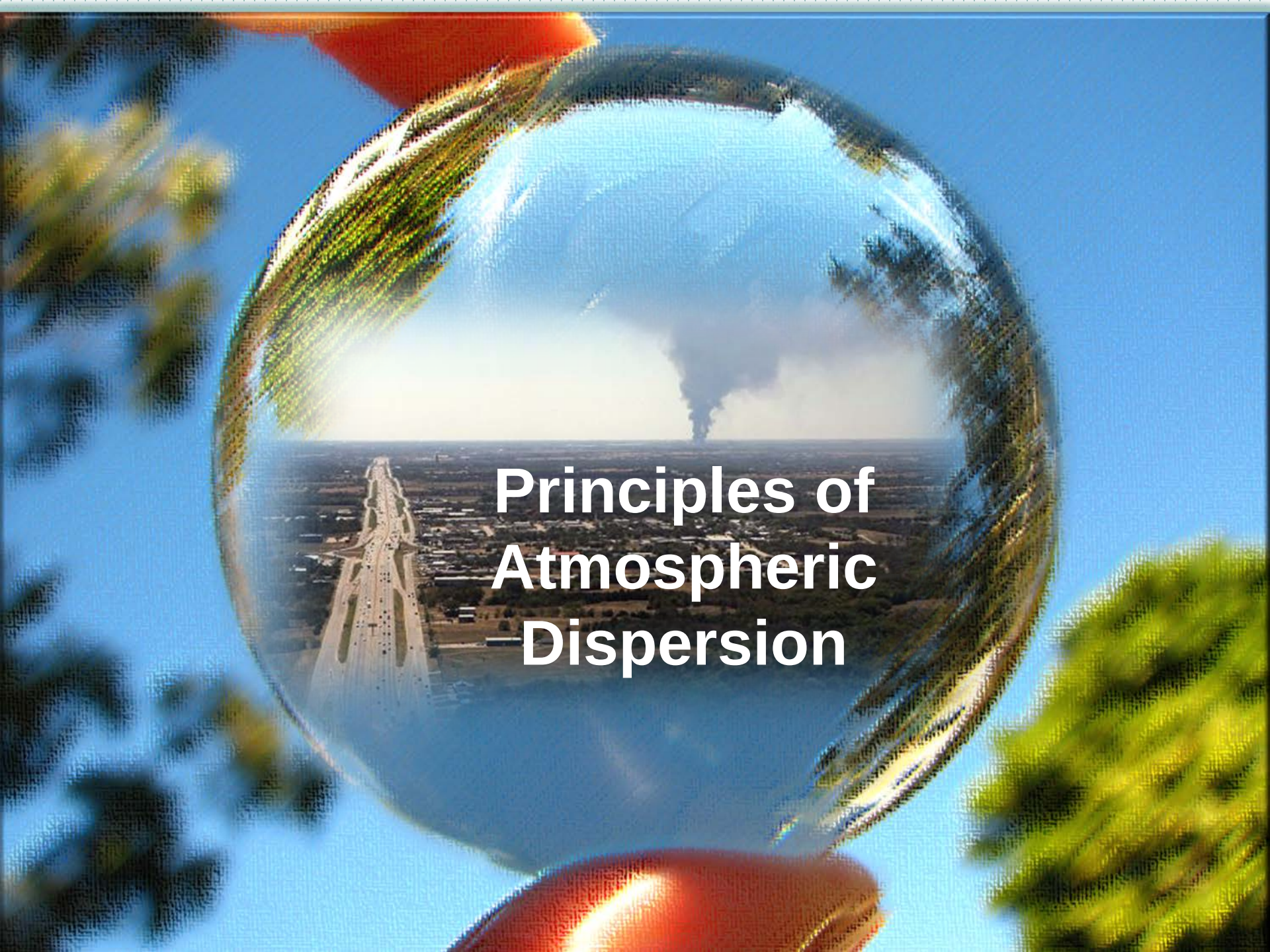
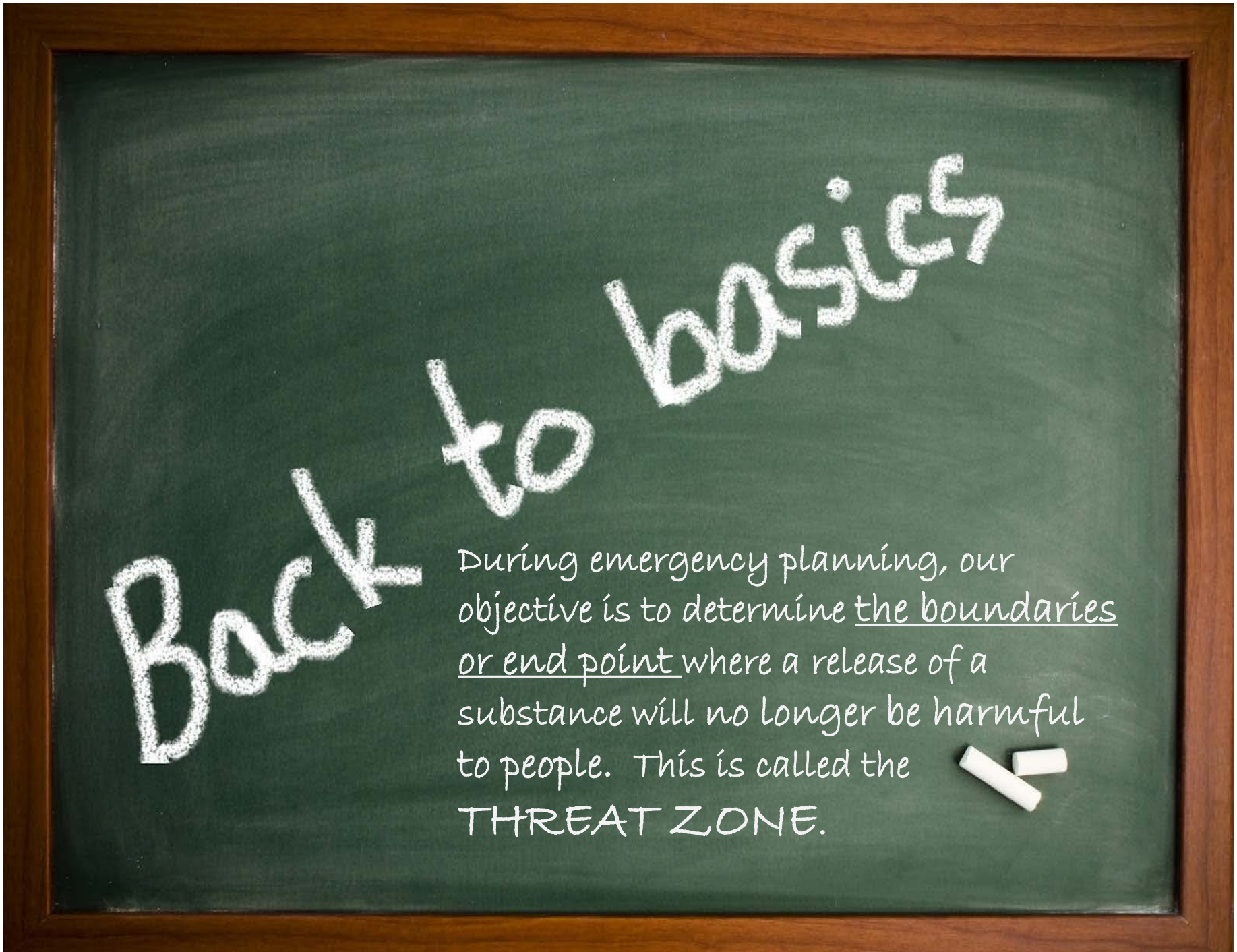

Principles of
Atmospheric
Dispersion

Atmospheric **Dispersion**

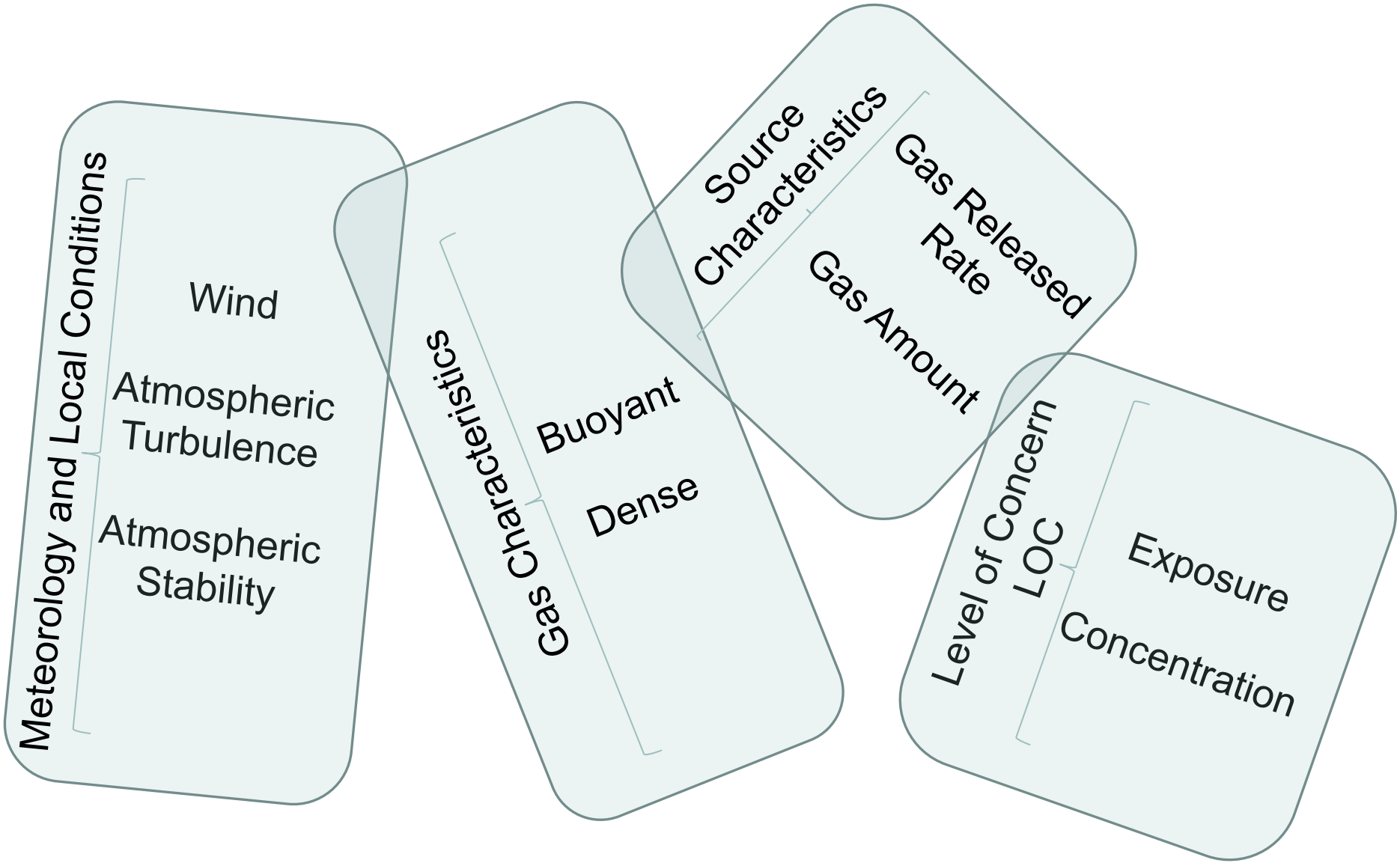
WHAT HAPPENS TO A CHEMICAL WHEN IT RELEASES INTO THE ATMOSPHERE?

