AIR DISPERSION MODELING
OF WELL BLOWOUT AND PIPELINE RUPTURE SCENARIOS
SALT CREEK FIELD

PREPARED FOR:

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1. INTRODUCTION

Howell Petroleum Corporation (Howell) is currently installing a carbon dioxide enhanced oil recovery system, also known as carbon dioxide flooding, at its Salt Creek Field. The flooding technique is used to increase oil production from fields that have been depleted using primary and secondary oil recovery methods. Howell retained Cameron-Cole LLC to perform air dispersion modeling studies to estimate downwind carbon dioxide and hydrogen sulfide concentrations resulting from various well blowout and pipeline rupture scenarios.

The Environmental Protection Agency (EPA) - approved Dense Gas Dispersion (DEGADIS) model was utilized to model vertical releases associated with the scenarios. DEGADIS is a dispersion model that estimates downwind or downgradient concentrations of dense (heavier than air) gases. DEGADIS is primarily used to determine distances of transit resulting in defined gas concentrations. For example, DEGADIS can be used to define the potential extent of migration of concentrations defined to be hazardous based on EPA risk assessment protocols or Occupational Safety and Health Administration (OSHA) exposure thresholds. DEGADIS is capable of modeling finite or continuous release sources either at ground level or as a defined jet. DEGADIS can also model transient scenarios, where flow rates vary with time.

A second EPA-approved model, SLAB, was employed to model horizontal releases resulting from pipeline ruptures. SLAB also simulates the atmospheric dispersion of denser-than-air releases. However, it was developed to model horizontal jet releases in addition to vertical jet releases. SLAB calculates the concentration at downwind locations by solving the conservation equations of mass, momentum, and energy. SLAB handles release scenarios including ground level and elevated jets, liquid pool evaporation, and instantaneous volume sources.

Modeling output was generally compared to the 10 minute Time Weighted Averages (TWA) of hydrogen sulfide (10 parts per million [ppm]) and carbon dioxide (5,000 ppm), the Immediately Dangerous to Life or Health (IDLH) threshold for hydrogen sulfide (100 ppm) and the Short Term Exposure Limit (STEL) for carbon dioxide (30,000 ppm).

2. WELL BLOWOUT SCENARIO

The DEGADIS model is accompanied by a number of various modules that can be executed in series. For the purpose of modeling the release of pressurized gas for a well blowout, the JETPLU module (based on the Ooms model) was used. This module is intended to predict the trajectory and dilution of a denser than air jet plume which has significant upward momentum. For a well blowout, the release rate would be extremely fast, and it was necessary to include the gas' momentum in the dispersion modeling. The JETPLU module outputs concentrations at ground level and at a selected level (five feet or the breathing zone, was used in this case) as well as the point at which the gas cloud impacts the ground. JETPLU in conjunction with a second module (DEGBRIDG) can create an input file to DEGADIS based on concentrations at the point at which the plume first contacts ground level. However, it was found that for all of the conditions modeled, the concentration of the plume after it touched down was well below 5,000 ppm carbon dioxide, and thus it was not necessary to run the DEGADIS model.

2.1. INPUT PARAMETERS

Howell supplied the expected exhaust gas parameters for a well blowout:

- Release Rate: 16 million standard cubic feet per day (MMSCFD)
- Release Temperature: 0°Fahrenheit (F)
- Pipe Diameter: 2.2 inches internal diameter
- Duration of blowout - 36 to 48 hours
- Gas composition -

  96.3% Carbon Dioxide

  0.7 % Nitrogen

  2.7 % Methane

  0.2 % Butane

  0.018% Hydrogen Sulfide

The gases released under these conditions will be moving very quickly, over 8,000 ft/sec, several times the speed of sound. Numerous hazards are associated with this type of release. The only hazard addressed by this report is the risk associated with inhalation of these gases.

For simplicity, it was assumed that the release was 100% carbon dioxide. At these concentrations, assuming that the hydrogen sulfide disperses with the carbon dioxide, the carbon dioxide concentration will be the primary inhalation concern for a well blowout. The modeling runs were made using the most conservative blowout duration, assuming a constant release that lasts 48 hours.

Howell requested that the well blowout be modeled with the weather parameters held constant at worst case conditions. With a high momentum release, such as the one proposed here, the model shows that the plume will lift into the air and then gradually drift downwind based on the influence of gravity.

2.2. SENSITIVITY ANALYSIS

In order to ascertain worst case conditions, a sensitivity analysis was performed. The initial analysis showed that the worst case weather conditions were hot ambient temperatures, low winds and high ambient pressures. The Pasquill Stability Class sensitivity analysis (Table 1) results showed that the worst of the three cases considered was the intermediate Stability Class (D) rather than either the more stable (F) or the less stable (B) Stability Classes considered. This is due to the complex interaction of Stability Class and elevated plumes. Thus it was considered appropriate to determine whether the worst case Stability Class remained Class D, after setting all other parameters to their final worst case settings in the model. The results of this secondary sensitivity analysis which include only the effect of Pasquill Stability Class are shown in Table 2. The results show that at these conditions, Stability Class D again results in the worst case scenario.

2.3. MODEL RESULTS

Despite these conservative assumptions, in all of the runs at all of the weather conditions tested, the maximum concentration of carbon dioxide at ground level and in the breathing zone (five feet) was 192 ppm, well below the lowest regulatory threshold of 5,000 ppm. Hydrogen sulfide concentrations are well below 1 ppm under all conditions, and are also not expected to be of concern.

It should be noted that this model does not evaluate conditions in the immediate vicinity of the blowout (generally a radius of about 100 feet from the center of the source) for these input parameters. However, if there is a blowout, people within the immediate vicinity of the blowout will face considerable hazards in addition to any inhalation hazard, and once the blowout has occurred, it is recommended that access in the immediate vicinity of the site be limited to those with appropriate respiratory apparatus and other appropriate safety gear.

3. HYDROGEN SULFIDE SCENARIOS

DEGADIS was utilized to model four scenarios depicting hydrogen sulfide releases at Howell's Salt Creek Field. The radii of exposure based on the Pasquill – Gifford equation for each of the scenarios was also calculated.

Three of the scenarios (Cases 1, 2 and 3) were based on the worst case conditions as determined by the Monte Carlo analyses contained in the Air Dispersion Modeling in Support of Risk Analysis Report (Cameron-Cole, April, 2005). The Monte Carlo simulations utilized actual weather conditions and varied the input parameters to determine the effects on the output from the DEGADIS model. It was determined that minimum wind speed, a Wind Stability Class of D and high ambient temperatures created the worst case conditions (highest downwind hydrogen sulfide concentrations). The fourth scenario utilized Case 3 input parameters except for the high ambient temperature. A lower ambient temperature was used to evaluate lesser downwind concentrations.

The details of each scenario and the associated output presented below.

3.1. CASE 1 – WELL BLOWOUT

- Wind speed - approximately 1 mile per hour (mph)
- Stability Class - B, D and F
- Ambient temperature - 100^{o}F
- Atmospheric pressure - 0.87 atmosphere (atm)
- Relative humidity - 56%
- Gas flow rate - 16 mmscfd
- Hydrogen sulfide concentration - 180 ppm
- Diameter - 2 7/8 inch tubing

Results - no breathing zone hydrogen sulfide concentrations greater than or equal to 10 ppm.

3.2. CASE 2 – WELL BLOWOUT

- Wind speed - approximately 1 mph
- Stability Class - B, D and F
- Ambient temperature - 100^{o}F
- Atmospheric pressure - 0.87 atm
- Relative humidity - 56%
- Gas flow rate - 16 mmscfd

- Hydrogen sulfide concentration - 450 ppm
- Diameter - 2 7/8 inch tubing, 5 inch casing and 8 5/8 inch casing

Results - no breathing zone hydrogen sulfide concentrations greater than or equal to 10 ppm.

3.3. CASE 3 – PIPELINE LEAK

- Wind speed - approximately 1 mph
- Stability Class - B, D and F
- Ambient temperature - 100°F and 32°F
- Atmospheric pressure - 0.87 atm
- Relative humidity - 56%
- Gas flow rate - 2.5 mmscfd
- Hydrogen sulfide concentration - 22,000 ppm
- Diameter – 4 inch pipe

Results - at 100°F, hydrogen sulfide concentrations in excess of 10 and 100 ppm were predicted (Figure 1). Hydrogen sulfide concentrations in excess of 10 ppm were also predicted with an ambient temperature of 32°F (Figure 2). Because of plume rise due to momentum and temperature, downwind breathing zone concentrations were only predicted to occur once the plume settled to the ground.

3.4. PASQUILL – GIFFORD RADIUS OF EXPOSURE

The more conservative Pasquill – Gifford Radius of Exposure calculation was also utilized to estimate the downwind distance the 100 and 500 ppm hydrogen sulfide plumes would drift before dissipating. Case 1 input parameters produced 100 and 500 ppm radii of exposure of 195 and 89 feet, respectively (Figure 3). Case 2 input parameters yielded 100 and 500 ppm radii of exposure of 347 feet and 158 feet, respectively (Figure 4). Finally, Case 3 calculations determined the 100 and 500 ppm radii of exposure would be 1,237 and 565 feet, respectively (Figure 5). The Pasquill – Gifford calculation does not allow for the input of ambient temperature, therefore, only three scenarios were calculated.

Hydrogen sulfide concentration results from the DEGADIS model and the Pasquill – Gifford Radius of Exposure calculation were plotted on a topographic map of the Salt Creek Field. Rather than plot the data based on specific wind directions, a circular concentration field was used to illustrate the potential hydrogen sulfide concentrations, regardless of wind direction. The DEGADIS model did not predict hydrogen sulfide concentrations greater than or equal to 10 ppm would result from Case 1 or Case 2 input data. Case 3 high temperature input data yielded a narrow band (six to 13 feet) of 10 and 100 ppm concentrations (Figure 6) 270 feet from the source. Case 3 low temperature input data resulted in a 10 ppm concentration band approximately 200 feet wide (Figure 7) 550 feet from the source.

