STATE OF ILLINOIS

ILLINOIS COMMERCE COMMISSION

ONE EARTH SEQUESTRATION, LLC	:	
	:	
APPLICATION PURSUANT TO THE	:	
CARBON DIOXIDE TRANSPORTATION	:	**Docket No. 23-0708**
AND SEQUESTRATION ACT (220 ILCS 75/1 et seq.)	:	
FOR A CERTIFICATE OF AUTHORITY TO	:	
CONSTRUCT AND OPERATE A CARBON	:	
DIOXIDE PIPELINE AND WHEN NECESSARY TO	:	
TAKE INTERESTS IN PROPERTY AS PROVIDED	:	
BY THE LAW OF EMINENT DOMAIN	:	

March 27, 2024
(Confidential & Proprietary designation removed April 18, 2024)

OES Exhibit 9.2

Air Dispersion Modeling Report

Dispersion Calculations for the OES Carbon Dioxide Pipeline

Introduction

Quest Consultants Inc. performed worst-case release and dispersion calculations to describe the behavior of a guillotine rupture along the One Earth Sequestration (OES) CO_2 Pipeline. The purpose of the study was to model the worst-case scenario for the proposed pipeline in order to better understand the potential public impacts. The proposed OES CO_2 Pipeline is a buried 12-inch carbon dioxide (CO_2) pipeline for CO_2 injection. The pipeline consists of 5.3 miles of 12-inch pipe, a 0.6 mile lateral of 8-inch pipe, and a 0.03 mile lateral of 8-inch pipe. Each lateral leads to an injection well.

Modeling Parameters

Although the exact composition of the pipeline gas is not yet known, it will consist predominantly of CO_2. Thus, the composition was modeled as 100% carbon dioxide. Three accidental release scenarios were considered:

1. Rupture of the mainline pipeline,
2. Rupture of a lateral pipeline, and
3. Rupture of an injection wellhead.

The following parameters were applied to the study.

Pipeline diameters	12-inch mainline with 8-inch laterals
Burial depth	6 feet minimum
Operating pressure	2,362 psig at pipeline inlet
Operating temperature	105 °F at pipeline inlet
Pipeline length	5.3 miles
Lateral lengths	0.6 and 0.03 miles
Valve Locations	2.4 and 4.3 mile points
Wellhead tubing diameter	5.5 inches
Well depth	7,000 feet

In addition, rupture events were assumed to be detected, valves shut, and pipeline flow terminated within 5 minutes. The rupture is assumed to form a crater, where the total release is the combined flow rate from both the downstream and upstream portions of the pipeline.

Atmospheric Conditions for Dispersion Calculations

Ten years of data from the Rantoul National Aviation Center Weather Station [NCEI, 2023], was analyzed to determine the local average relative humidity and average temperature values.

Relative humidity	= 79%
Average temperature	= 54 °F
Atmospheric stability	= Pasquill-Gifford D (stable) and F (extremely stable)

Atmospheric stability is classified by the letters A through F. In general, the most unstable atmosphere is characterized by stability class A. Stability A would correspond to an atmospheric condition where there is strong solar radiation and moderate winds. This combination of radiation and winds allows for rapid fluctuations in the air and thus greater mixing of the released gas with time. Stability D is characterized by fully overcast or partial cloud cover during both daytime and nighttime. The atmospheric turbulence is not as great during D conditions as during A conditions; thus, the gas will not mix as quickly with the surrounding atmosphere. Stability F corresponds to the most "stable" atmospheric conditions. Stability F generally occurs during the early morning hours before sunrise (thus, no solar radiation) and under low winds. The combination of low winds and lack of solar heating allows for an atmosphere which appears calm or still and thus restricts the ability to actively mix with the released gas.

Two weather conditions were applied to this study to demonstrate dispersion during worst-case and average weather conditions. The worst-case weather condition is defined as F stability and 4.5 mph (2 m/s) winds. Whereas average weather conditions are modeled with D stability and 11.2 mph (5 m/s) winds.

Endpoints

Carbon dioxide is a colorless, odorless gas. The major hazard associated with CO_2 is asphyxiation. At low concentrations, CO_2 may only produce mild effects to people. At high concentrations, CO_2 can cause nausea, vomiting, asphyxiation, and even death. The physiological effects of airborne toxic materials depend on the concentration of the toxic vapor in the air being inhaled and the length of time an individual is exposed to this concentration.

The CO_2 concentrations in the report titled "Design and Operation of CO_2 Pipelines" [Det Norske Veritas, 2010] are clearly identified as those pertaining to occupational exposure. These concentrations, reproduced in Tables 1 and 2, should be applied to workers in a facility where CO_2 may be present in an intermittent or continuous manner. The low CO_2 concentrations (e.g., 5,000 ppm, 10,000 ppm, and 20,000 ppm) for long exposure times (e.g., over one hour) have little meaning when evaluating the potential exposure of the public to CO_2 exposure following an accidental release. The reasons for this conclusion can be summarized as follows.

- The wind does not blow steadily at the same speed and direction for more than one hour.
- The atmospheric conditions (e.g., stability, temperature, etc.) do not remain the same for more than one hour.
- Members of the public who are outside are generally mobile and do not remain in the same location for more than one hour.

The CO_2 concentrations used in this analysis are: 50,000, 20,000, and 5,000 ppm.