Presentation Objective:

Use **basic scientific principles** to **improve planning and preparedness** for **hazardous chemical releases**


Back to basics
During emergency planning, our objective is to determine the boundaries or end point where a release of a substance will no longer be harmful to people. This is called the THREAT ZONE.

Elements Influencing Dispersion / Threat Zone



Elements Influencing Dispersion

Meteorology and Local Conditions

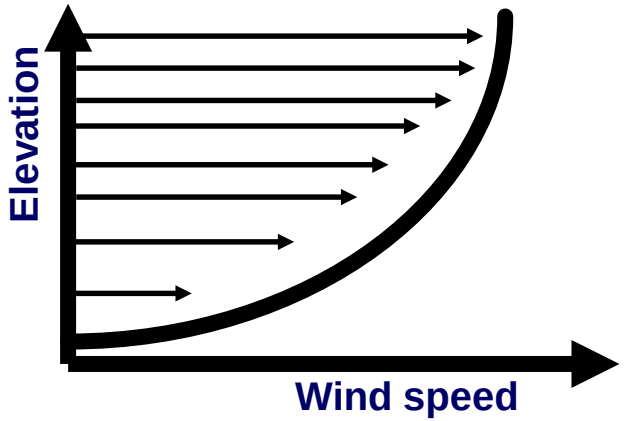
- Wind
- Atmospheric Turbulence
- Atmospheric Stability

Elements Influencing Dispersion

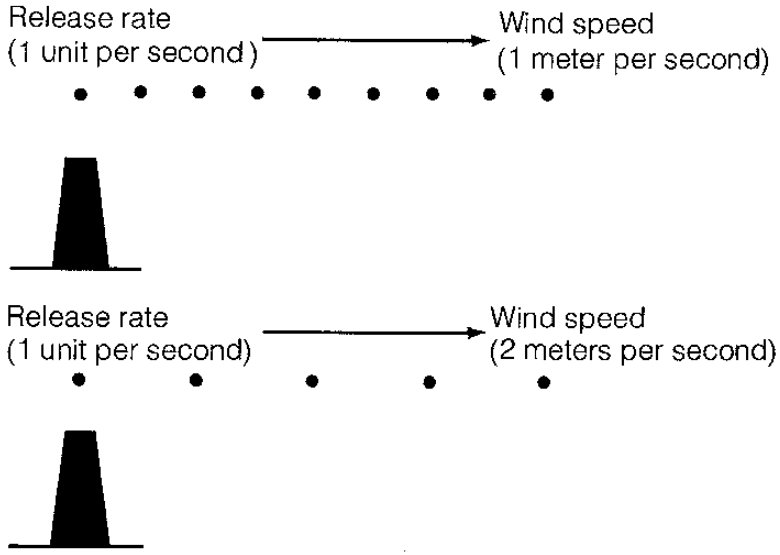
Meteorology and Local Conditions

Wind

As elevation increases the wind speed increases



Wind speed affects dilution

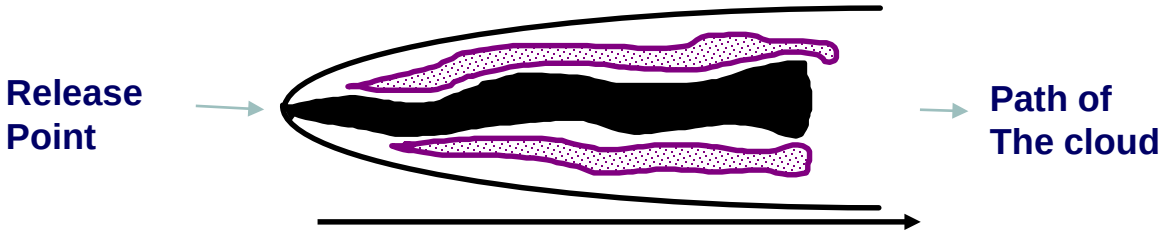


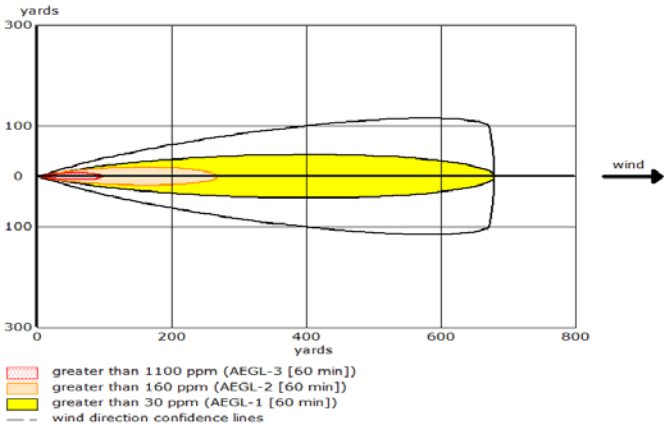
Atmospheric Turbulence

Elements Influencing Dispersion

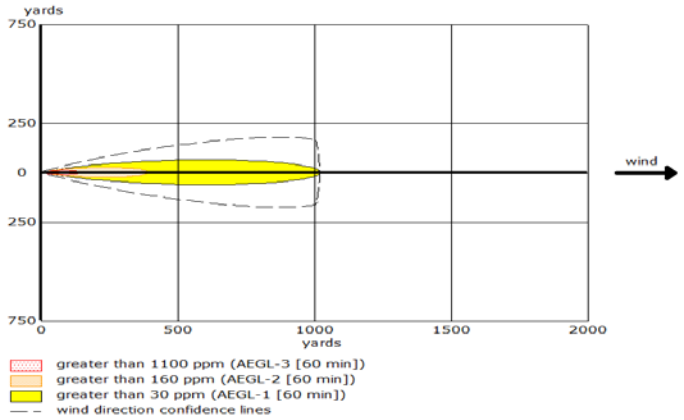
Gas releases have a high concentration within their initial central core, and a lower gas concentration at their fringes, due to turbulence. Distance dilutes a gas release until the release reaches a boundary or end point.

Plume Boundaries and Concentration Distribution





Higher wind speed
Shorter Threat Zone



Lower wind speed
Longer Threat Zone

Forces Influencing Dispersion

Meteorology and Local Conditions

Atmospheric Turbulence

Thermal Turbulence

Caused by heating/cooling of earth surface

Typical vertical flows

The way in which land features modify patterns of air flow. Wind typically shifts speed and direction as it flows up or down slopes, around large hills and obstacles and valleys - turning where terrain features turn.

Mechanical Turbulence

Caused by air moving over and around structures/vegetation

Affected by surface roughness

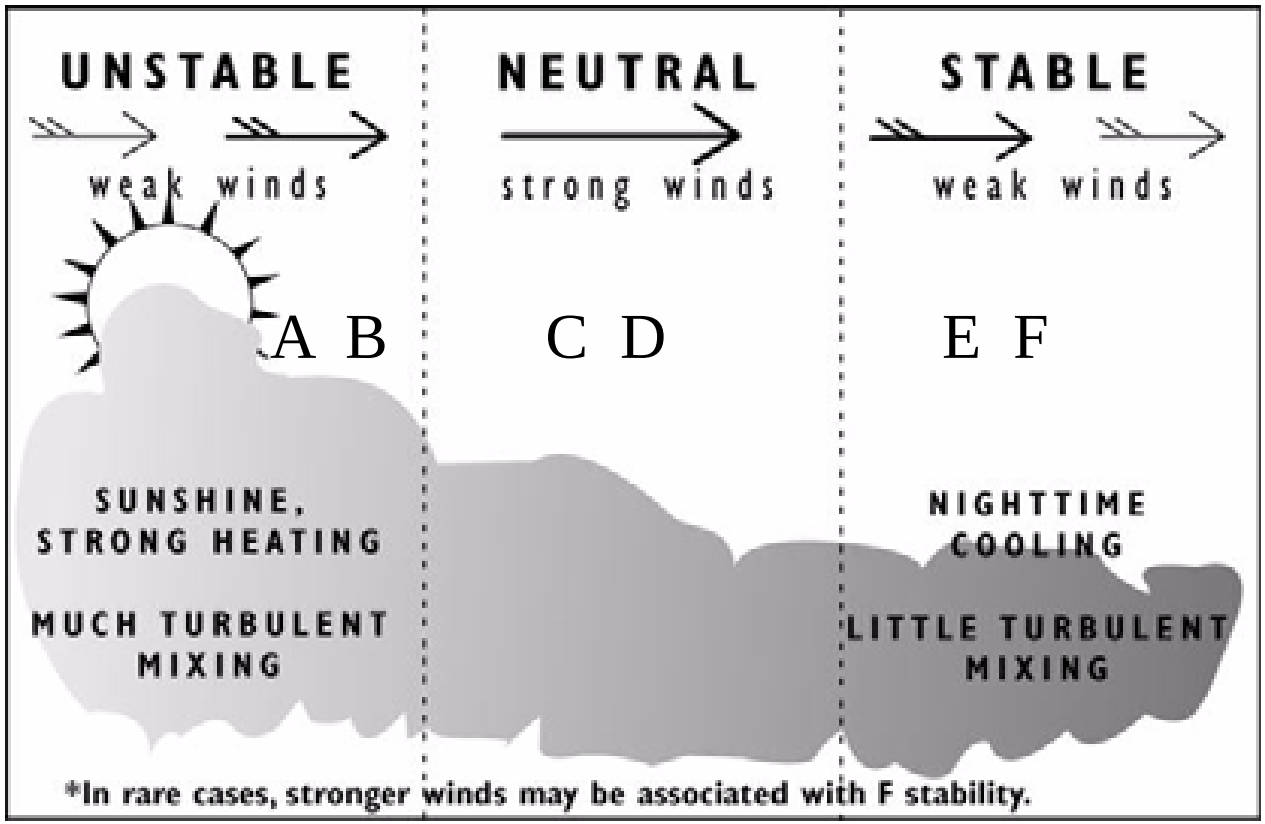
Increases with wind speed

Forces Influencing Dispersion

Meteorology and Local conditions

Atmospheric Stability

Atmospheric stability is an index of the amount of atmospheric turbulence present
The greater the turbulence, the better the diffusion