The Pasquill – Gifford Radius of Exposure calculation does not take into account plume rise. So, the 100 and 500 ppm concentration fields are assumed to extend uniformly from the source to the downwind limits of exposure. Cases 1, 2 and 3 radii of exposure are presented on Figures 8, 9 and 10, respectively.

4. COMPARISON OF SLAB RESULTS WITH THE CONTROLLED RELEASE DATA

On May 17, 2005 carbon dioxide was released from a wellhead at the 12WC2NE14 location in order to validate and field test the dispersion modeling. The controlled release commenced at 5:00 a.m. and continued for 30 minutes. The flow rate was held constant at 8.0 MMSCFD, while the release pressure was maintained at 1000 pounds per square inch (psi). Additional details on the experimental procedures and equipment are included in Appendix A.

Weather conditions were estimated based on data from Casper, Wyoming as recorded on the website www.wunderground.com. Casper weather conditions at 4:53 a.m. were as follows:

- Temperature 60.1° F
- Humidity 42%
- Wind Speed 6.9 mph
- Wind Direction SE

Based on the time of day and the wind speed, the Pasquill Stability Class was estimated to be C, or moderately unstable.

Eight carbon dioxide monitors were installed at locations specified with a bearing (degrees off north) and a distance from the source. Four of the monitors were placed one foot off of the ground, and four were placed in the breathing zone, four feet off the ground. The eight locations are presented in Table 3.

Monitoring results are included in Appendix B. Monitoring results prior to the start of the test suggest that background levels at the monitoring locations are about 600 ppm, although measured values range from 556 ppm (Location 5) to 806 ppm (Location 6).

The SLAB model was run using a horizontal release rate of 8 MMSCFD (4.9 kilograms per second [kg/s] of carbon dioxide) exiting through a 2 - inch diameter pipe. The model results are plotted in Figures 11 through 13. The monitoring data recorded 15 minutes after the start of the controlled release are included on the figures.

Generally, the monitoring results from Locations 3, 5 and 8 are close to background levels throughout the controlled release. This is not surprising considering they are west, or north of the source. The pressurized plume was being released directly east. However all three sites have occasional hits of higher carbon dioxide levels, presumably due to shifting winds. The SLAB model predicts that the plume will move due east from the source, and that there will be no impacts to the north, south and west of the source.

Monitoring Location 1 showed carbon dioxide concentrations ranging from about 600 ppm to a high of over 6,000 ppm after the monitoring location is first impacted about 10 minutes into the controlled release. In comparison, the model predicts concentrations would be about 20,000 ppm at this location.

Monitoring Location 2 showed a similar but slightly lower concentration range. Measured carbon dioxide concentrations ranged from background (approximately 600 ppm) to a high near 5,800 ppm. This was in good agreement with the model which predicted a concentration of about 3000 ppm.

Monitoring Locations, 4, 6 and 7 were within one foot of the surface and showed considerably higher concentrations. Location 4 generally showed concentrations that varied between 9,000 and 13,000 ppm. The modeled concentration was about 5,000 ppm. Over the course of the release period, the concentration at Location 6 remained about 8,000 ppm. In comparison, the modeled concentration was about 1,000 ppm. Location 7 concentrations varied widely from about 8,000 ppm up to a maximum of almost 14,000 ppm. In comparison, the modeled concentration was only about 300 ppm.

The modeled concentrations varied above and below, although within an order of magnitude of, the measured concentrations. The only exception was Location 7, for which the monitored concentrations were about 40 times higher than the modeled concentrations. Disparities may be attributable to shifting winds, or more likely, the variable topography of the site. Neither DEGADIS nor SLAB were designed to allow for specific topographical input data. Both models use very basic terrain factors, which can lead to skewed results.

5. PIPELINE RUPTURE - HORIZONTAL AND VERTICAL RELEASES

Thirty-two different scenarios were modeled. These included both a horizontal and a vertical release, four different release rates, carbon dioxide and hydrogen sulfide components, and receptors located at ground level (the worst case for heavier than air gases) and at four feet (generally considered the breathing zone). The results are included in Table 4 and Figures 14 through 21. Horizontal jet releases were modeled using SLAB, and vertical jet releases were modeled using the DEGADIS model.

All runs were made at F stability and a wind speed of 1 meter per second. These are considered extremely stable conditions at which dispersion is minimized. This will result in the highest maximum concentrations for horizontal releases.

Hydrogen sulfide concentrations were assumed to be 322 ppm in the released gas. Since neither the SLAB model nor the DEGADIS model have the capabilities to predict emissions of secondary constituents, it was assumed that hydrogen sulfide dispersed with the carbon dioxide and their relative concentrations remained constant. Thus, the 30,000 ppm carbon dioxide (STEL) contour coincides with the 10 ppm hydrogen sulfide contour (10 minute TWA), and the 300,000 ppm carbon dioxide contour approximates the 100 ppm hydrogen sulfide (IDLH) contour.

5.1. HORIZONTAL RELEASES

The results of the horizontal release modeling show that the scenario release rates could result in carbon dioxide impacts exceeding 30,000 ppm (STEL) 300 feet from the source and 5,000 ppm (10 minute TWA) 4100 feet from the source. Modeled hydrogen sulfide concentrations exceeded 10 ppm (10 minute TWA) approximately 300 feet from the source. Hydrogen sulfide concentrations are not predicted to exceed 100 ppm (IDLH) in the breathing zone. However, hydrogen sulfide concentrations are predicted to exceed 100 ppm (IDLH) at ground level, but only within the first 13 or 14 feet of the source.

5.2. VERTICAL RELEASES

The plumes resulting from vertical jet release scenarios are predicted to dissipate before settling to the ground. Concentrations exceeding 5,000 ppm carbon dioxide (10 minute TWA) and 10 ppm hydrogen sulfide (10 minute TWA) are not predicted to occur in the breathing zone or at ground level.

TABLES

Table 1

Sensitivity Analysis - Well Blowout Modeling

Howell Petroleum
Salt Creek Field, Wyoming

Parameters	Baseline	Tested Values	Change from Baseline					
			Breathing Zone (1.5 m above ground)			Ground Level		
			Max. Concentration	Distance to Max. Concentration	% Increase over Baseline Max. Concentration	Max. Concentration	Distance to Max. Concentration	% Increase over Baseline Max. Concentration
Windspeed (mph)	3	1	71.8	9,000	3.7	66.8	1,022	3.9
		6	4.9	65,790	-0.7	4.1	99,940	-0.7
Elevation at which Windspeed is Measured (meters)	10							
Surface Roughness (meters)	0.2							
Pasquill Stability Class	F	B	30.3	1,602	1.0	24.7	8,551	0.8
		D	62.0	46,520	3.0	50.3	57,130	2.7
Monin-Obukhov	Calculated							
Ambient Temp. (K)	310.8	244.1	5.5	77,980	-0.6	4.9	96,790	-0.6
		280.2	10.4	46,520	-0.3	9.0	57,130	-0.3
Ambient Pressure (atm)	0.83	0.87	16.8	31,130	0.1	14.7	37,920	0.1
		0.79	14.1	37,830	-0.1	12.5	45,520	-0.1
Relative Humidity (%)	56							
Abs. Humidity	Calculated							
Ambient Air Density	Calculated							
Gas Temp. (K)	255							
Flow Rate (kg/s)	11.6							
Source Radius (m)	0.0558							
Source Elevation (m)	0.4 [a]							
Carbon Dioxide Concentration	Baseline		15.4	34,330	0.0	13.6	41,460	0.0

[a] Minimum allowed by model

Table 2

Sensitivity Analysis - Stability Class

Howell Petroleum
Salt Creek Field, Wyoming

Parameters	Baseline	Tested Values	Change from Baseline: Breathing Zone (1.5 m above ground): Max. Concentration (ppm)	Breathing Zone: Distance to Max. Concentration	Breathing Zone: % Increase over Baseline Max. Concentration	Ground Level: Max. Concentration (ppm)	Ground Level: Distance to Max. Concentration	Ground Level: % Increase over Baseline Max. Concentration
Windspeed (mph)	1							
Elevation at which	10							
Surface Roughness (meters)	0.2							
Pasquill Stability Class	D	B	134.1	1,124	-0.8	112.8	1,330	-0.9
		F	71.8	9,003	-0.6	66.8	9,716	-0.6
Monin-Obukhov	Calculated							
Ambient Temp. (K)	310.8							
Ambient Pressure (atm)	0.87							
Relative Humidity (%)	56							
Abs. Humidity	Calculated							
Ambient Air Density	Calculated							
Gas Temp. (K)	255							
Flow Rate (kg/s)	11.6							
Source Radius (m)	0.0558							
Source Elevation (m)	0.4 [a]							
Baseline Worst Case (Carbon Dioxide)	D	D	192.4	1,370	0.0	181.5	1,454	0.0
Hydrogen Sulfide Concentration			0.035			0.033		

[a] Minimum allowed by model

Table 3

Controlled Release
Monitor Locations

Location	Distance From Ground (feet)	Distance From Source (feet)	Bearing From Source
1	4	53	64°
2	4	110	122°
3	4	59	210°
4	1	206	89°
5	1	146	187°
6	1	450	98°
7	1	400	76°
8	4	103	360°

Notes:

Bearing From Source = degrees off North

Table 4

SLAB Modeling Results
Pipeline Rupture
Horizontal Release

Receptor Height (feet)	Source Release Rate (MMSCFD)	Pipe Diameter (inches)	Maximum Distance From Source at which CO_2 Concentration Exceeds 5,000 ppm (feet)	Maximum Distance From Source at which H_2S Concentration Exceeds 100 ppm (feet)	Maximum Distance From Source at which CO_2 Concentration Exceeds 30,000 ppm and H_2S Exceeds 10 ppm (feet)
4	10	3	905	NA	148
4	30	6	1889	NA	260
4	250	12	4047	NA	268
4	290	16	4049	NA	263
Ground level	10	3	1018	14	192
Ground level	30	6	1982	13	293
Ground level	250	12	4087	13	270
Ground level	290	16	4089	13	266

Notes:

Maximum occurs along centerline of plume in the direction of the release.