Table 1
Acute Health Effects of High Concentrations of Inhaled CO_2

CO_2 Concentration in Air [ppm]	Exposure	Effects on Humans
170,000 – 300,000	Within 1 minute	Loss of controlled and purposeful activity, unconsciousness, convulsions, coma, death
>100,000 – 150,000	1 minute to several minutes	Dizziness, drowsiness, severe muscle twitching, unconsciousness
70,000 – 100,000	Few minutes	Unconsciousness, near unconsciousness
	1.5 minutes to 1 hour	Headache, increased heart rate, shortness of breath, dizziness, sweating, rapid breathing
60,000	1-2 minutes ≥ 16 minutes Several hours	Hearing and visual disturbances Headache, difficult breathing (dyspnea) Tremors
40,000 – 50,000	Within a few minutes	Headache, dizziness, increased blood pressure, uncomfortable breathing (Equivalent to concentrations expired by humans)
30,000	1 hour	Mild headache, sweating, and difficult breathing at rest
20,000	Several hours	Headache, difficult breathing upon mild exertion
5,000 – 10,000	8 hours	Acceptable occupational hazard level

Low Temperature Hazards

A release from a carbon dioxide pipeline results in an expanding fluid that produces a reduced fluid temperature. As the released CO_2 mixes with air, the temperature of the CO_2/air mixture increases until it reaches the temperature of the surrounding air.

In order to determine the potential hazards associated with exposure to cold CO_2/air temperatures, a relationship between air temperature, exposure time, and wind speed (air movement) must be used. Work completed by Tikuisis and Frim [1994] developed a correlation between these three parameters for people exposed to cold air. The study found that if a person is exposed to 6 to 12 mph winds with an air temperature of -4 °F, they would be expected to survive for more than eight hours. The basis of the work was to define the survival time associated with exposure to cold temperatures. In this sense, the work is focused on long term exposure (e.g., exposure times on the order of hours) while the accidental release modeling that is the subject of this study focused on exposure times less than one hour. Thus, using the survival time approach (hours of exposure) will produce a conservative result since persons near the pipeline would not be expected to be exposed to a cold cloud for more than an hour.

Table 2
Occupational Exposure Limits

Exposure Time	CO_2 [ppm]	Comment	Reference
10 hours	5,000	Time weighted average	NIOSH (US)
8 hours	5,000	Time weighted average	OSHA (US)
	5,000	Occupational Long Term Exposure Limit (LTEL)	COSHH HSE (UK)
60 min	40,000	Emergency Exposure Level for submarine operations	NRC (US)
	25,000	Emergency Exposure Level for submarine operations	NRC (US)
	50,000	Suggested Long Term Survivability Exposure Limit	HSE (UK)
	20,000	Maximum exposure limit	Compressed Gas Association 1990
20 min	30,000	Maximum exposure limit	Compressed Gas Association 1990
15 min	15,000	Occupational Short Term Exposure Limit (STEL)	COSHH HSE (UK)
	30,000	Short Term Exposure Limit (STEL)	NIOSH (US)
10 min	40,000	Maximum exposure limit	Compressed Gas Association 1990
7 min	50,000	Maximum exposure limit	Compressed Gas Association 1990
5 min	50,000	Suggested Short Term Exposure Limit (STEL)	HSE (UK)
	60,000	Maximum exposure limit	Compressed Gas Association 1990
3 min	70,000	Maximum exposure limit	Compressed Gas Association 1990
1 min	150,000	Exposure limit	NORSOK (Norway)
<1 min	40,000	Maximum Occupational Exposure Limit	NIOSH (US)

Calculations in this study were preformed to calculate the temperature of the released CO_2 as it mixes with air accounting for the temperature drop due to pipeline release, mixing of CO_2 and air, and air humidity. Based on these calculations, a temperature of -4 °F corresponds to a cloud concentration of 220,000 ppm CO_2 and may reach up to 800 feet. Since the CO_2 concentration associated with a temperature of -4 °F is much greater than 50,000 ppm CO_2, the low temperature hazards associated with an accidental release from the pipeline will always be smaller than the CO_2 inhalation hazard associated with 50,000 ppm CO_2. Thus, low temperature hazards are not addressed further in this study.

Modeling Software

When performing site-specific consequence analysis studies, the ability to accurately model the release, dilution, and dispersion of gases and aerosols is important if an accurate assessment of potential exposure is to be attained. For this reason, Quest uses a modeling package, CANARY by Quest®, that contains a set of complex models that calculate release conditions, initial dilution of the vapor (dependent upon the release characteristics), and the subsequent dispersion of the vapor introduced into the atmosphere. The models contain algorithms that account for thermodynamics, mixture behavior, transient release rates, gas cloud density relative to air, initial velocity of the released gas, and heat transfer effects from the surrounding atmosphere and the substrate. The release and dispersion models contained in the QuestFOCUS package (the predecessor to CANARY by Quest) were reviewed in a United States Environmental Protection Agency (EPA) sponsored study [TRC, 1991] and an American Petroleum Institute (API) study [Hanna, Strimaitis, and Chang, 1991]. In both studies, the QuestFOCUS software was evaluated on technical merit (appropriateness of models for specific applications) and on model predictions for specific releases. One conclusion drawn by both studies was that the dispersion software tended to overpredict the extent of the gas cloud travel, thus resulting in too large a cloud when compared to the test data (i.e., a conservative approach).