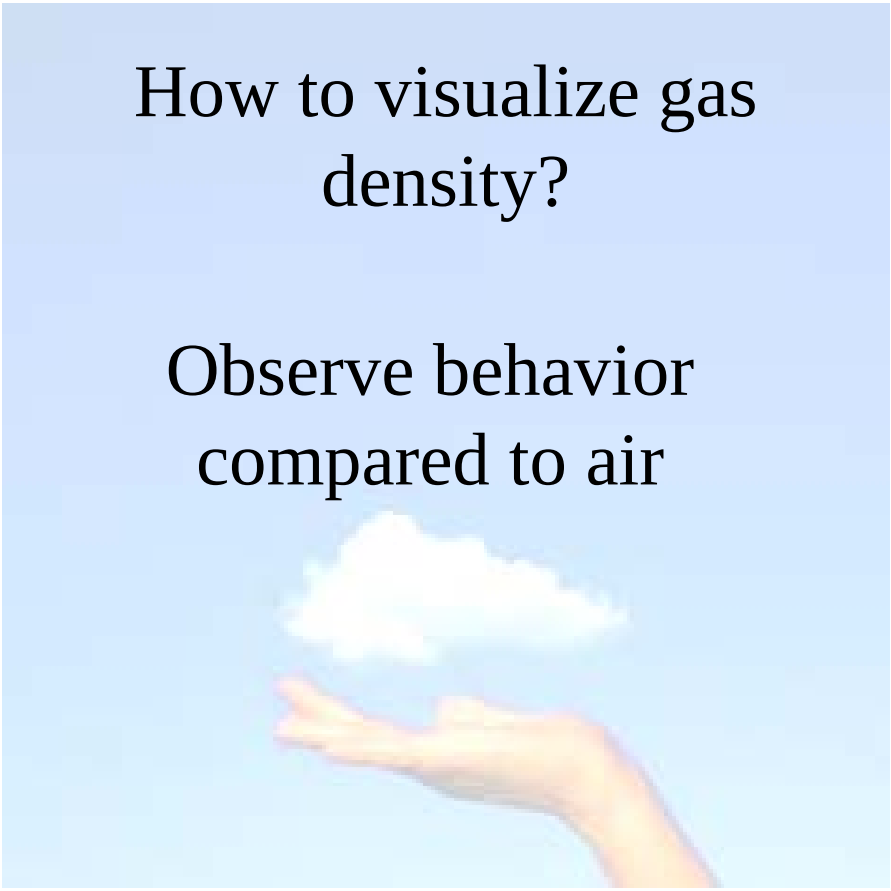
Elements Influencing Dispersion

Gas Characteristics

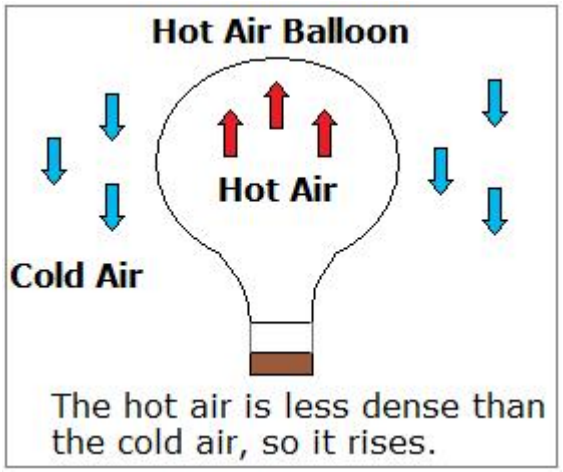
- Buoyant
- Dense

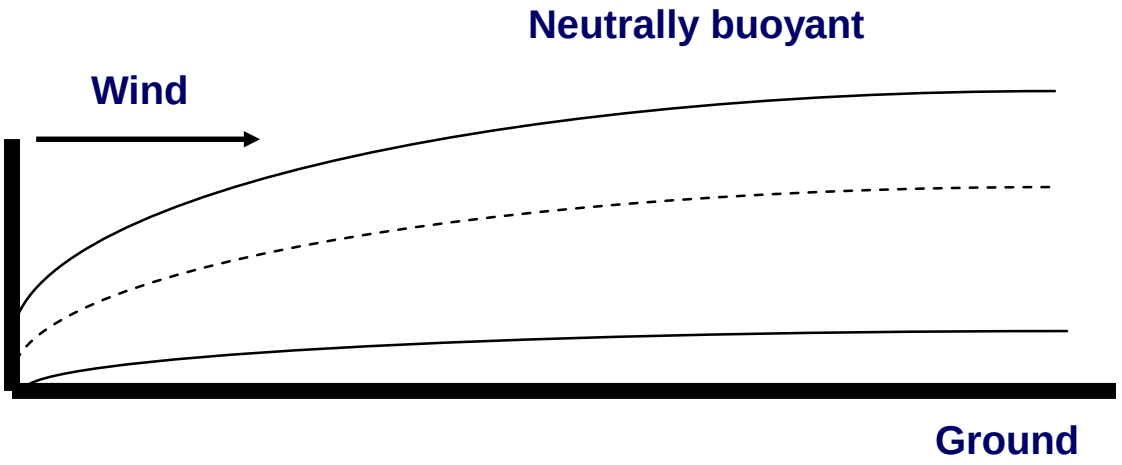
How to visualize gas density?

Observe behavior compared to air

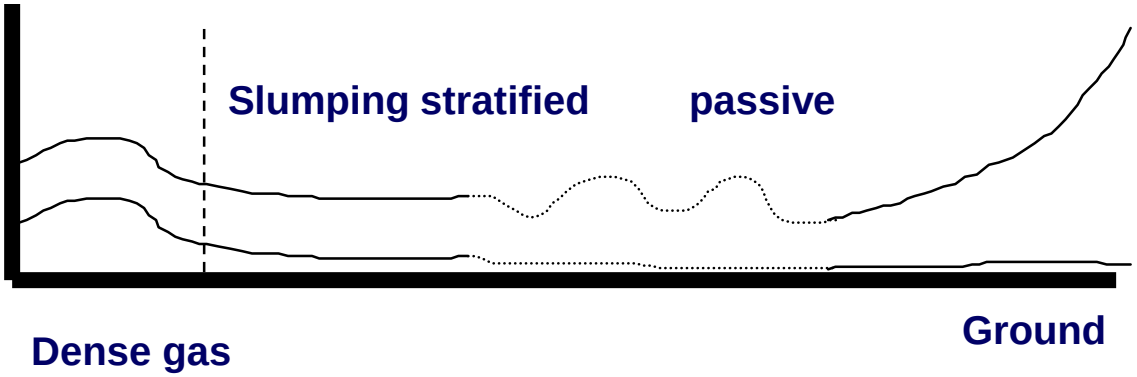


Buoyant and Heavy Gases



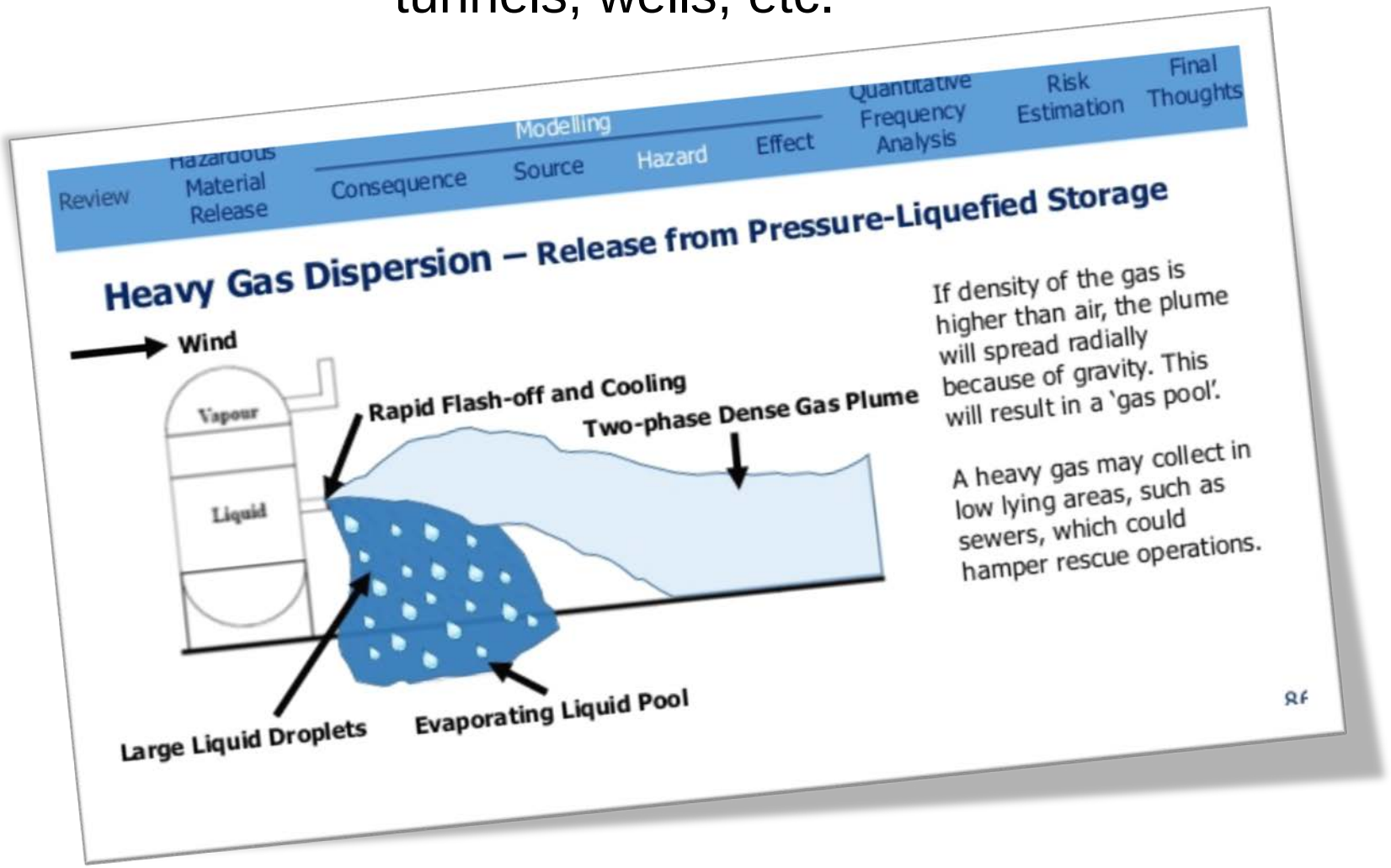


Gases denser than air affected by gravity and flow towards and along ground level