F Stability

Windspeed = 1 meter/second

FIGURES

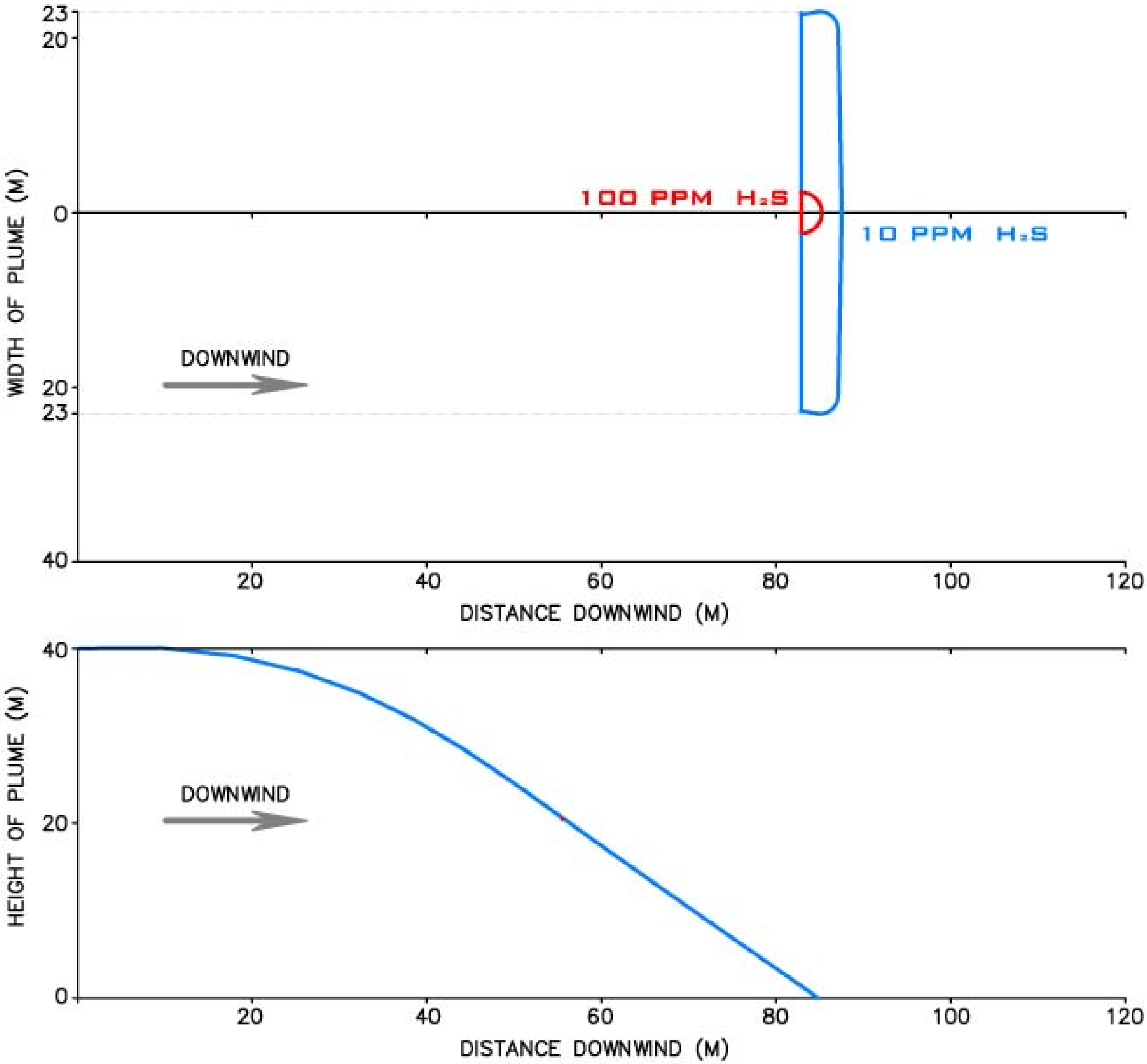

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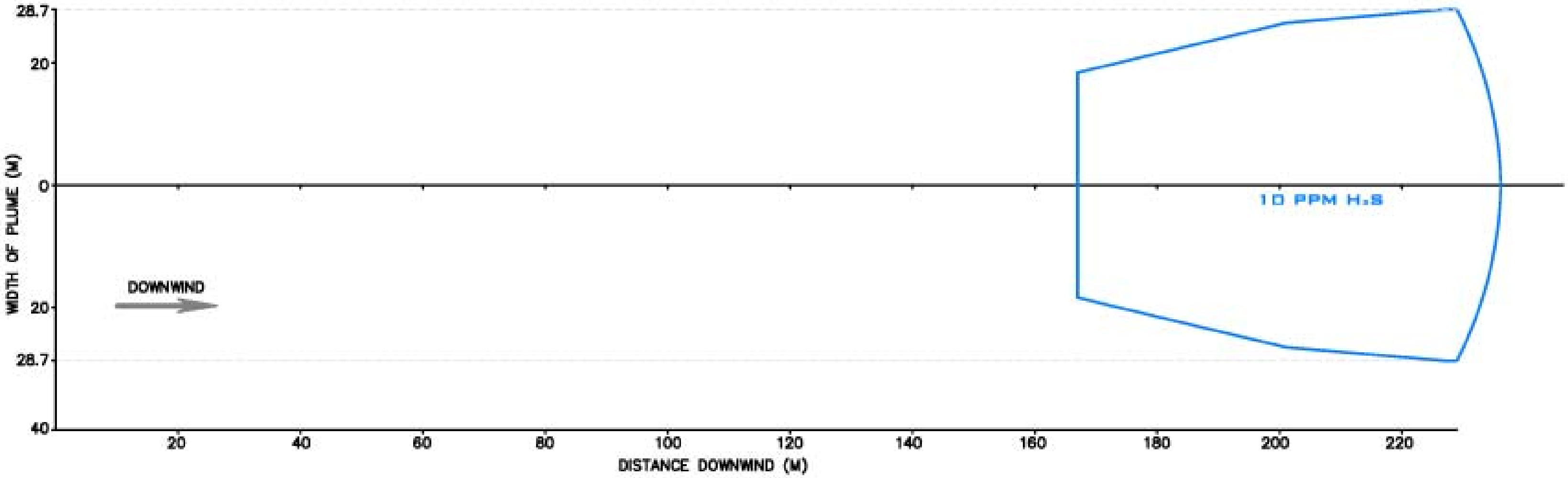
FIGURE 1