A study prepared for the Minerals Management Service [Chang, et al., 1998] reviewed models for use in modeling routine and accidental releases of flammable and toxic gases. CANARY by Quest received the highest possible ranking in the science and credibility areas. In addition, the report recommends CANARY by Quest for use when evaluating toxic and flammable gas releases. Specific models contained in the CANARY by Quest software package have also been extensively reviewed.

Release and Dispersion Modeling

Releases were modeled from a rupture of the mainline pipeline, lateral pipeline, and injection well. The scenarios assume that the release is detected and the pipeline source is fully shut down within 5 minutes. During the first minutes of the rupture event, the pressure in the pipeline drops rapidly. The duration of the rupture events along the pipeline, accounting for valve closure, ranged from 20-60 minutes. Dispersion modeling was performed for the scenario during worst-case and average weather conditions. The results of the modeling are summarized in Table 3.

The graphical results for the mainline pipeline and the lateral pipeline are presented Figures 1 through 8. In addition, the hazard vulnerability zones are presented in Figures 9 and 10 to show all potential hazard impacts along the pipeline route. All dispersion cases modeled show that the cloud returns to near grade for all three endpoints. The maximum extent is 4,040 feet to 5,000 ppm due to a rupture of a 12-inch mainline pipeline during worst-case weather conditions. The results show a large pressure drop in the first five minutes of the release and continues to drop over the remainder of the release. This pressure drop will result in a significant decay in release rate and dispersion distances over the duration of the release.

The area was evaluated to determine if a flat terrain assumption was appropriate for the areas surrounding the pipeline route. The surrounding terrain along the 5.3-mile pipeline route varies in elevation by approximately 110 ft. While there are small variations in terrain, there are no major terrain features that would necessitate incorporating terrain features into the dispersion modeling. Thus, the flat terrain assumption was deemed appropriate for all areas along the pipeline route.

The vulnerability zones depicted in this study are based on a 12-inch mainline pipeline rupture and 8-inch lateral pipeline ruptures. These results represent the worst-case scenarios of the potential releases along the mainline and laterals.

Table 3
Summary of Results

Release Scenario	Wind Speed [mph]	Atmospheric Stability	Downwind Distance to: [ft]		
			50,000 ppm	20,000 ppm	5,000 ppm
Rupture of a 12″ Pipeline	4.5	F	1,560	2,280	4,040
	11.2	D	1,110	1,650	2,950
Rupture of a 8″ Lateral	4.5	F	1,100	1,590	2,840
	11.2	D	860	1,290	2,350
Rupture of a Wellhead	4.5	F	290	450	820
	11.2	D	190	310	630

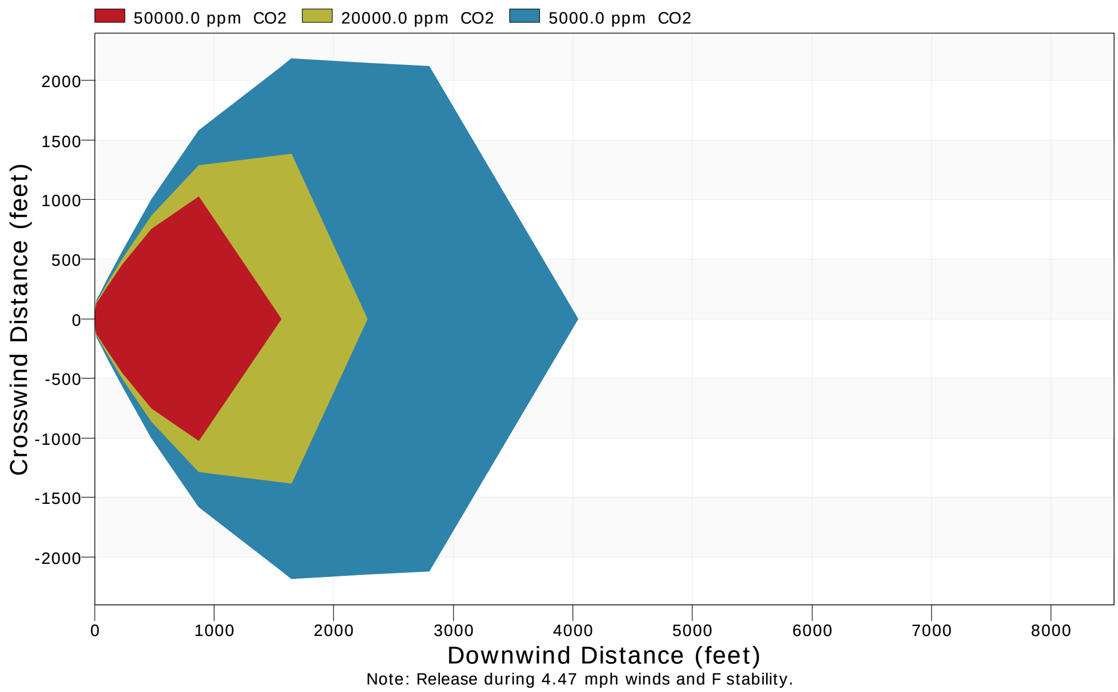

Figure 1
Dispersion - Overhead View of a Mainline Rupture During Worst-Case Weather Conditions