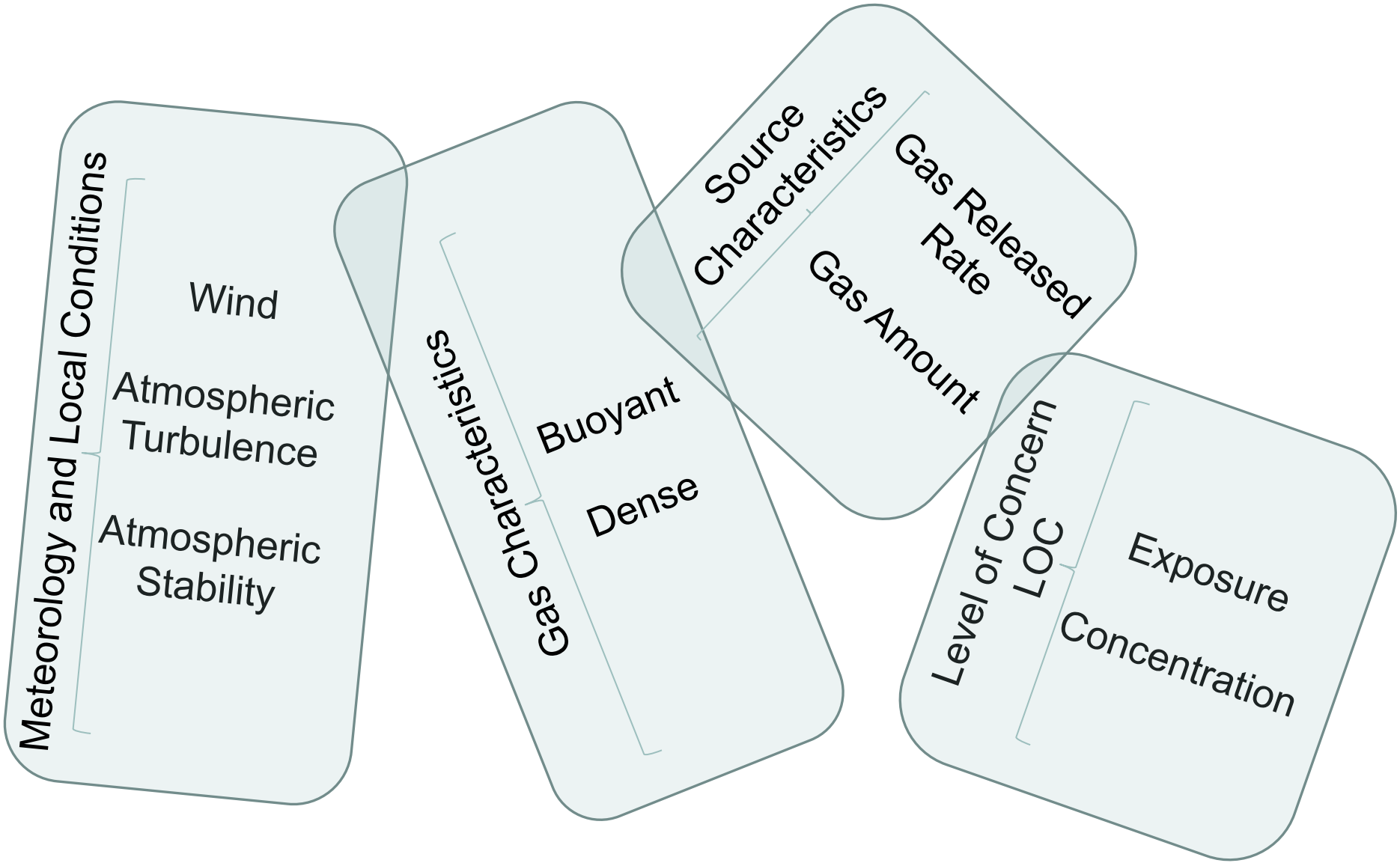


More about heavy gases

Denser gas clouds can disappear by entering basements, tunnels, wells, etc.



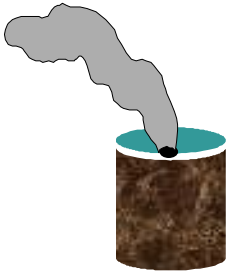
Elements Influencing Dispersion / Threat Zone

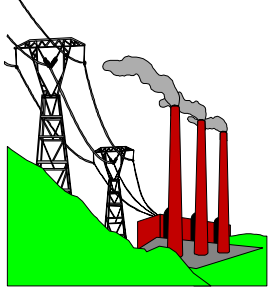


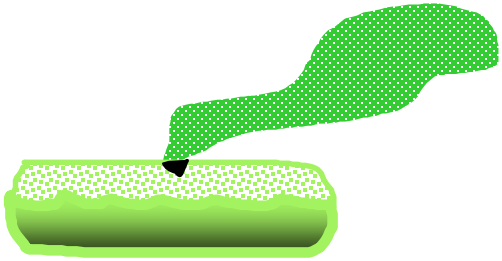
Elements Influencing Dispersion

Source Characteristics

Courtesy of LA County Fire



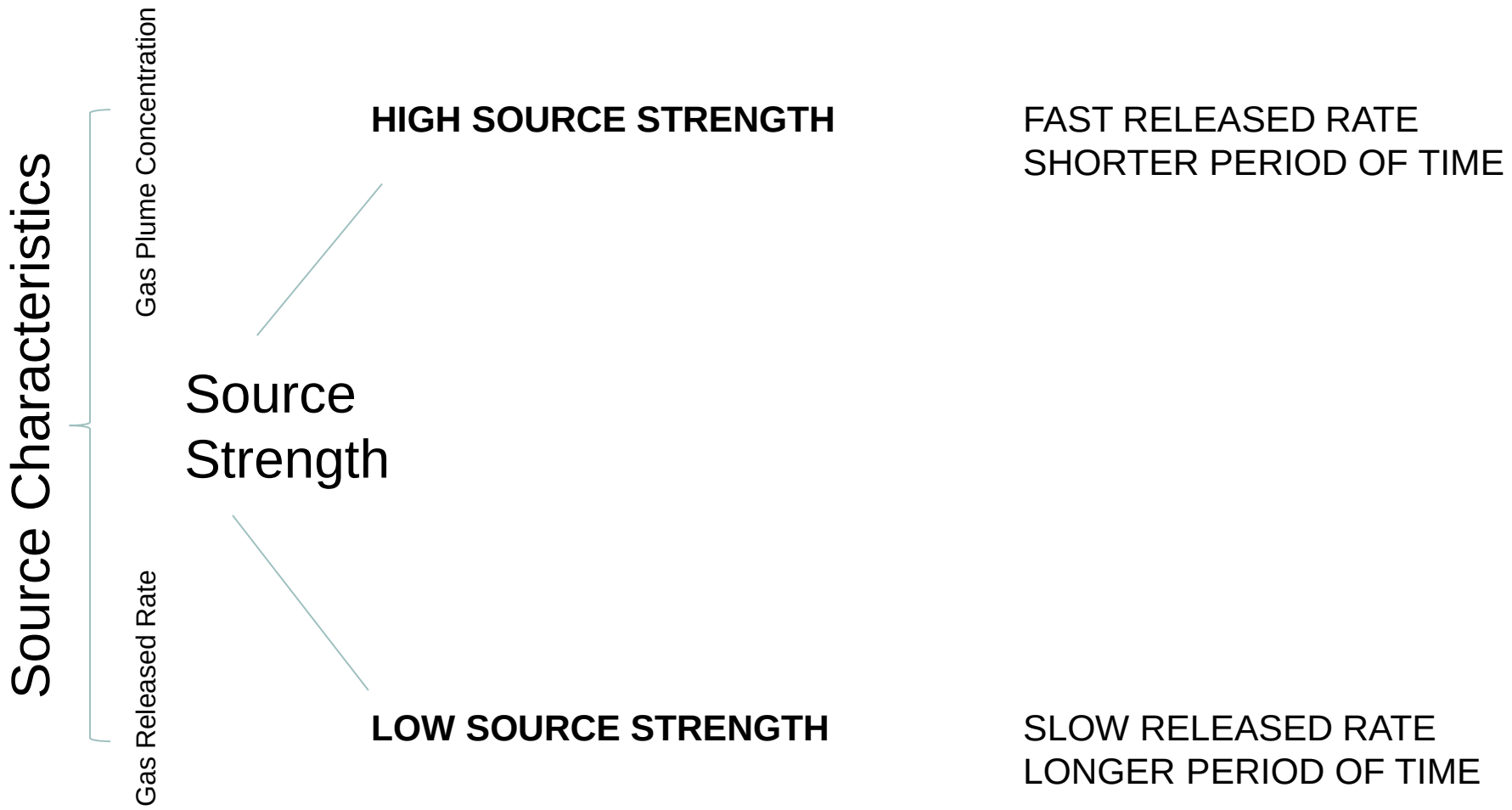




ALOHA can model four types of sources:

Source	Toxic Scenarios	Fire Scenarios	Explosion Scenarios
Direct			
Direct Release	Toxic Vapor Cloud	Flammable Area (Flash Fire)	Vapor Cloud Explosion
Puddle			
Evaporating	Toxic Vapor Cloud	Flammable Area (Flash Fire)	Vapor Cloud Explosion
Burning (Pool Fire)		Pool Fire	
Tank			
Not Burning	Toxic Vapor Cloud	Flammable Area (Flash Fire)	Vapor Cloud Explosion
Burning		Jet Fire or Pool Fire	
BLEVE		BLEVE (Fireball and Pool Fire)	
Gas Pipeline			
Not Burning	Toxic Vapor Cloud	Flammable Area (Flash Fire)	Vapor Cloud Explosion
Burning (Jet Fire)		Jet Fire	

Forces Influencing Dispersion



Forces Influencing Dispersion

Source Characteristics

Source Variance

VARIABLE Source Strength

Fluctuates between High and Low Source Strength over time

PUDDLE
TANK
GAS PIPELINE

CONSTANT Source Strength

Relatively unchanged over time (GAUSSIAN MODEL)
DIRECT

Source Characteristics

Gaussian Plume Equation

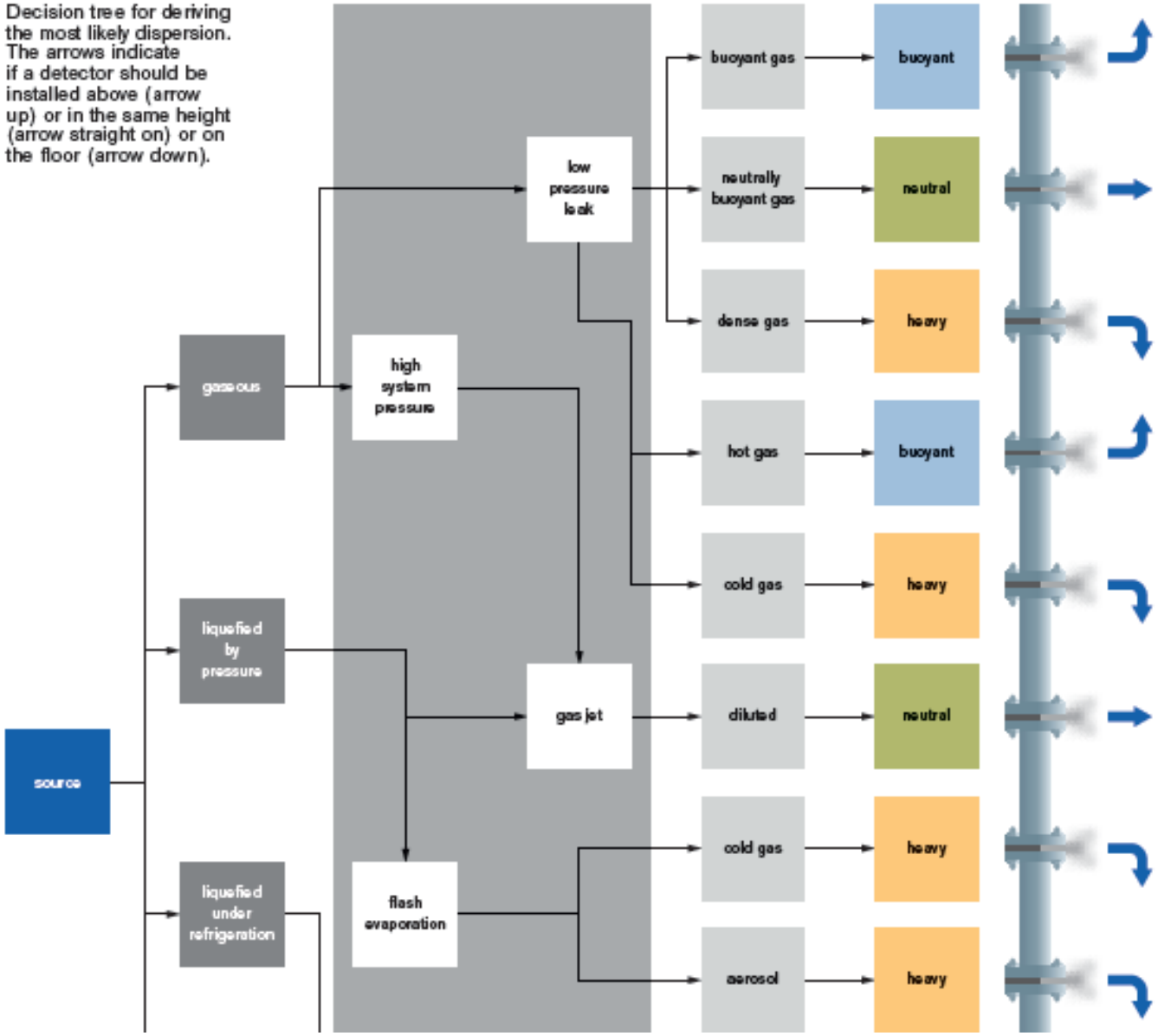
$$C(x,y,z) = \frac{Q}{2\pi u \sigma_y \sigma_z} \times \left[\exp - \left(\frac{y^2}{2\sigma_y^2}\right)\right]\left\{\exp\left(\frac{-(z-H)^2}{2\sigma_z^2}\right) + \exp\left(\frac{-(z+H)^2}{2\sigma_z^2}\right)\right\}$$

C = Concentration of the chemical in air. [M/L^3]
Q = Rate of chemical emission. [M/T]
u = Wind speed in x direction. [L/T]
σ_y = Standard deviation in y direction. [L]
σ_z = Standard deviation in z direction. [L]
y = Distance along a horizontal axis perpendicular to the wind. [L]
z = Distance along a vertical axis. [L]
H = Effective stack height. [L]

Source: www.draeger.com

RECOMMENDATION FOR TRANSMITTER PLACEMENT

Decision tree for deriving the most likely dispersion. The arrows indicate if a detector should be installed above (arrow up) or in the same height (arrow straight on) or on the floor (arrow down).



Elements Influencing Threat Zone

Level of Concern
LOC

- **Exposure**
- **Concentration**

Level of Concern Value
Level above which a threat to people or property may exist.

Generally, the ***lower the toxic LOC value*** for a substance, the ***more toxic the substance*** is by inhalation.

Chlorine Levels of Concern

Level of Concern

LOC

- Exposure
- Concentration

AEGLs (Acute Exposure Guideline Levels)

Final AEGLs for Chlorine (7782-50-5)

Exposure Period	AEGL-1	AEGL-2	AEGL-3
10 minutes	0.5 ppm	2.8 ppm	50 ppm
30 minutes	0.5 ppm	2.8 ppm	28 ppm
60 minutes	0.5 ppm	2 ppm	20 ppm
4 hours	0.5 ppm	1 ppm	10 ppm
8 hours	0.5 ppm	0.71 ppm	7.1 ppm

(NAC/NRC, 2013)

ERPGs (Emergency Response Planning Guidelines)

Chemical	ERPG-1	ERPG-2	ERPG-3
Chlorine (7782-50-5)	1 ppm ✪	3 ppm	20 ppm

✪ indicates that odor should be detectable near ERPG-1.
(AIHA, 2013)

PACs (Protective Action Criteria)

Chemical	PAC-1	PAC-2	PAC-3
Chlorine (7782-50-5)	0.5 ppm	2 ppm	20 ppm

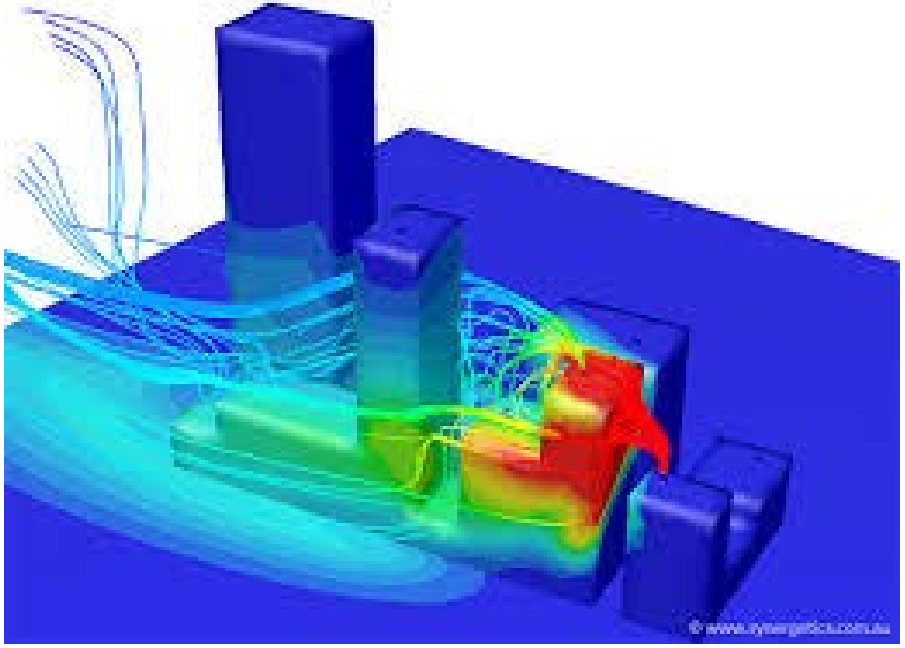
(SCAPA, 2012)
Subcommittee on Consequence Assessment and Protective Actions

IDLH: 10 ppm (NIOSH, 2003)

Modeling Dispersion

All plume models represent the “best guess” using the information available at the time.

NO plume modeling capability is 100% accurate and should NOT guide **all** decision making.



We're not worried how far the last wisp of the chemical plume travels downwind.

We are worried about how much of the plume is above our level of concern – the Threat Zone.