BLOWOUT PLUME DISPERSION
HIGH TEMPERATURE
HOWELL PETROLEUM

SCALE:	DATE:	DWG NO.
AS NOTED	3/23/05	1065-35



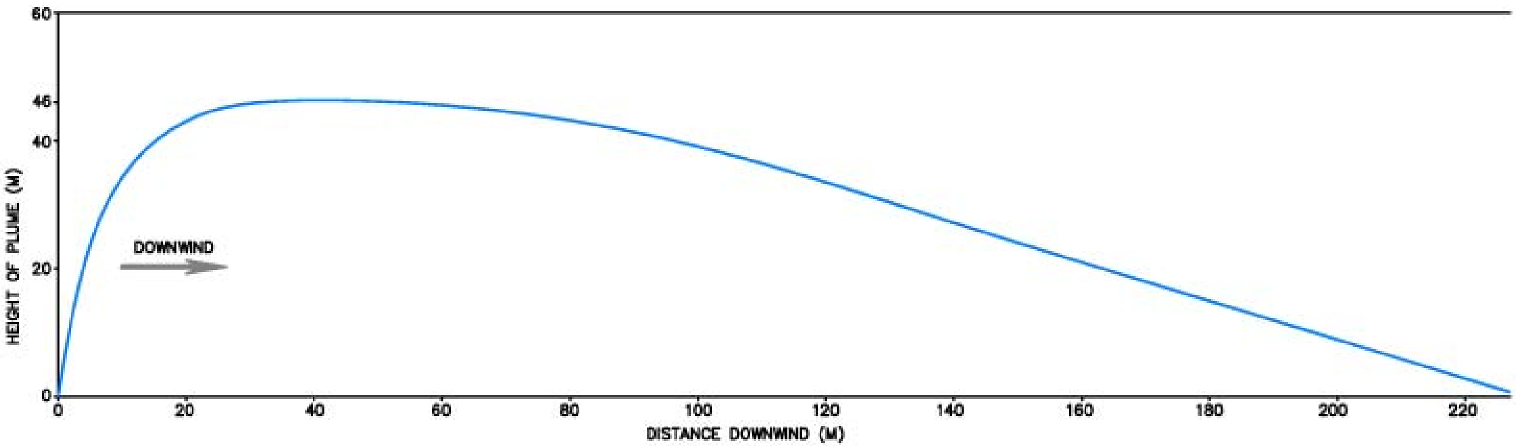


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FIGURE 2

BLOWOUT PLUME DISPERSION
LOW TEMPERATURE
HOWELL PETROLEUM

SCALE:	DATE:	DWG NO.
AS NOTED	8/5/05	1065-36

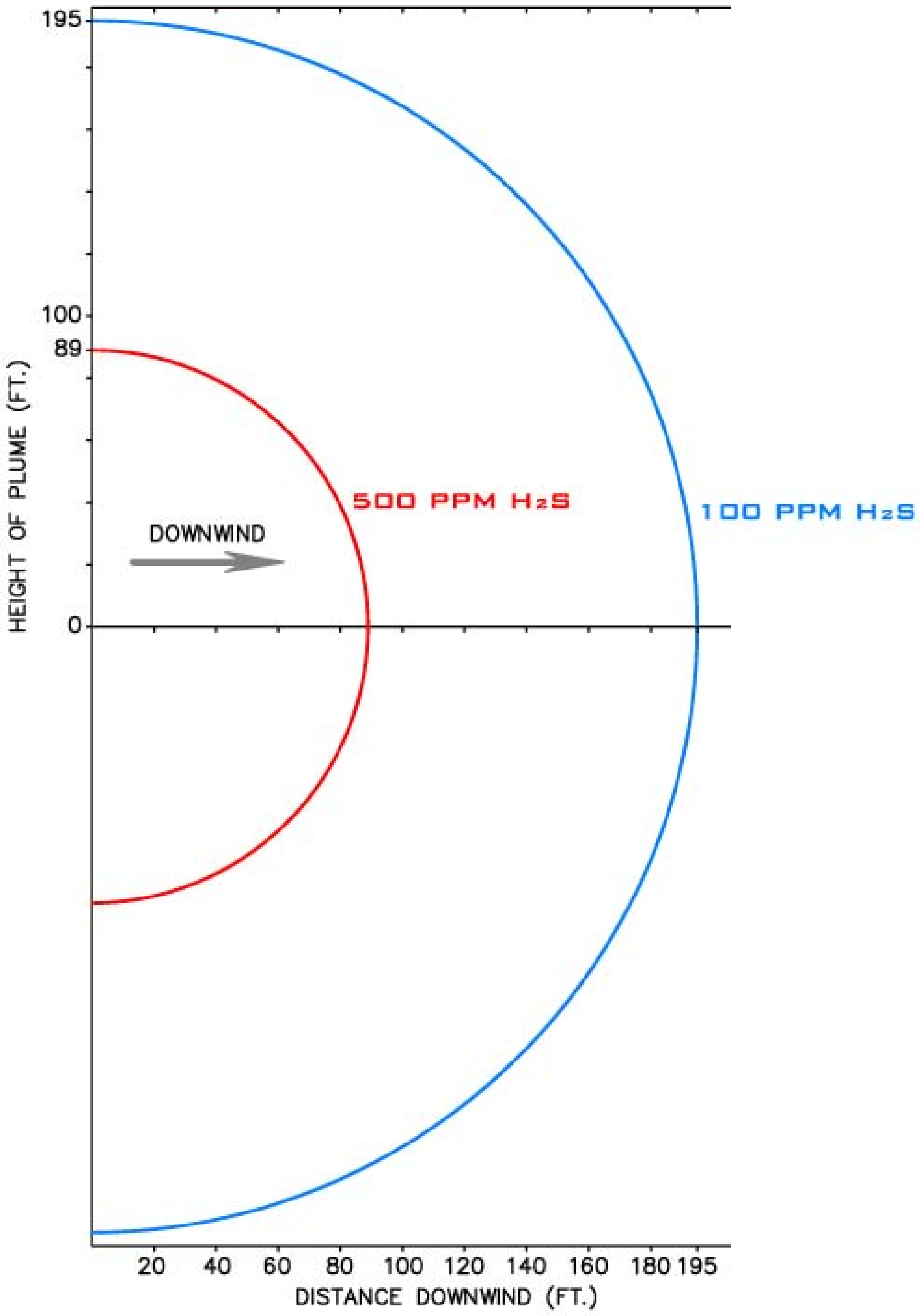

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FIGURE 3		
PASQUILL-GIFFORD RADIUS OF EXPOSURE BLOWOUT-CASE 1 HOWELL PETROLEUM		
SCALE: AS NOTED	DATE: 8/5/05	DWG NO. 1065-37

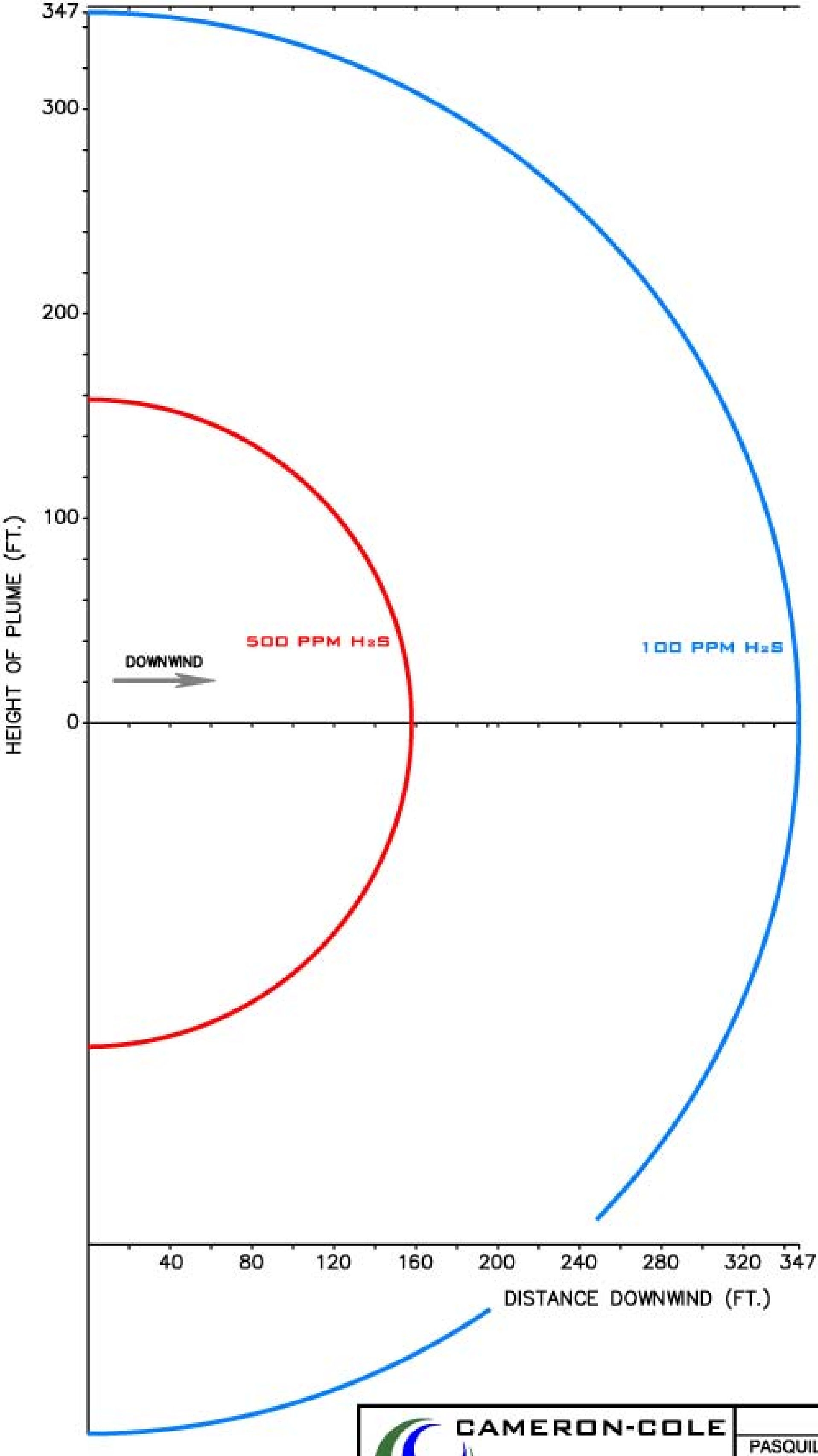

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FIGURE 4		
PASQUILL-GIFFORD RADIUS OF EXPOSURE BLOWOUT-CASE 2 HOWELL PETROLEUM		
SCALE: AS NOTED	DATE: 8/5/05	DWG NO. 1065-38