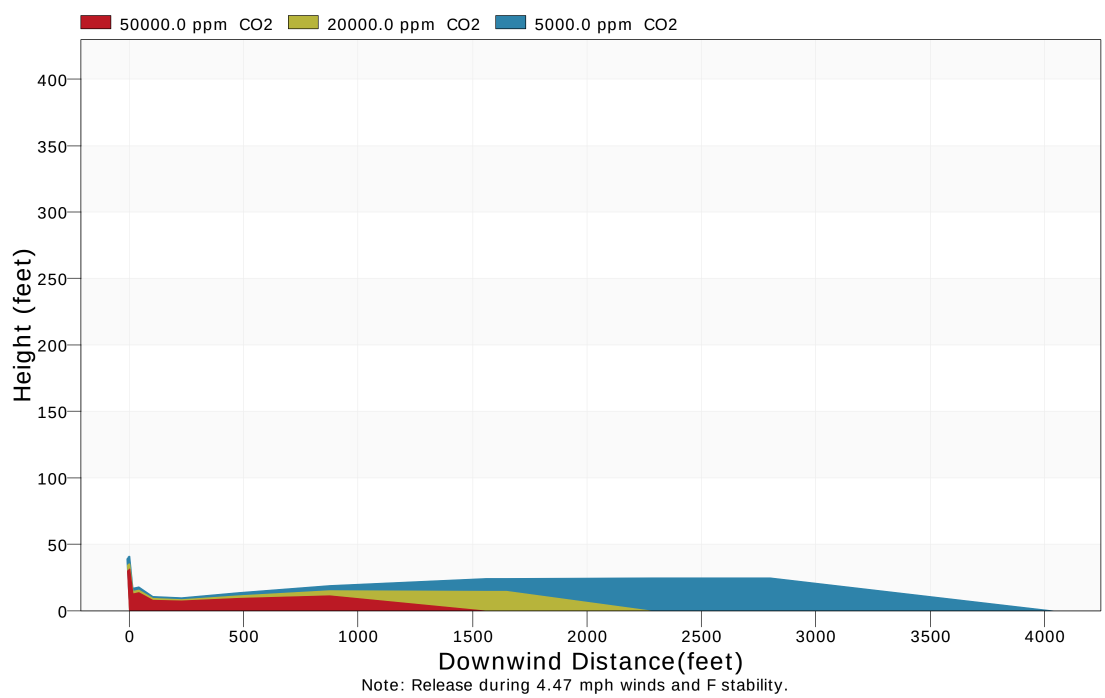

Figure 2
Dispersion - Side View of a Mainline Rupture During Worst-Case Weather Conditions

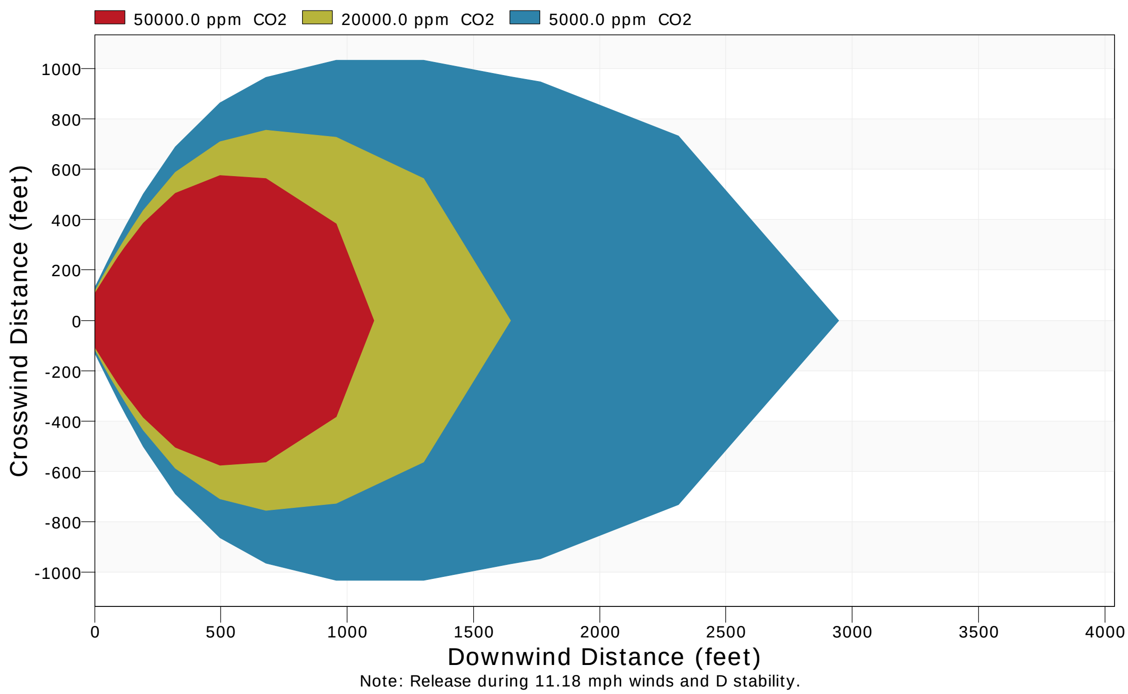

Figure 3
Dispersion - Overhead View of a Mainline Rupture During Average Weather Conditions