Scenario

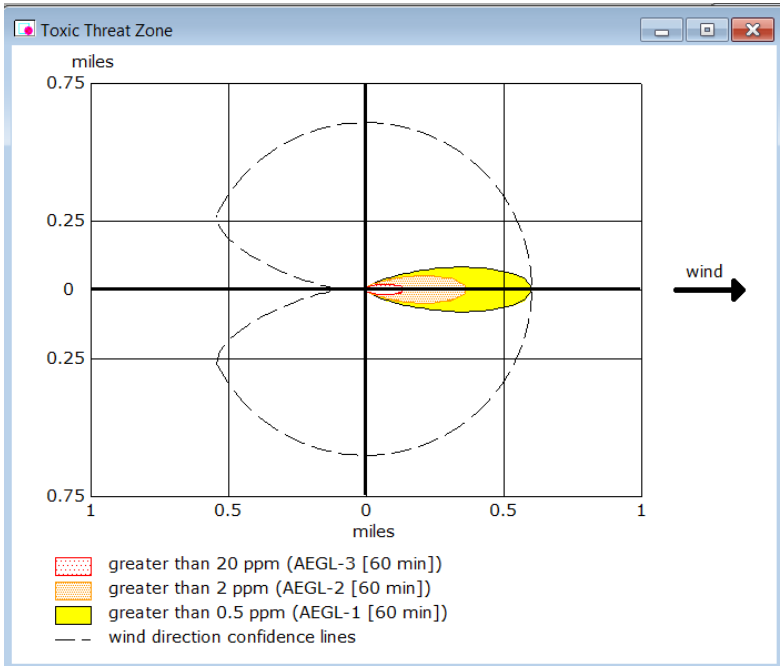
Location: Near Dallas, TX

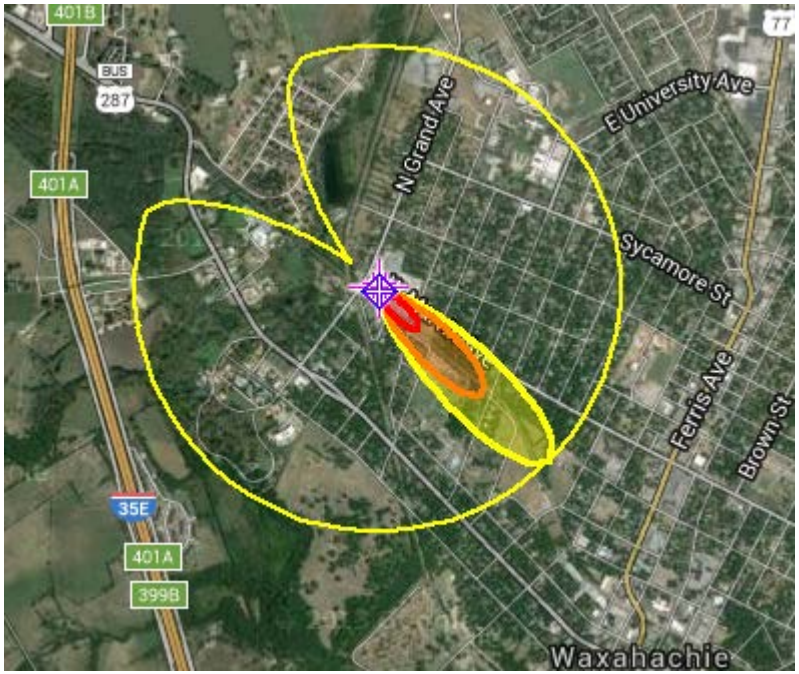
Source: Rupture in a Cylindrical Tank

Heavy Gas: Chlorine

Footprint: Approx. 1067 yards

Model: Heavy Gas



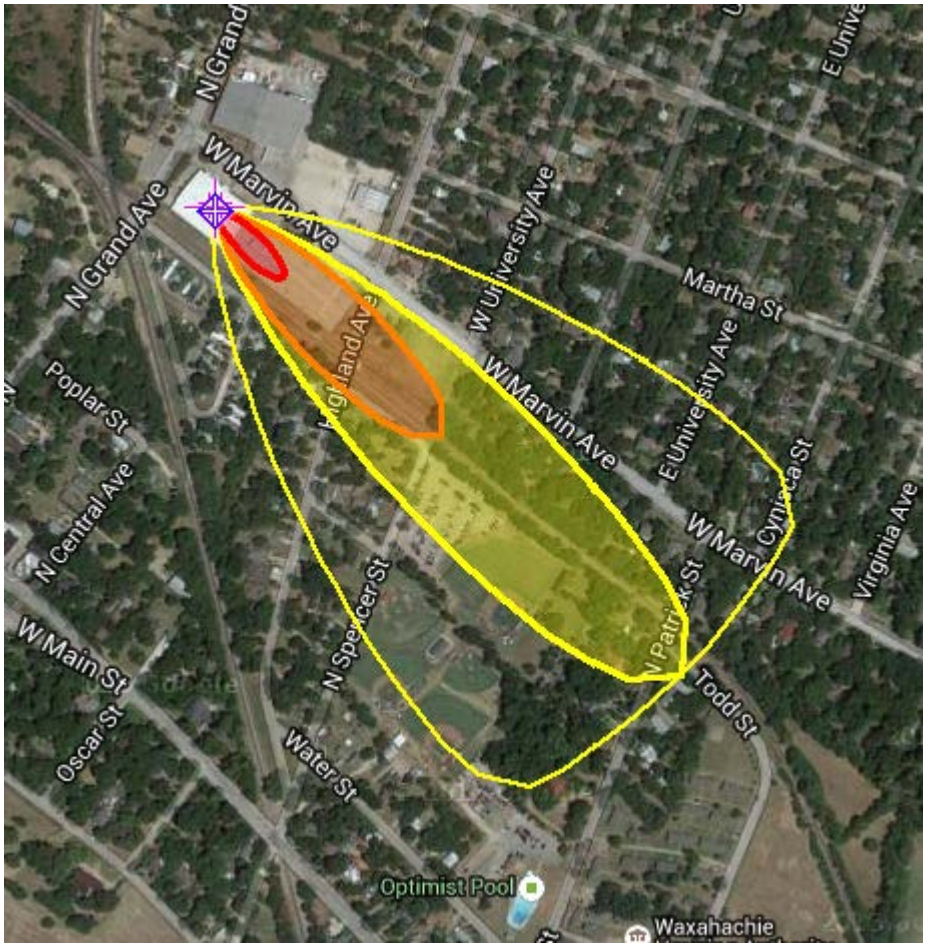


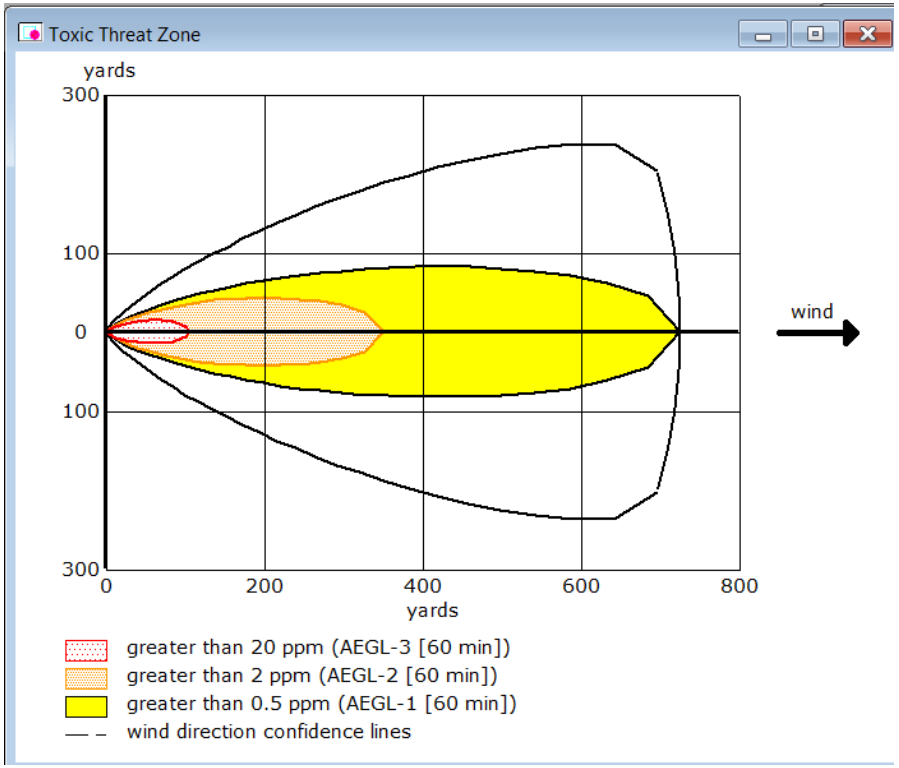
Considering that all other factors are the same, if you increase ..... what happens to footprint/plume of concern (shorter or longer)

Wind speed .... ?

When we increased wind speed in ALOHA, the model reached a distance of <1067yards

Shorter (dispersed faster)



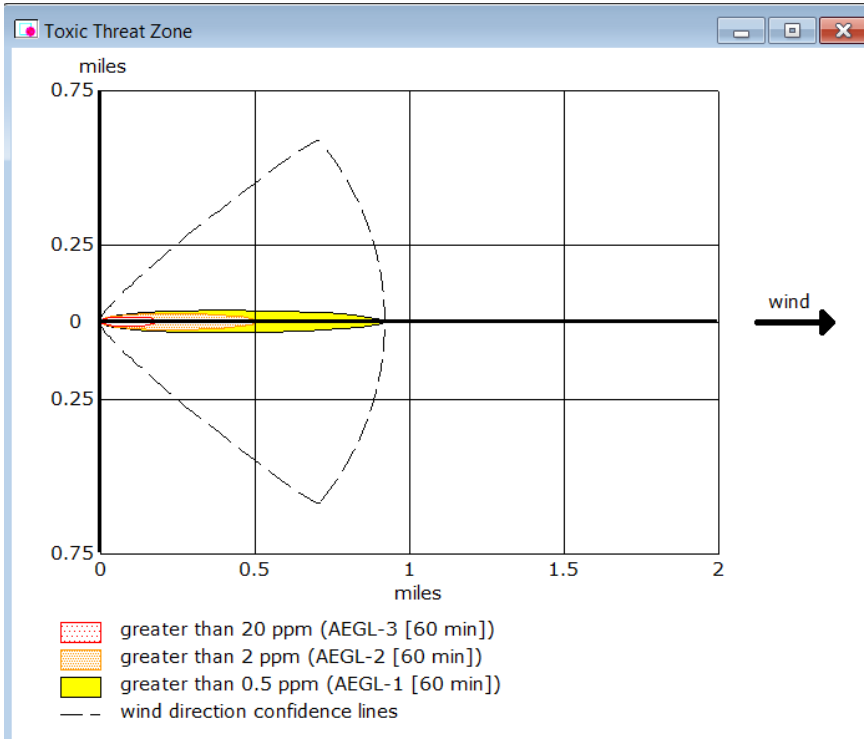


Considering that all other factors are the same, if you increase ..... what happens to footprint/plume of concern (shorter or longer)

Atmospheric stability towards F .... ?

When we increased Atmospheric Stability towards F, the model reached a distance >1067 yards

Longer (more stable atmosphere).