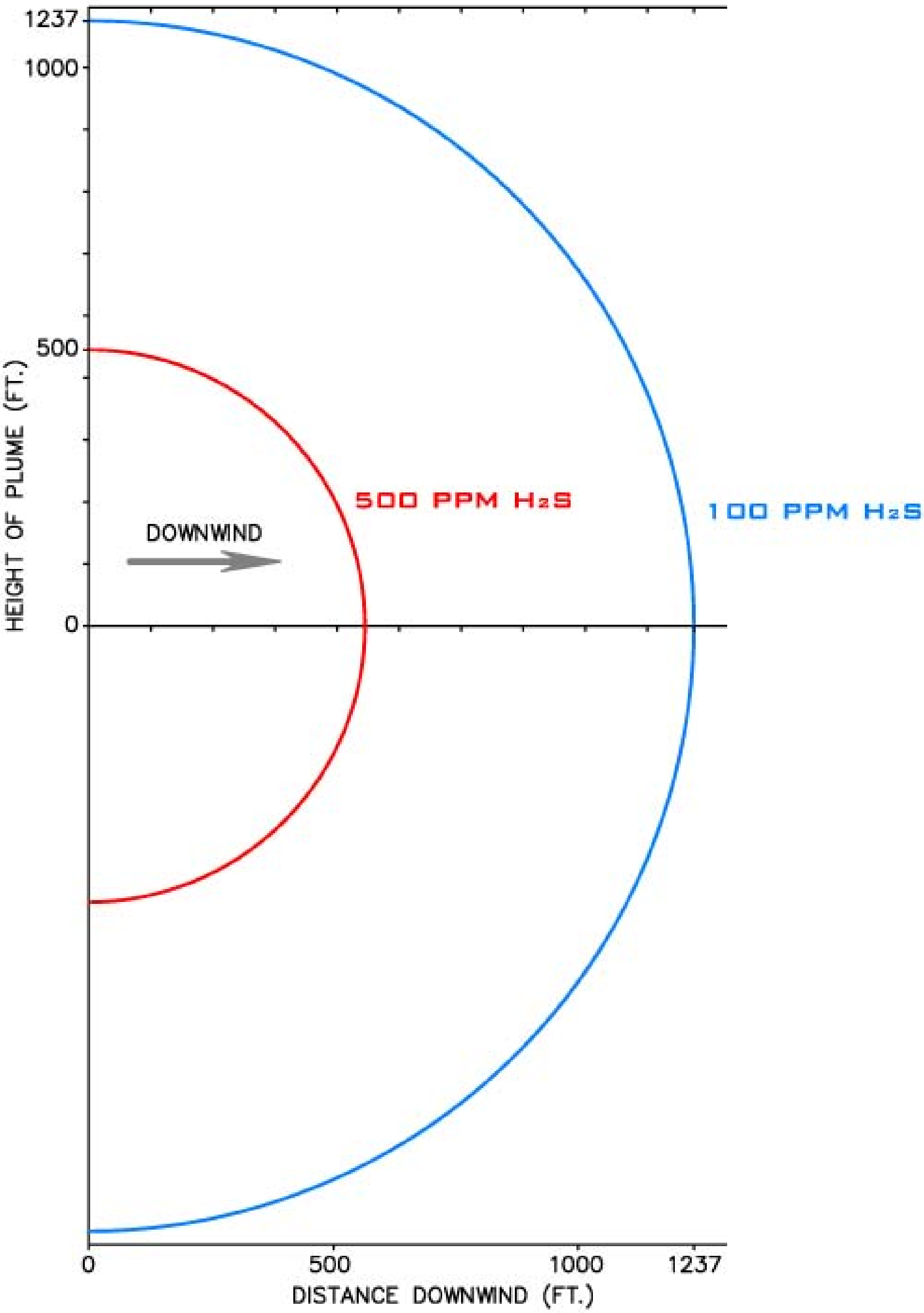

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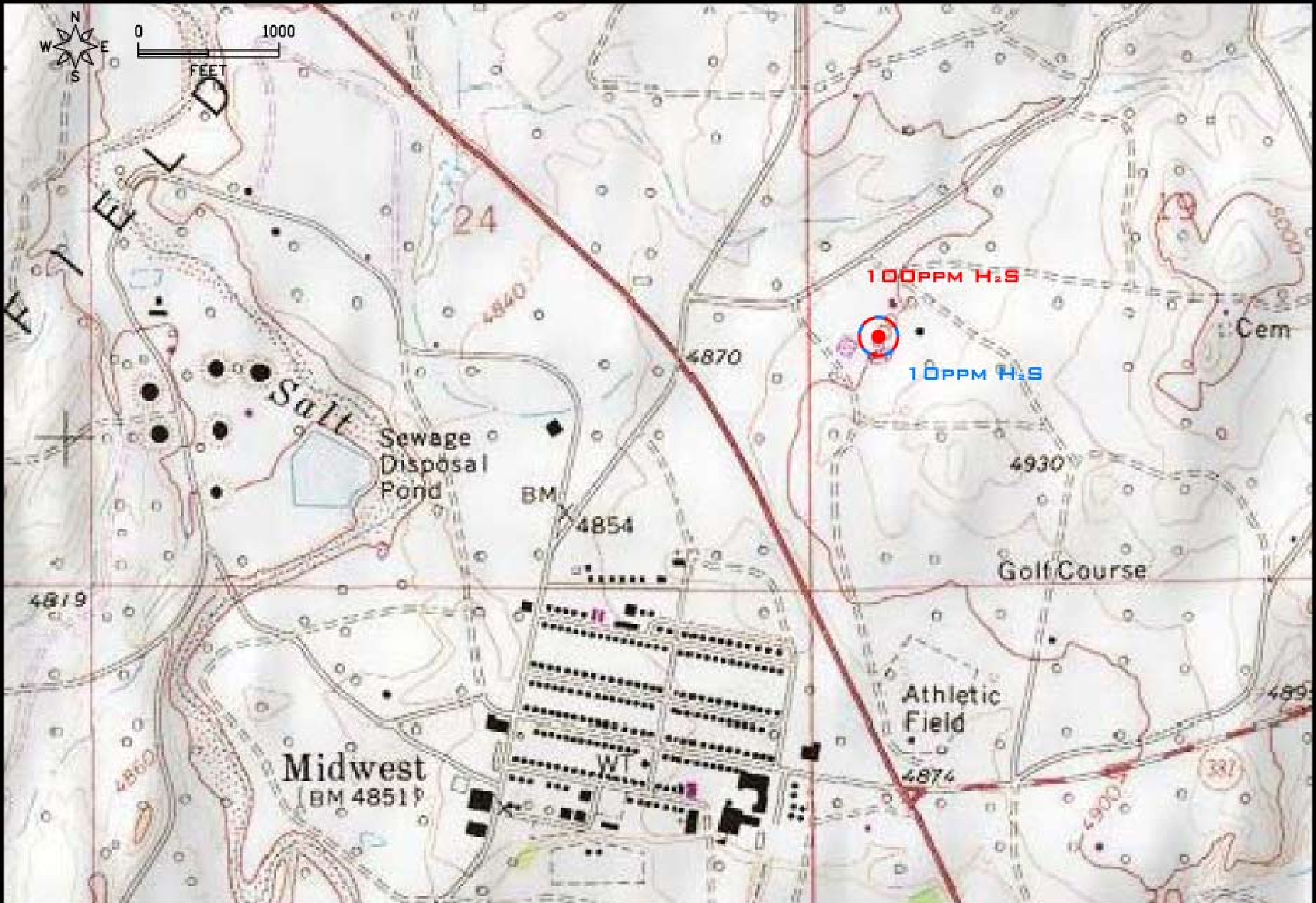
FIGURE 5

PASQUILL-GIFFORD RADIUS OF EXPOSURE
PIPELINE LEAK-CASE 3
HOWELL PETROLEUM

SCALE:	DATE:	DWG NO.
AS NOTED	8/5/05	1065-39



10 PPM H_2S - MAXIMUM DISPERSION 272 TO 285 FT.
100 PPM H_2S - MAXIMUM DISPERSION 272 TO 278 FT.

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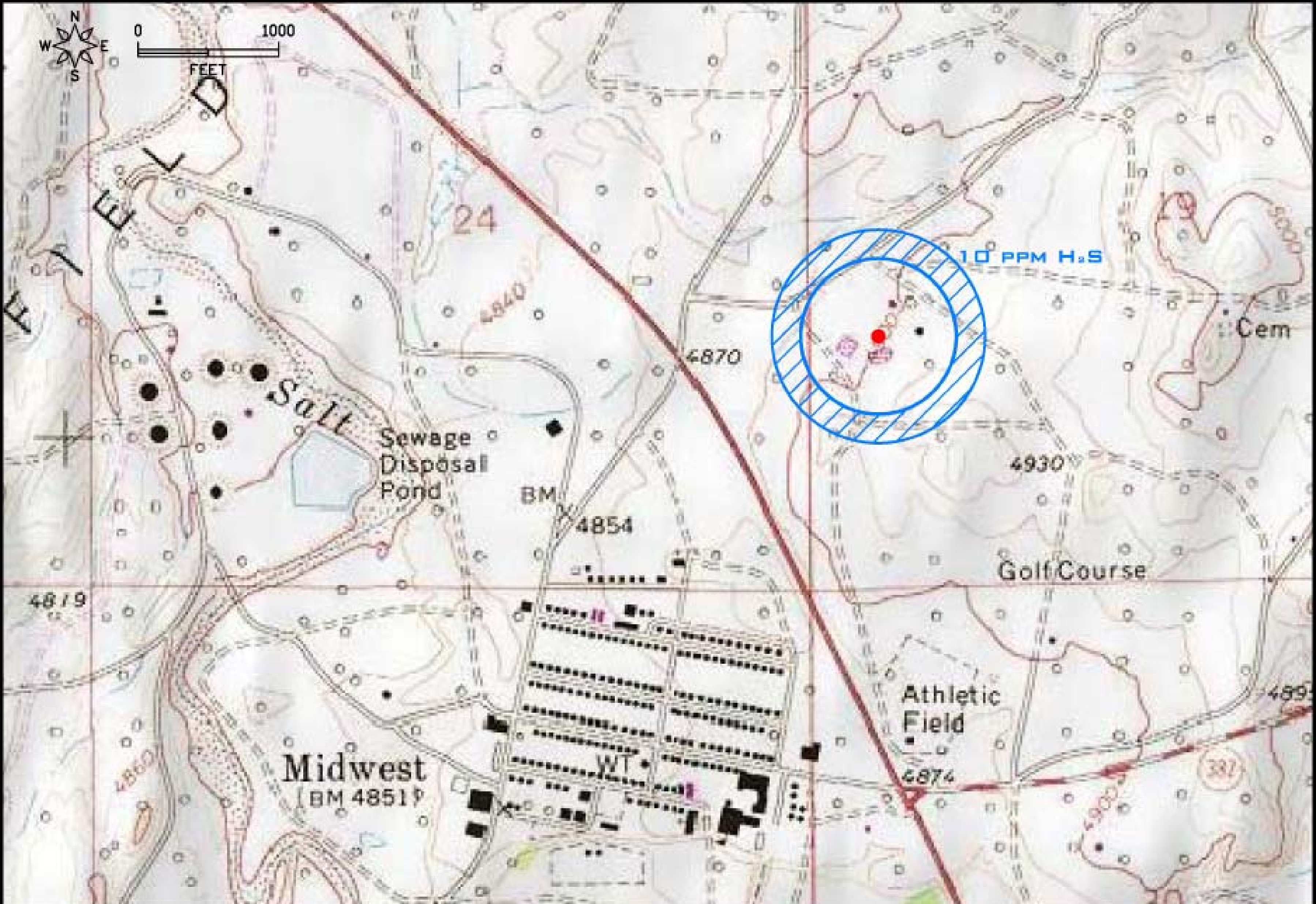
FIGURE 6