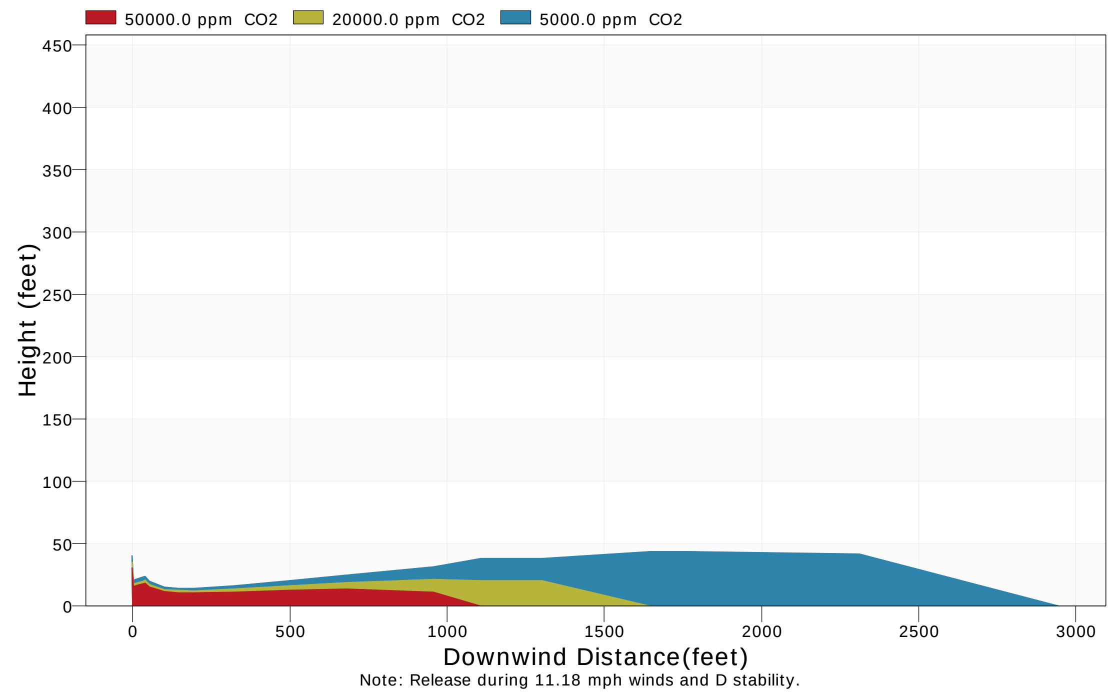

Figure 4
Dispersion - Side View of a Mainline Rupture During Average Weather Conditions

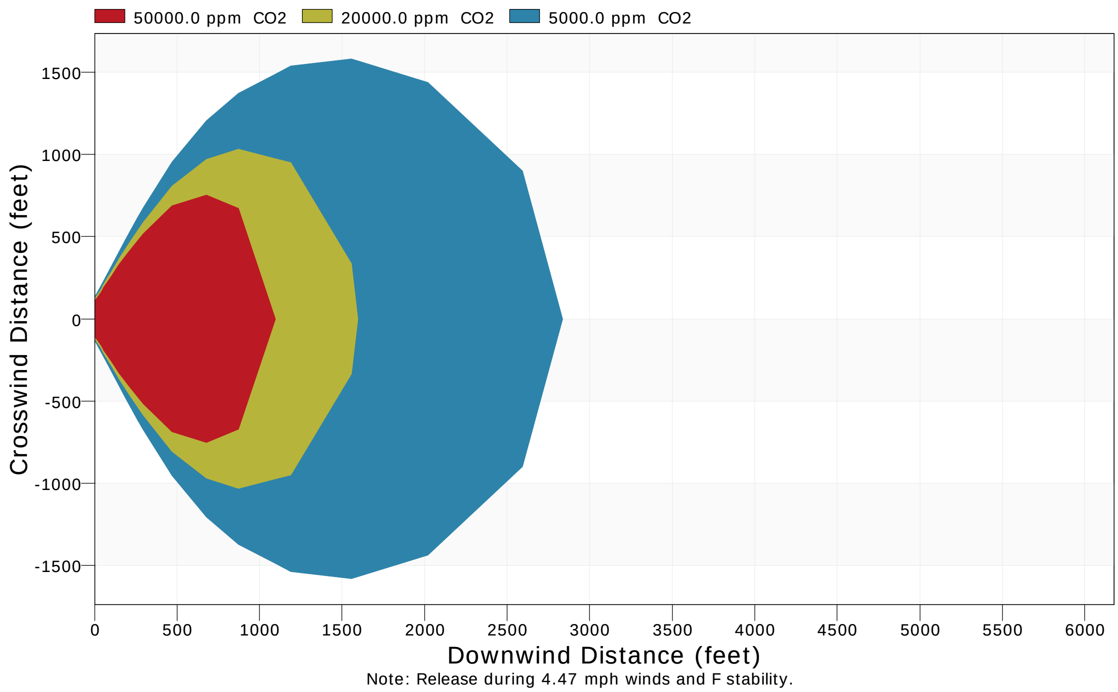

Figure 5
Dispersion - Overhead View of a Lateral Rupture During Worst-Case Weather Conditions

