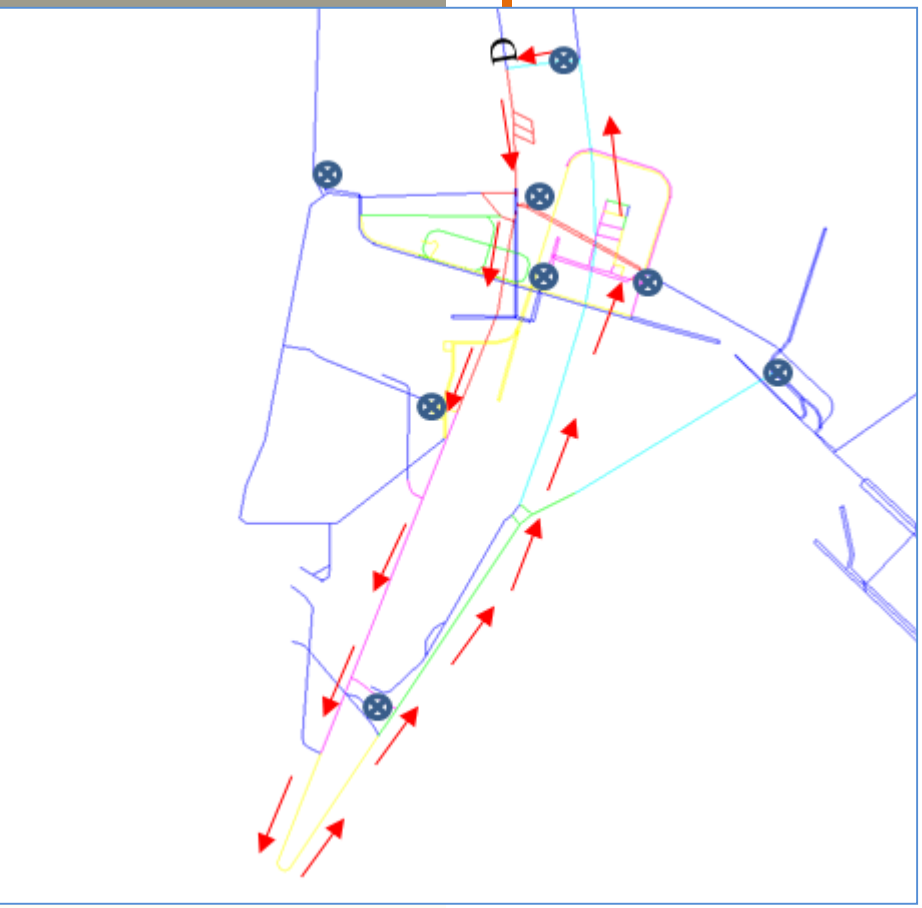
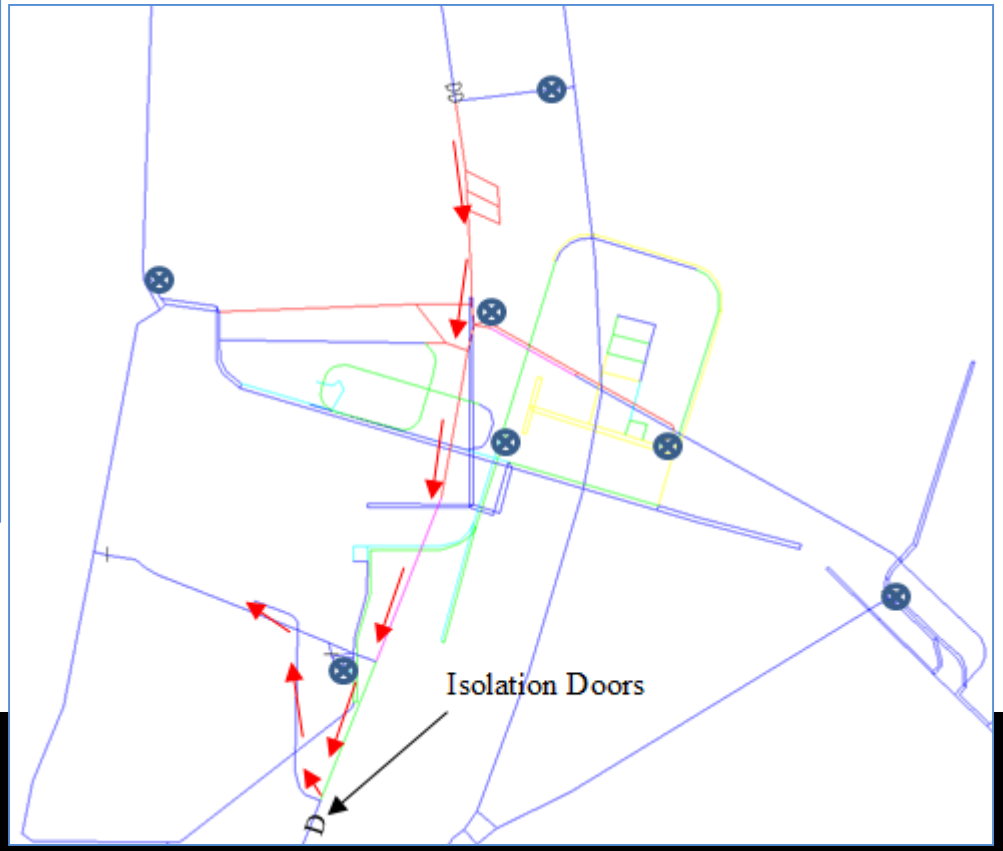


Fire Model 1:
Lubrication Bay Fire Mitigation Strategies



Recirculation Loop



Installation of an “Isolation” Door Would Prohibit Recirculation and not Block Egress

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Conclusions

- Fire simulation is an important and powerful tool to be used when designing a ventilation system.
- It can be used for both system design, training, and the development of procedures for mitigation
- The results of the study will only be as good as the inputs (an accurate correlated model is necessary to start the process)