PIPELINE LEAK PLUME DISPERSION
HIGH TEMPERATURE - CASE 3
HOWELL PETROLEUM

SCALE:	DATE:	DWG NO.
1" = 1000'	8/5/05	1065-40



10 PPM H_2S - MAXIMUM DISPERSION 548 TO 751 FT.
100 PPM H_2S - NOT PREDICTED IN BREATHING ZONE

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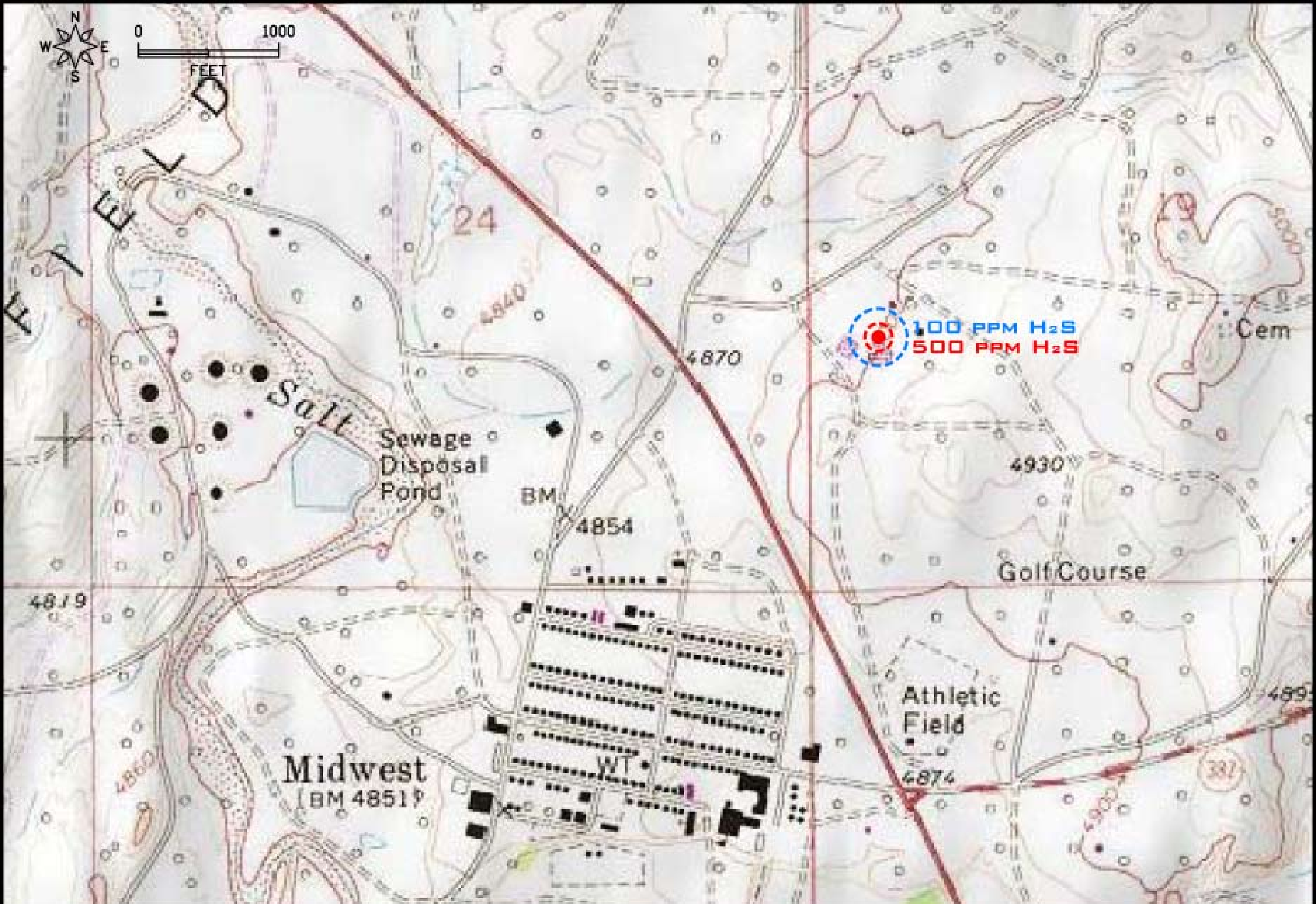
FIGURE 7

PIPELINE LEAK PLUME DISPERSION
LOW TEMPERATURE - CASE 3
HOWELL PETROLEUM

SCALE:	DATE:	DWG NO.
1" = 1000'	8/5/05	1065-41



CASE 1

100 PPM H2S - MAXIMUM DISPERSION 195 FT.

500 PPM H2S - MAXIMUM DISPERSION 89 FT.

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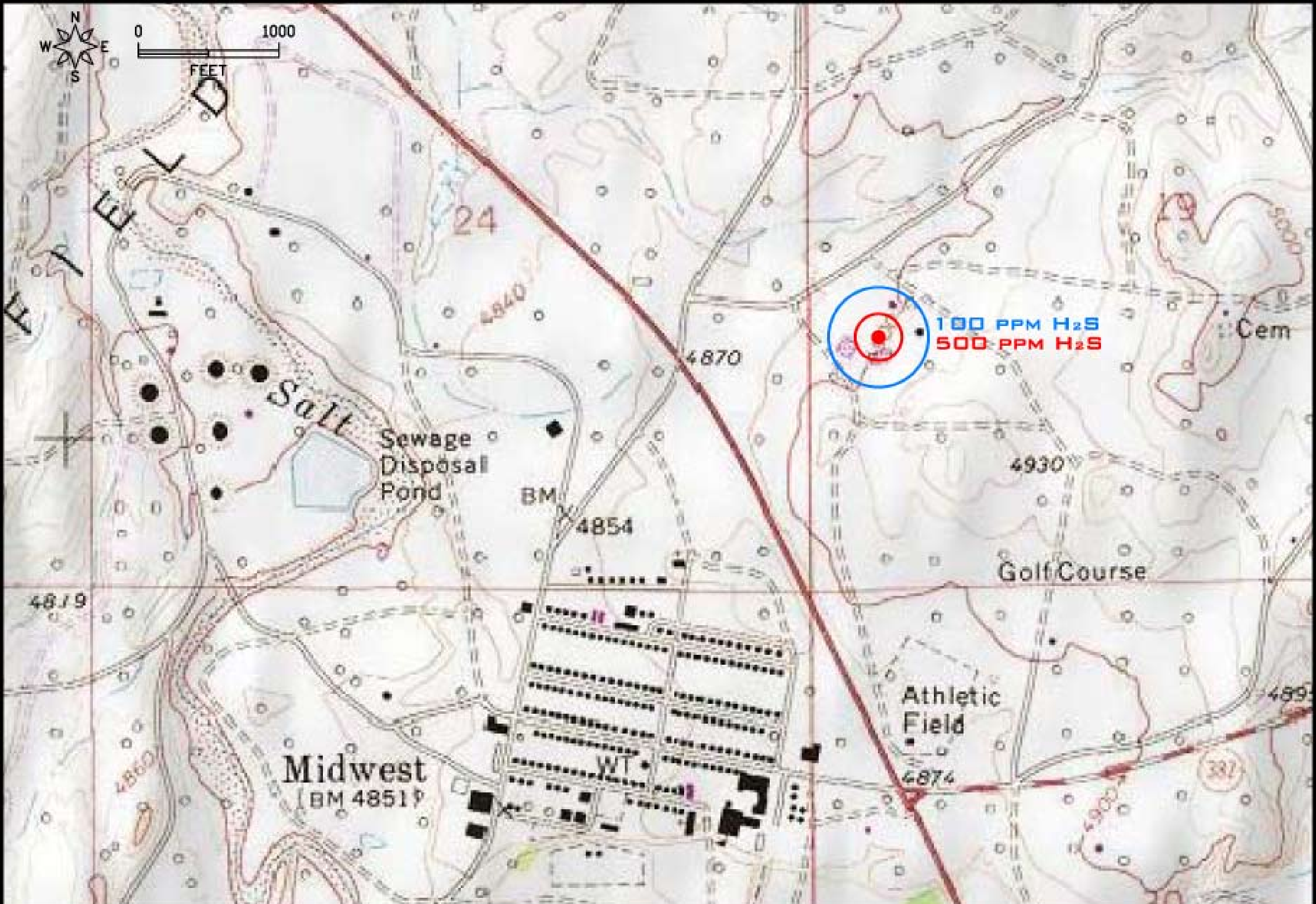
FIGURE 8