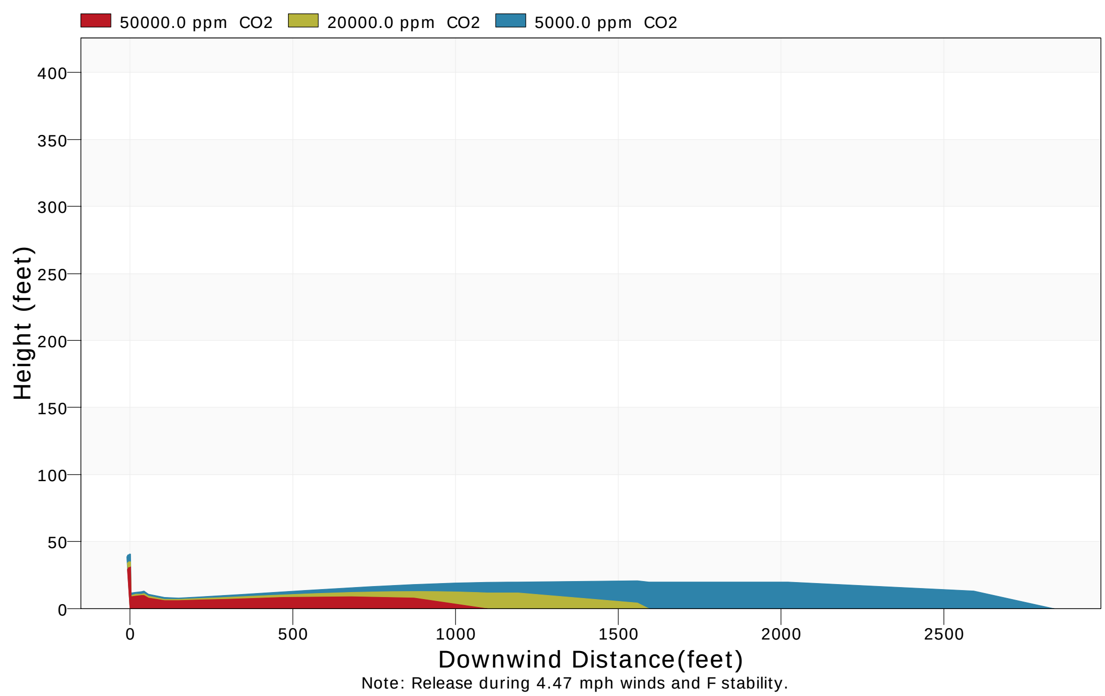

Figure 6
Dispersion - Side View of a Lateral Rupture During Worst-Case Weather Conditions

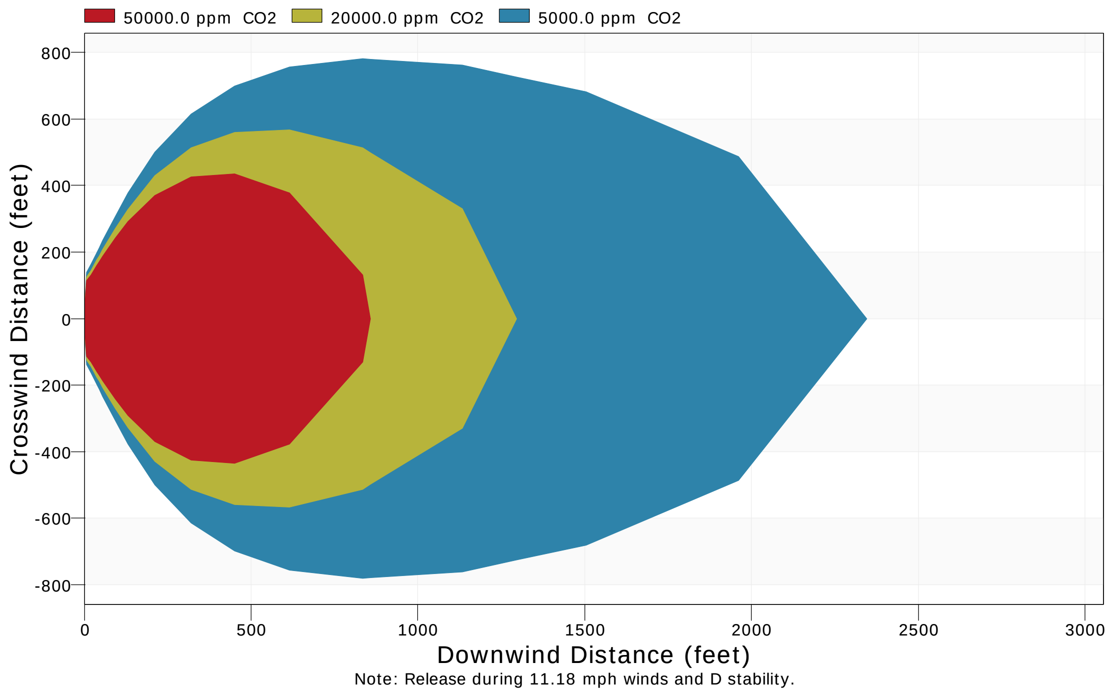

Figure 7
Dispersion - Overhead View of a Lateral Rupture During Average Weather Conditions