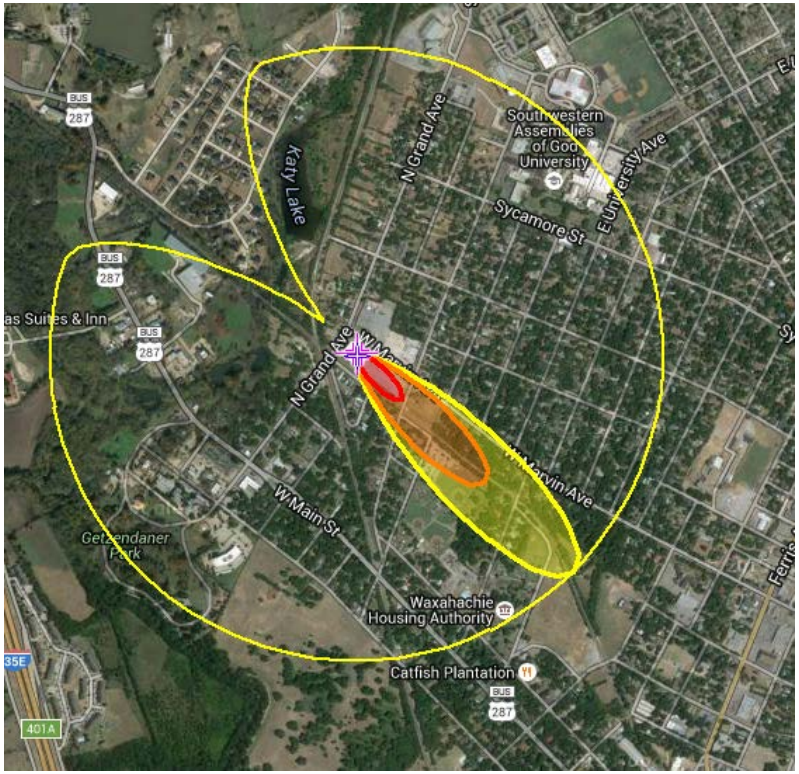


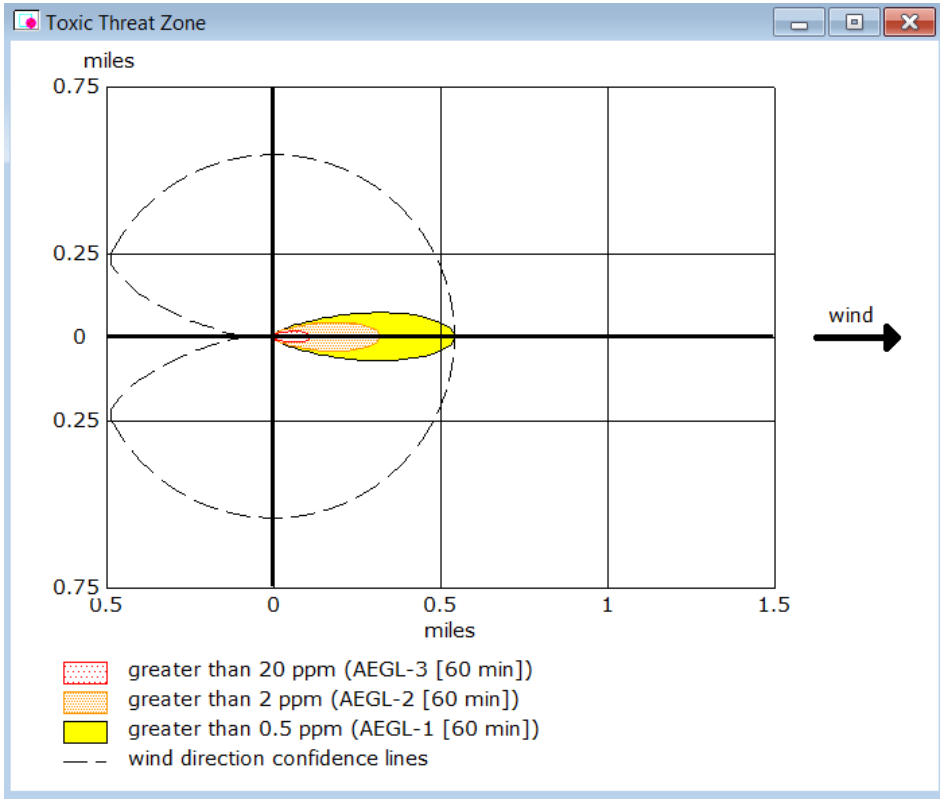
Considering that all other factors are the same, if you increase ..... what happens to footprint/plume of concern (shorter or longer)

Ground roughness .... ?

When we increased ground roughness, the model reached a distance of <1067 yards.

Shorter (dispersed faster)



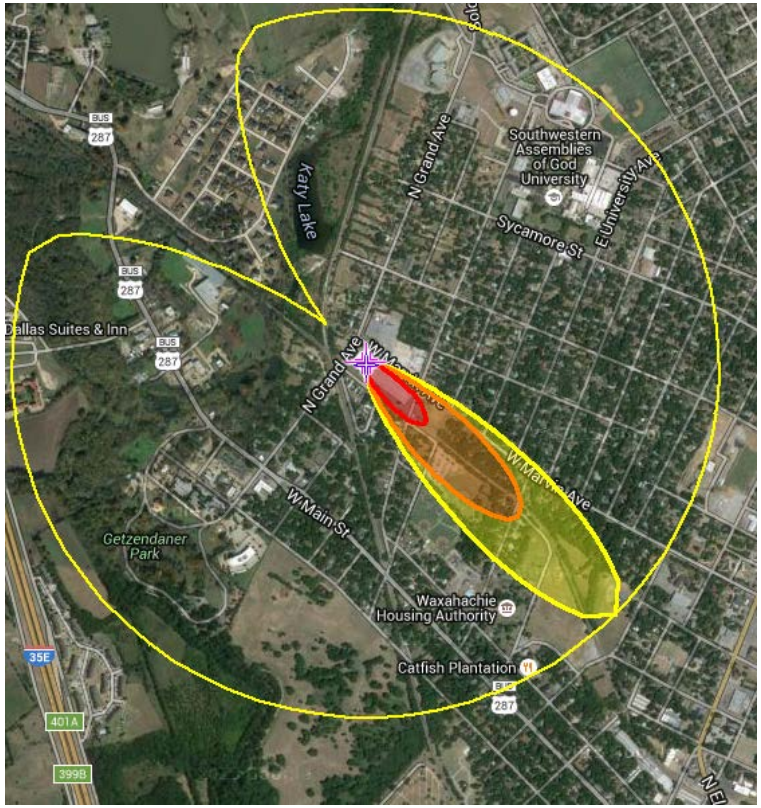


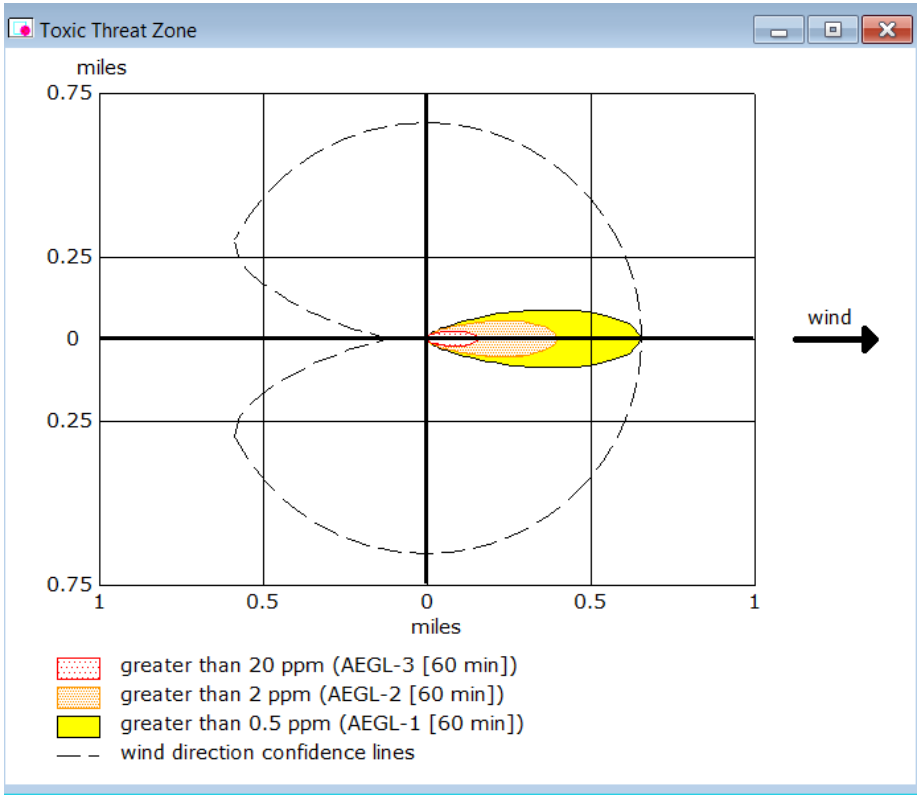
Considering that all other factors are the same, if you increase ..... what happens to footprint/plume of concern (shorter or longer)

Release rate .... ?

When we increased the released rate, the model reached a distance of >1067 yards.