PASQUILL-GIFFORD RADIUS OF EXPOSURE
BLOWOUT-CASE 1
HOWELL PETROLEUM

SCALE:	DATE:	DWG NO.
1" = 1000'	8/5/05	1065-42



CASE 2

100 PPM H_2S - MAXIMUM DISPERSION 347 FT.

500 PPM H_2S - MAXIMUM DISPERSION 158 FT.

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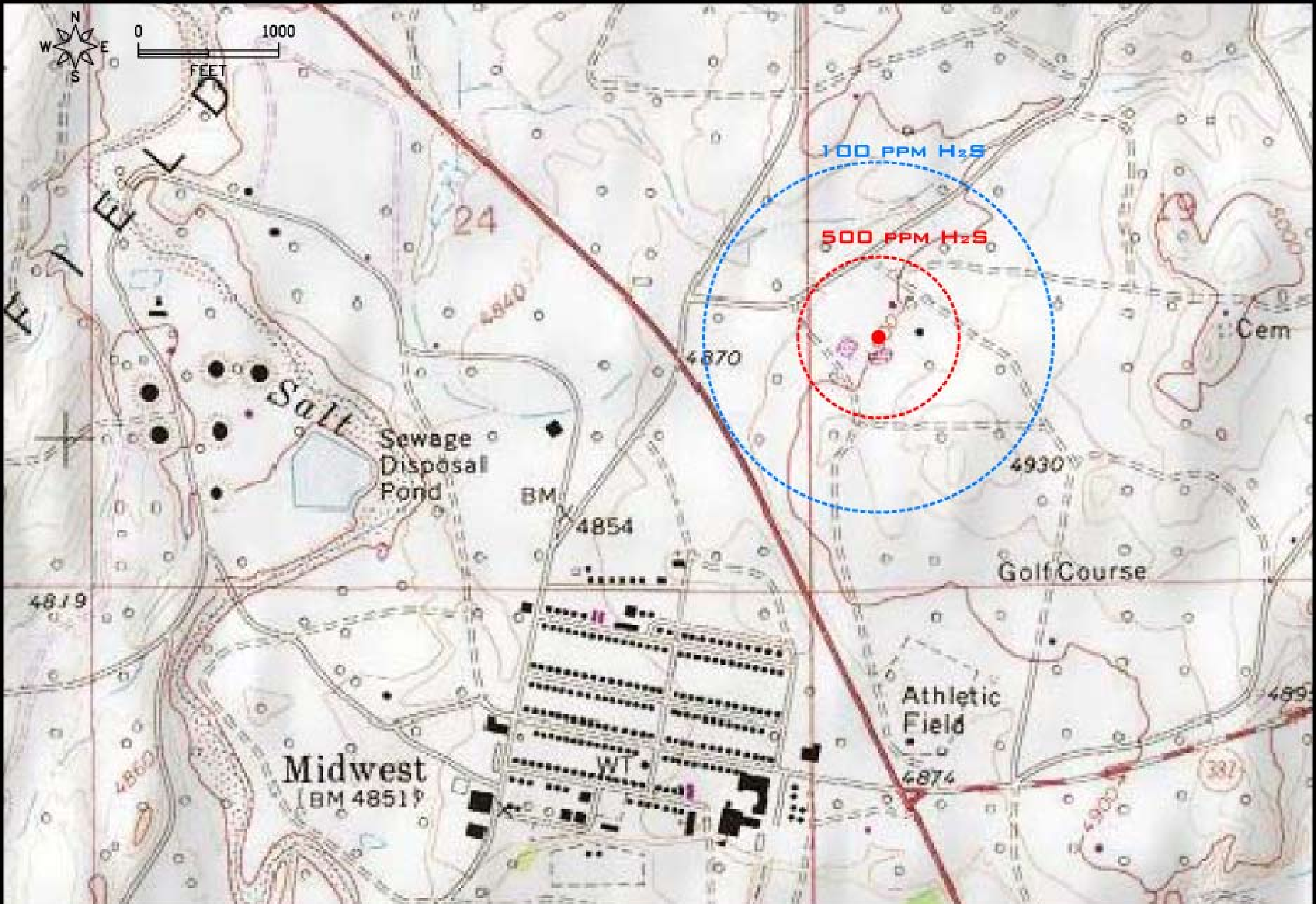
FIGURE 9

PASQUILL-GIFFORD RADIUS OF EXPOSURE
BLOWOUT-CASE 2
HOWELL PETROLEUM

SCALE:	DATE:	DWG NO.
1" = 1000'	8/5/05	1065-43



CASE 3

100 PPM H_2S - MAXIMUM DISPERSION 1237 FT.

500 PPM H_2S - MAXIMUM DISPERSION 565 FT.

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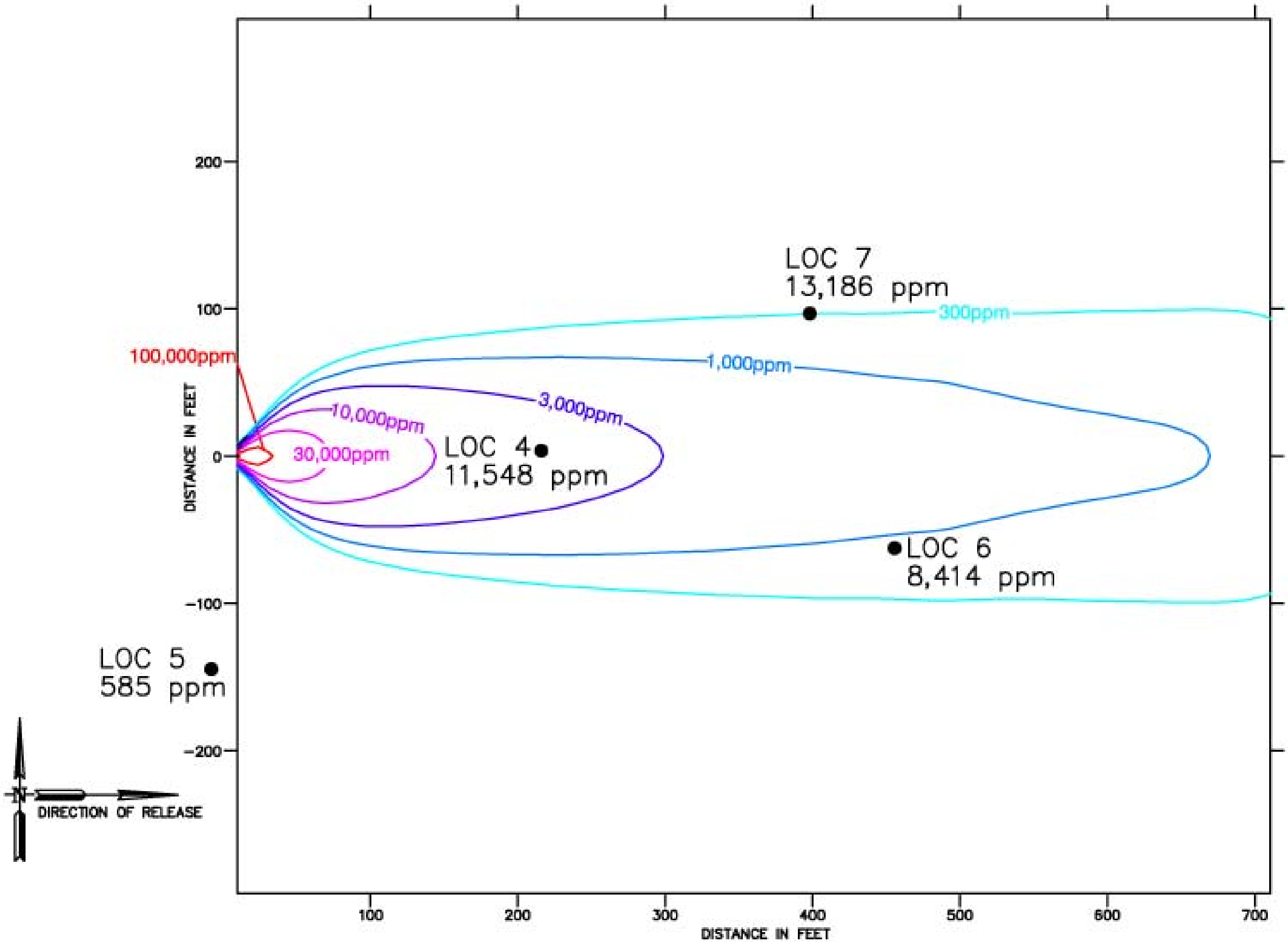
FIGURE 10

PASQUILL-GIFFORD RADIUS OF EXPOSURE
PIPELINE LEAK-CASE 3
HOWELL PETROLEUM

SCALE:	DATE:	DWG NO.
1" = 1000'	8/5/05	1065-44

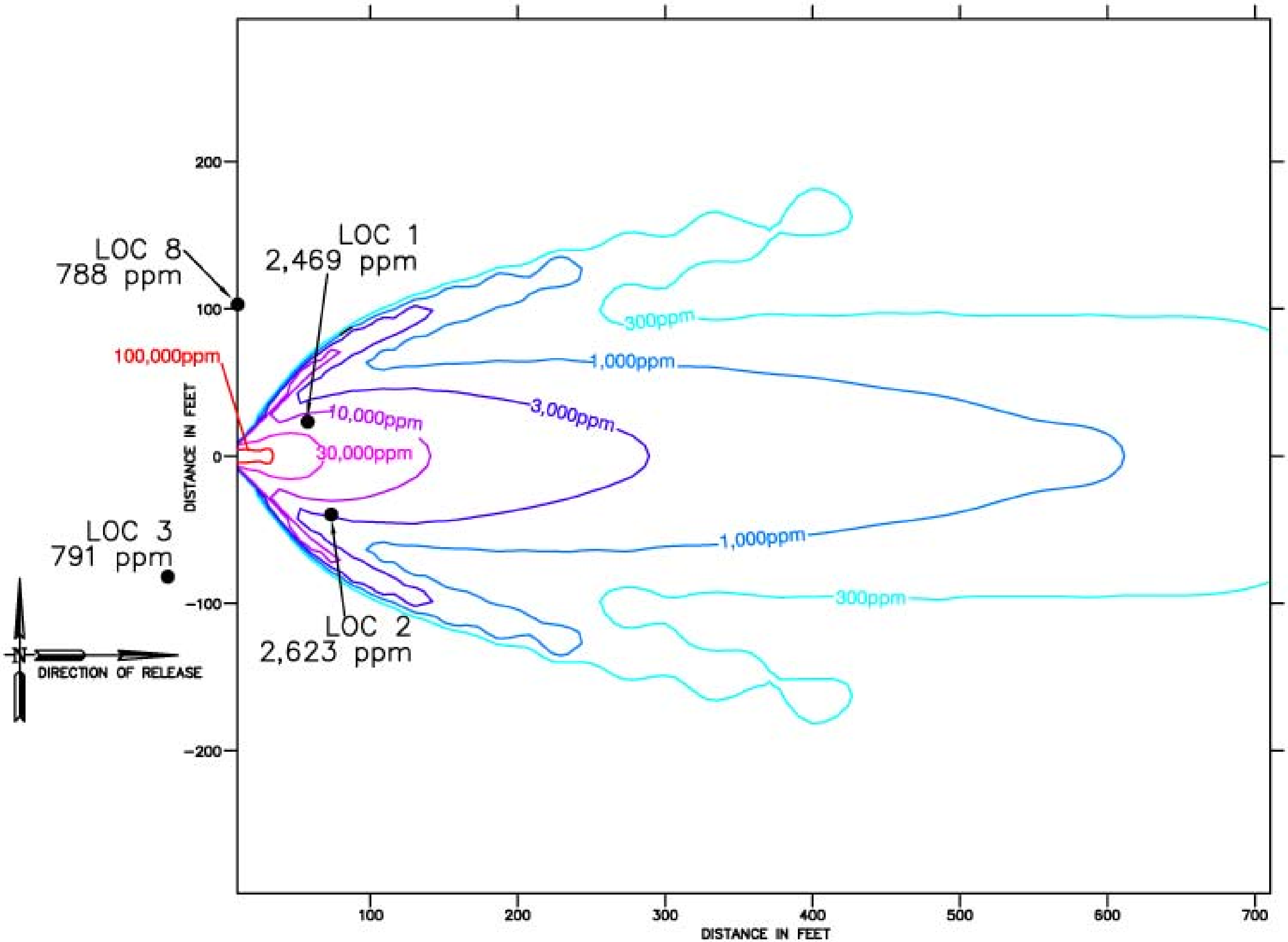


LEGEND

● MONITORING RESULTS FOR 5/17/05 CO_2 TEST

—300— SLAB MODEL OUTPUT ISOCONCENTRATION CONTOUR (CO_2 ppm)