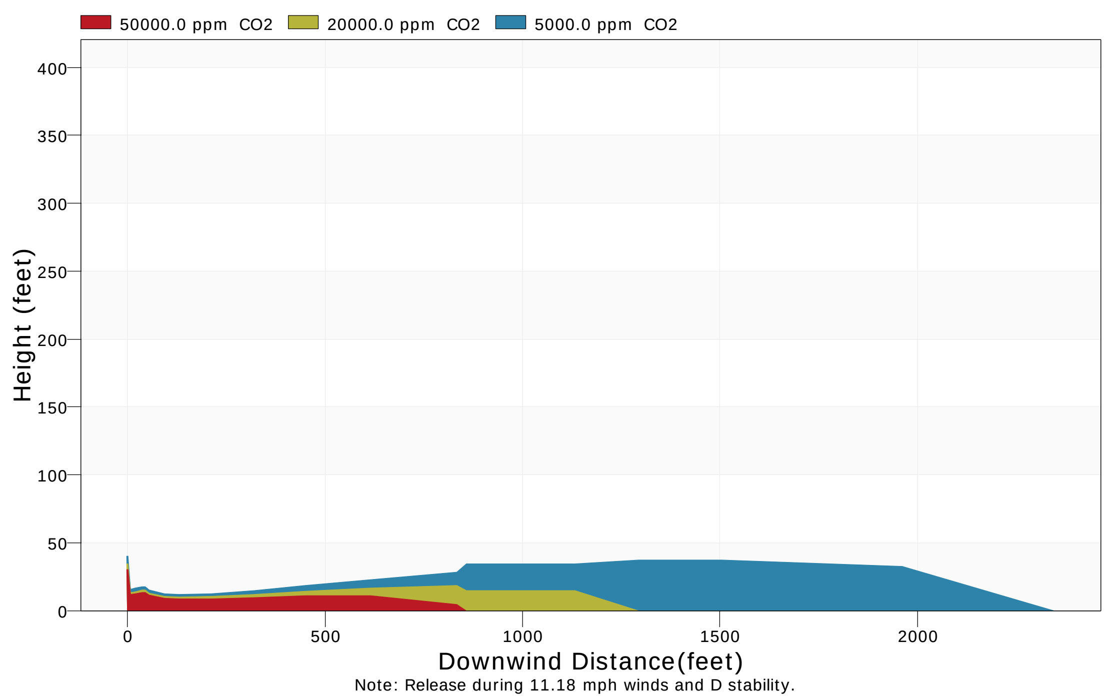

Figure 8
Dispersion - Side View of a Lateral Rupture During Average Weather Conditions