Longer (more released at one time)



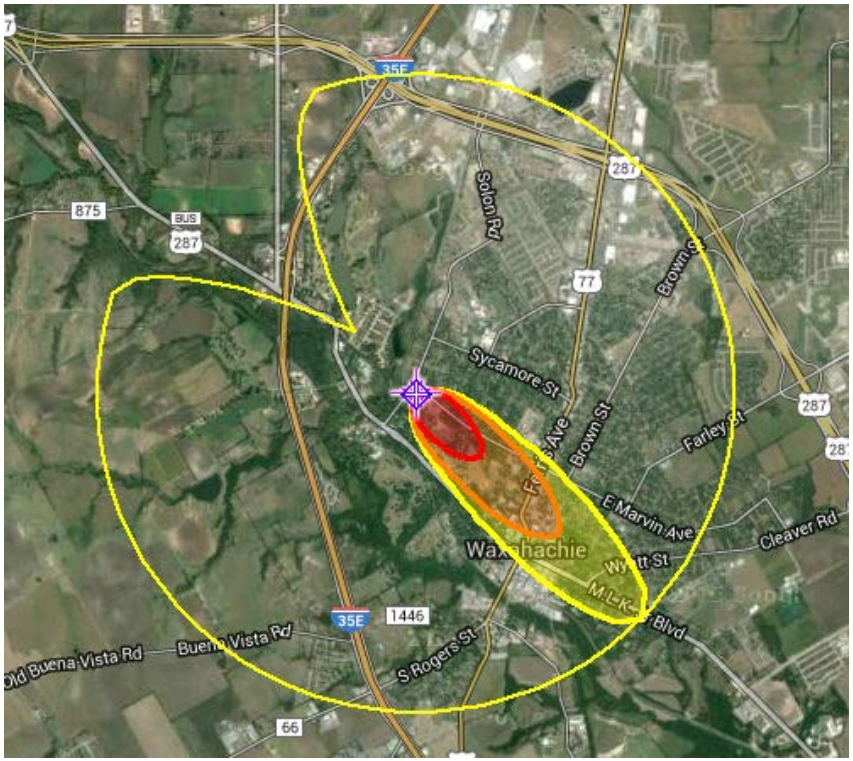


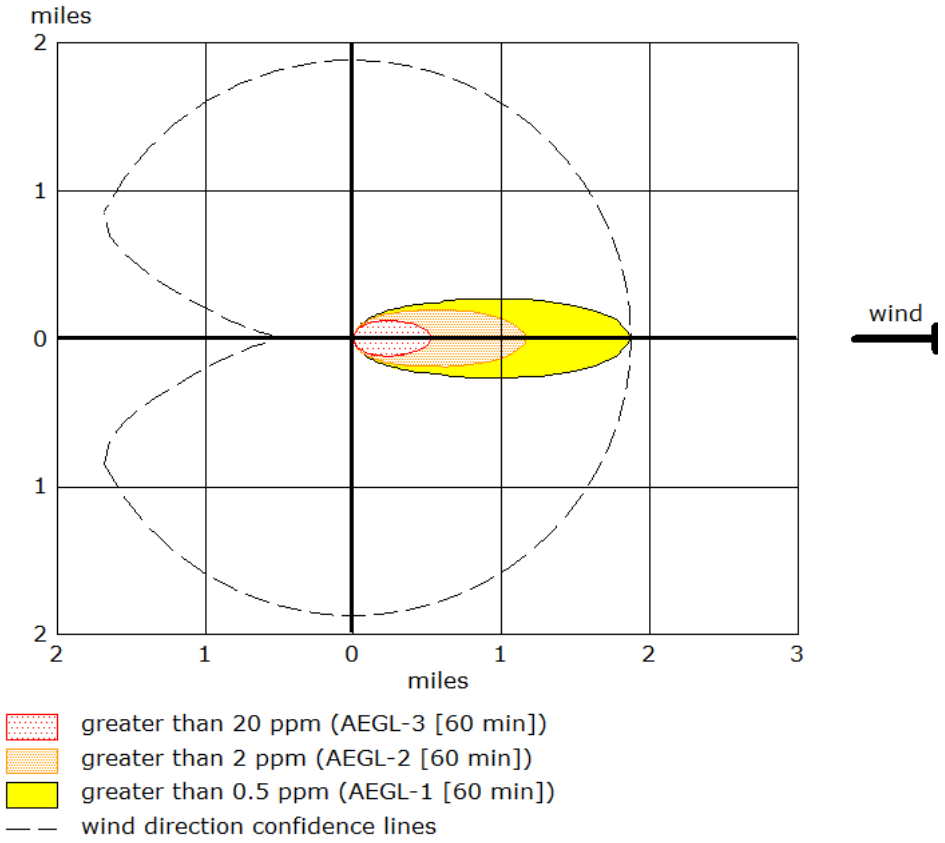
Considering that all other factors are the same, if you increase ..... what happens to footprint/plume of concern (shorter or longer)

Tank rupture size .... ?

When we increased tank rupture size, the model reached a distance of >1067 yards.

Longer (increases release rate)



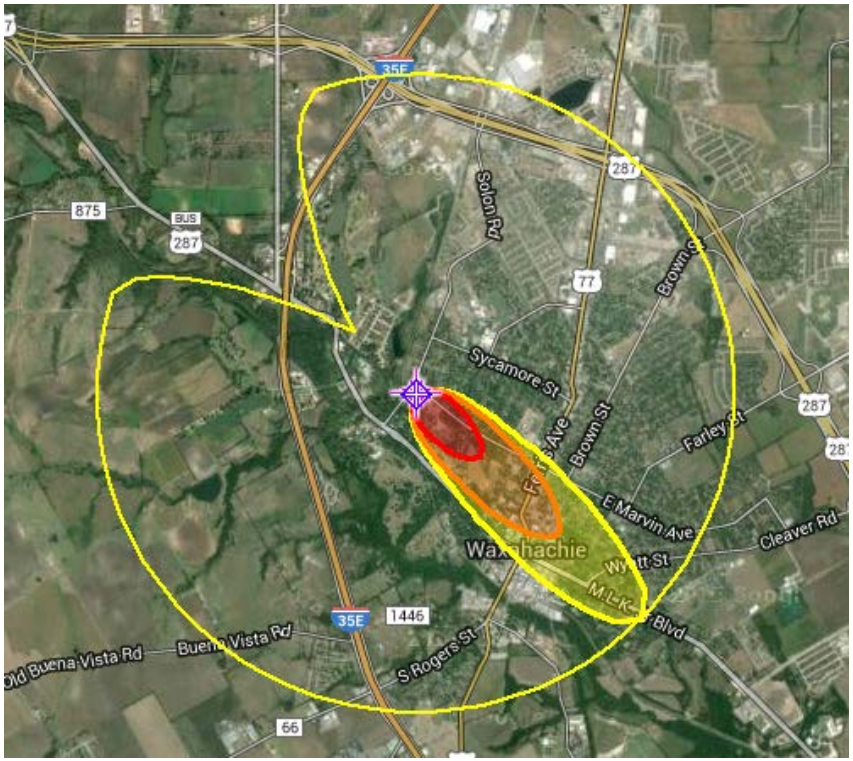


Considering that all other factors are the same, if you increase ..... what happens to footprint/plume of concern (shorter or longer)

Solar radiation…?

When we increased solar radiation, it can cause the threat zone to be both

Longer / shorter



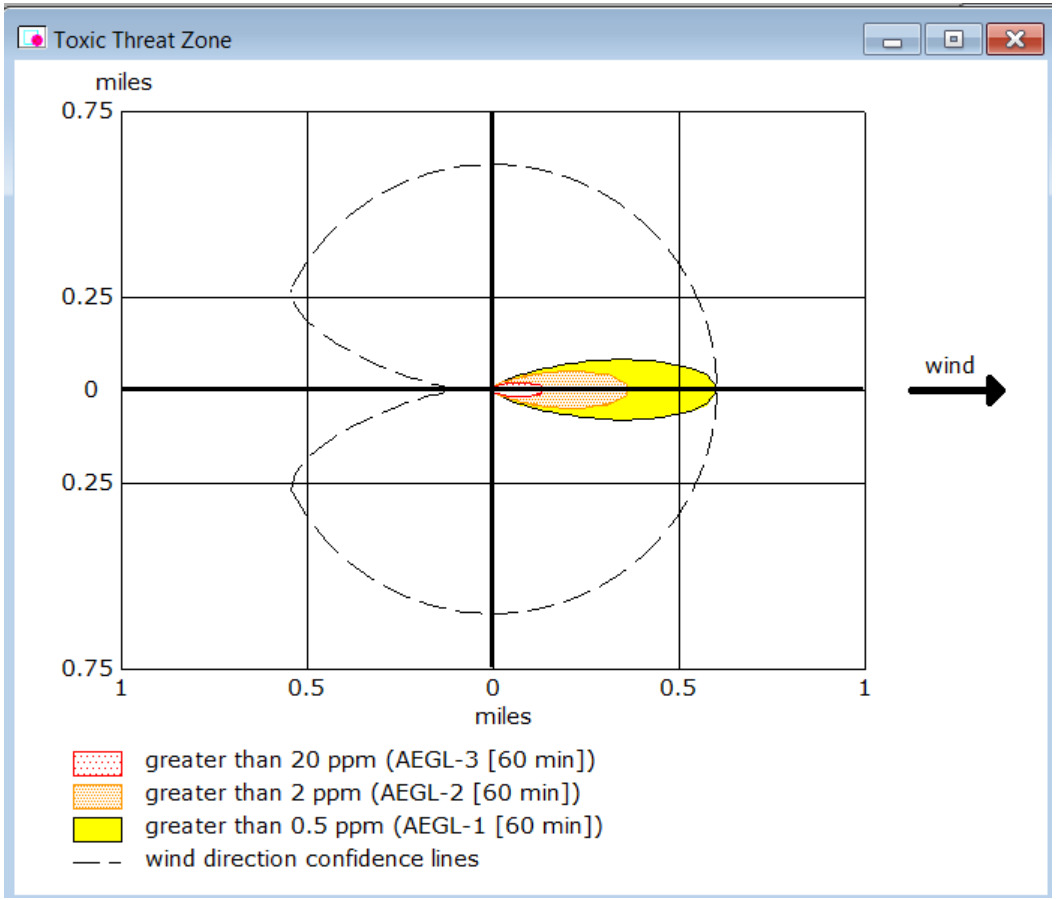
?

Considering that all other factors are the same, if you increase ..... what happens to footprint/plume of concern (shorter or longer)

LOC…?

When we increased LOC, the model reached a distance of >1067 yards.

Shorter



Chlorine

```
THREAT ZONE:
  Model Run: Heavy Gas
  Red    : 243 yards --- (20 ppm = AEGL-3 [60 min])
  Orange: 644 yards --- (2 ppm = AEGL-2 [60 min])
  Yellow: 1067 yards --- (0.5 ppm = AEGL-1 [60 min])
```

Summary

Considering that all other factors are the same, if you increase ..... what happens to Threat Zone (shorter or longer)

Wind Speed	**Shorter Footprint**
Ground Roughness	**Shorter Footprint**
Atmospheric Stability (Towards F)	**Longer Footprint**
Release Rate	**Longer Footprint**
Tank Rupture Size	**Longer Footprint**
Solar Radiation	**Both Longer/shorter Footprint**
Level of Concern	**Shorter Footprint**

Download
ALOHA Software
And Materials at:
www.epa.gov/cameo

ALOHA Software
ALOHA Fact Sheet
ALOHA Example Scenarios
ALOHA Pages – Ask Doctor ALOHA articles, Level of Concern Guide, sharing in Esri's ArcMap, or find an instructor.

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