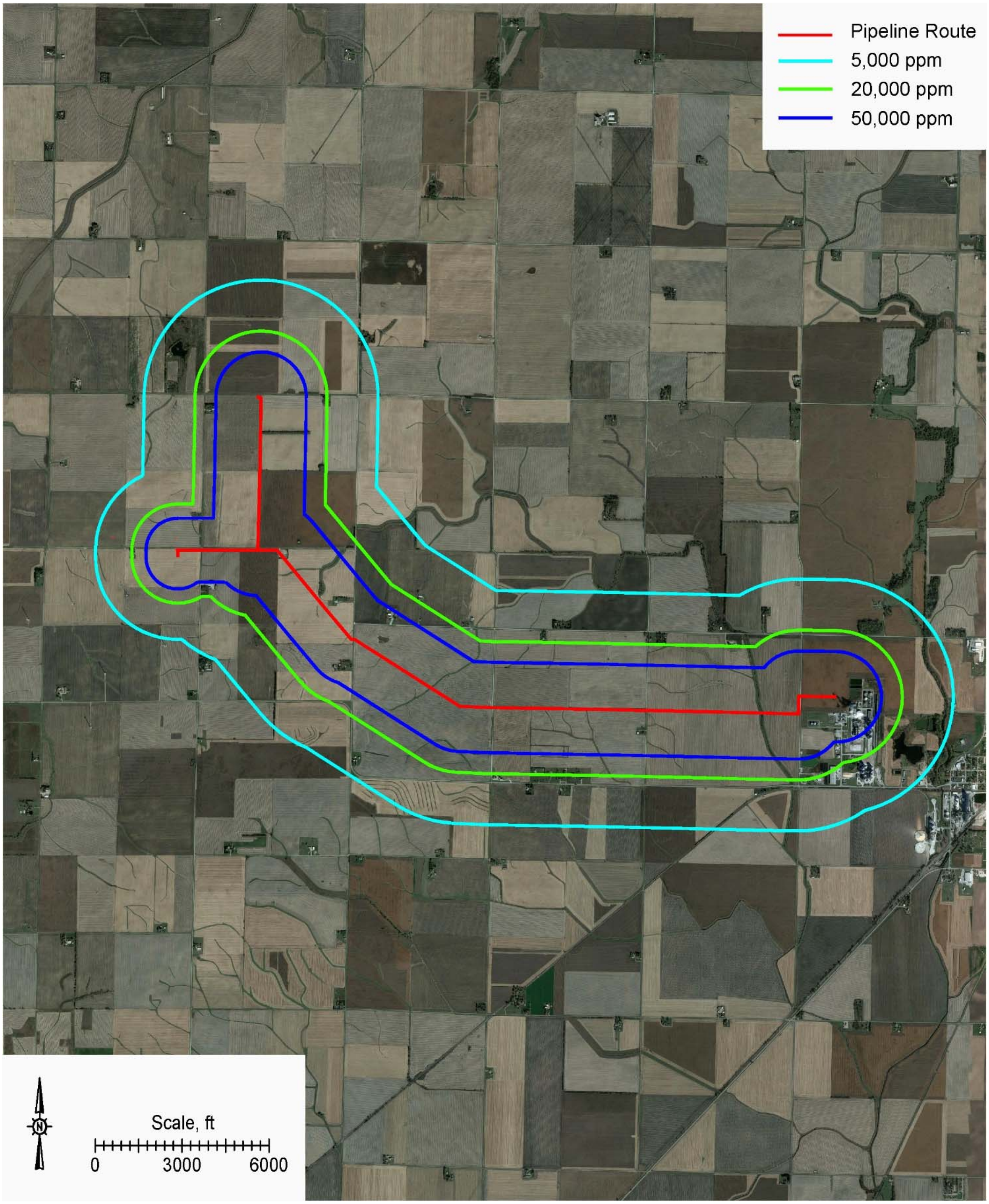

Figure 9
Dispersion Vulnerability Zones for a Rupture During Worst-Case Weather Conditions

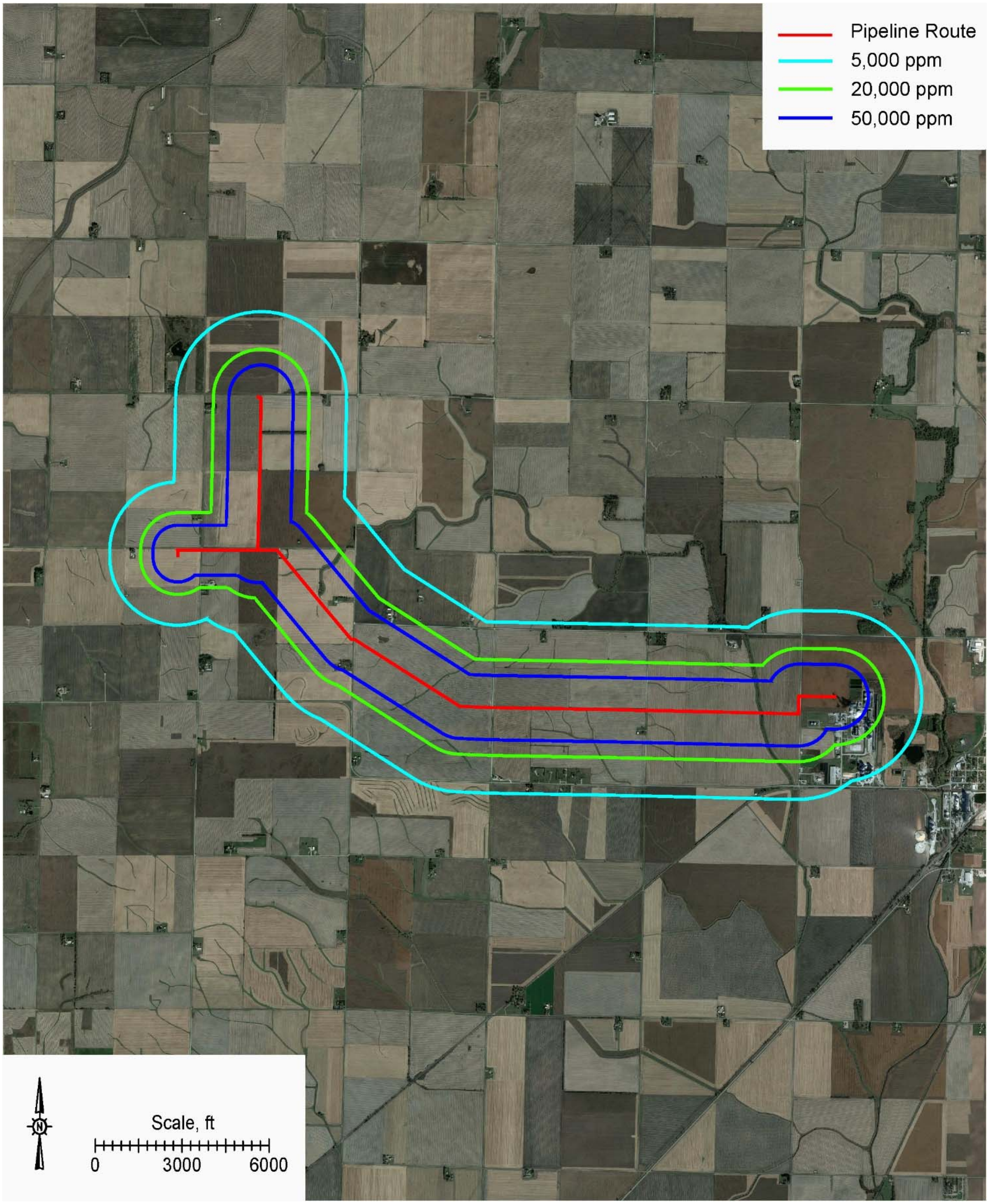

Figure 10
Dispersion Vulnerability Zones for a Rupture During Average Weather Conditions

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