CAMERON-COLE	FIGURE 11 SLAB MODEL RESULTS vs 5/17/05 TEST RELEASE OF CO_2 - RECEPTOR HEIGHT OF 1 FOOT 15 MINUTES AFTER START OF RELEASE HOWELL PETROLEUM		
	SCALE: AS NOTED	DATE: 8/5/05	DWG NO. 1065-47



LEGEND

● MONITORING RESULTS FOR 5/17/05 CO_2 TEST

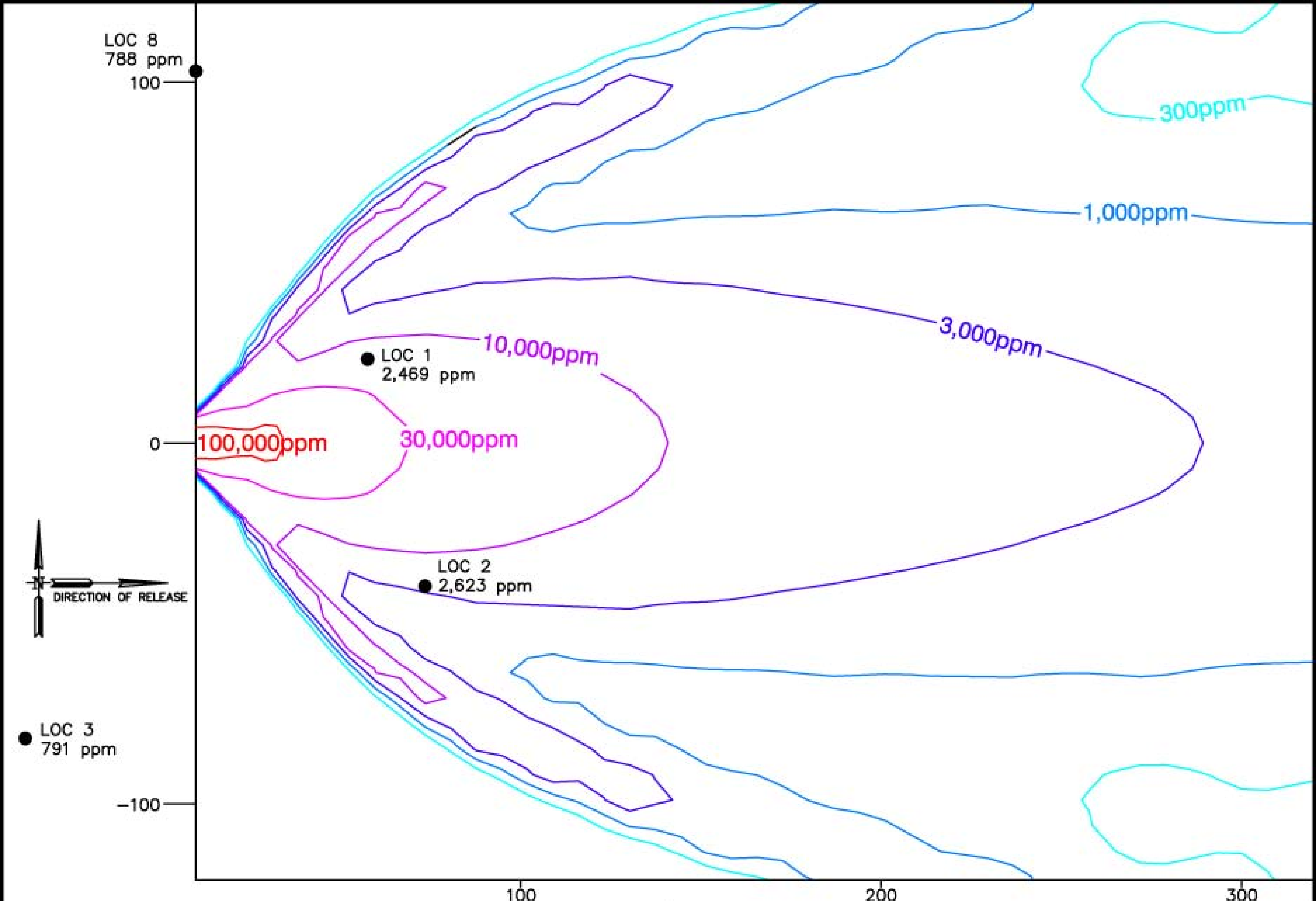
—300— SLAB MODEL OUTPUT ISOCONCENTRATION CONTOUR (CO_2 ppm)

CAMERON-COLE

FIGURE 12

SLAB MODEL RESULTS vs 5/17/05 TEST RELEASE OF CO_2 - RECEPTOR HEIGHT OF 4 FEET 15 MINUTES AFTER START OF RELEASE HOWELL PETROLEUM

SCALE:	DATE:	DWG NO.
AS NOTED	8/5/05	1065-45



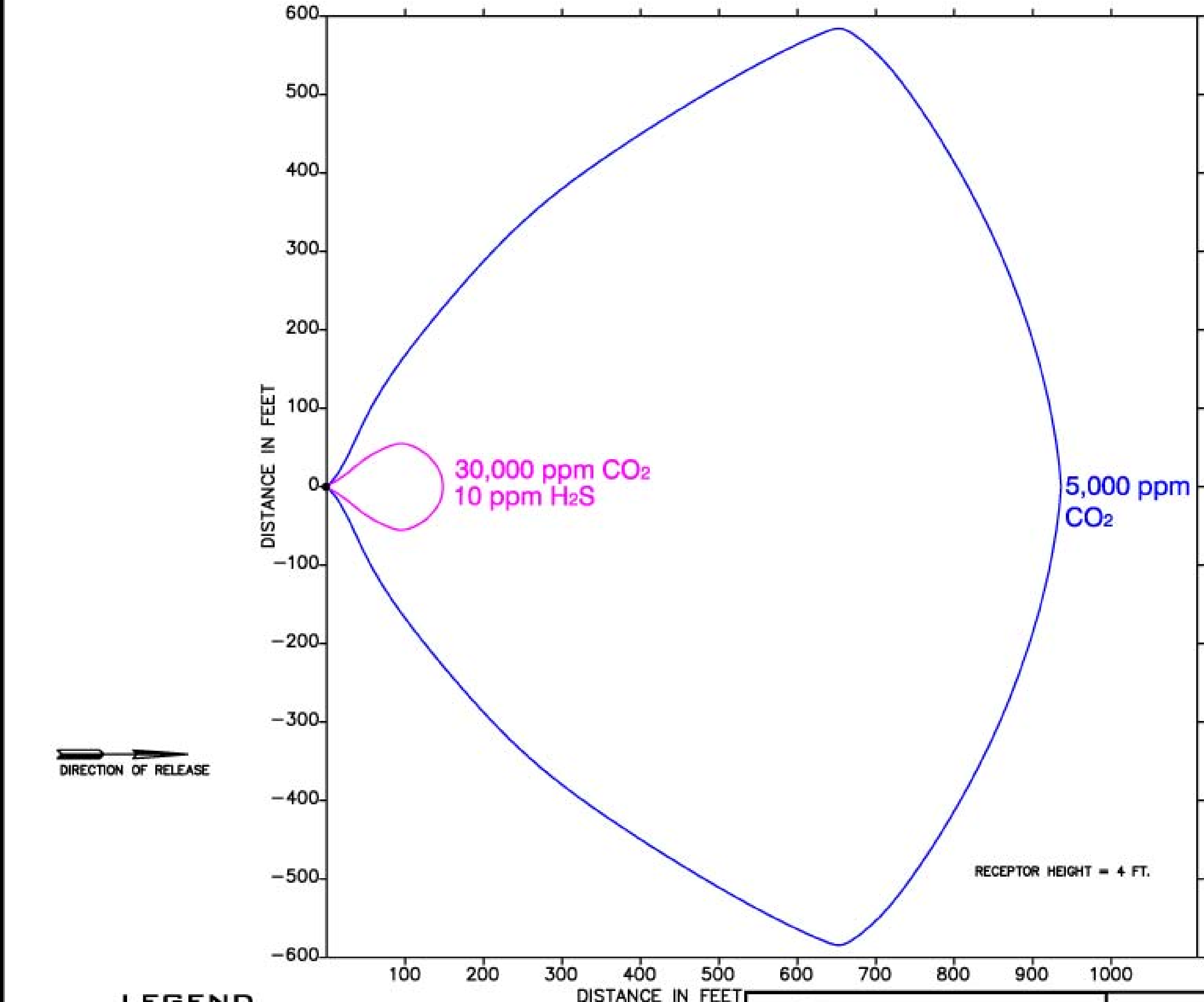
LEGEND

● MONITORING RESULTS FOR 5/17/05 CO_2 TEST

—300— SLAB MODEL OUTPUT ISOCONCENTRATION CONTOUR (CO_2 ppm)

CAMERON-COLE

FIGURE 13		
SLAB MODEL RESULTS vs 5/17/05 ZOOM VIEW TEST RELEASE OF CO_2-RECEPTOR HEIGHT OF 4 FT. 15 MINUTES AFTER START OF RELEASE HOWELL PETROLEUM		
SCALE: AS NOTED	DATE: 8/5/05	DWG NO. 1065-46



LEGEND

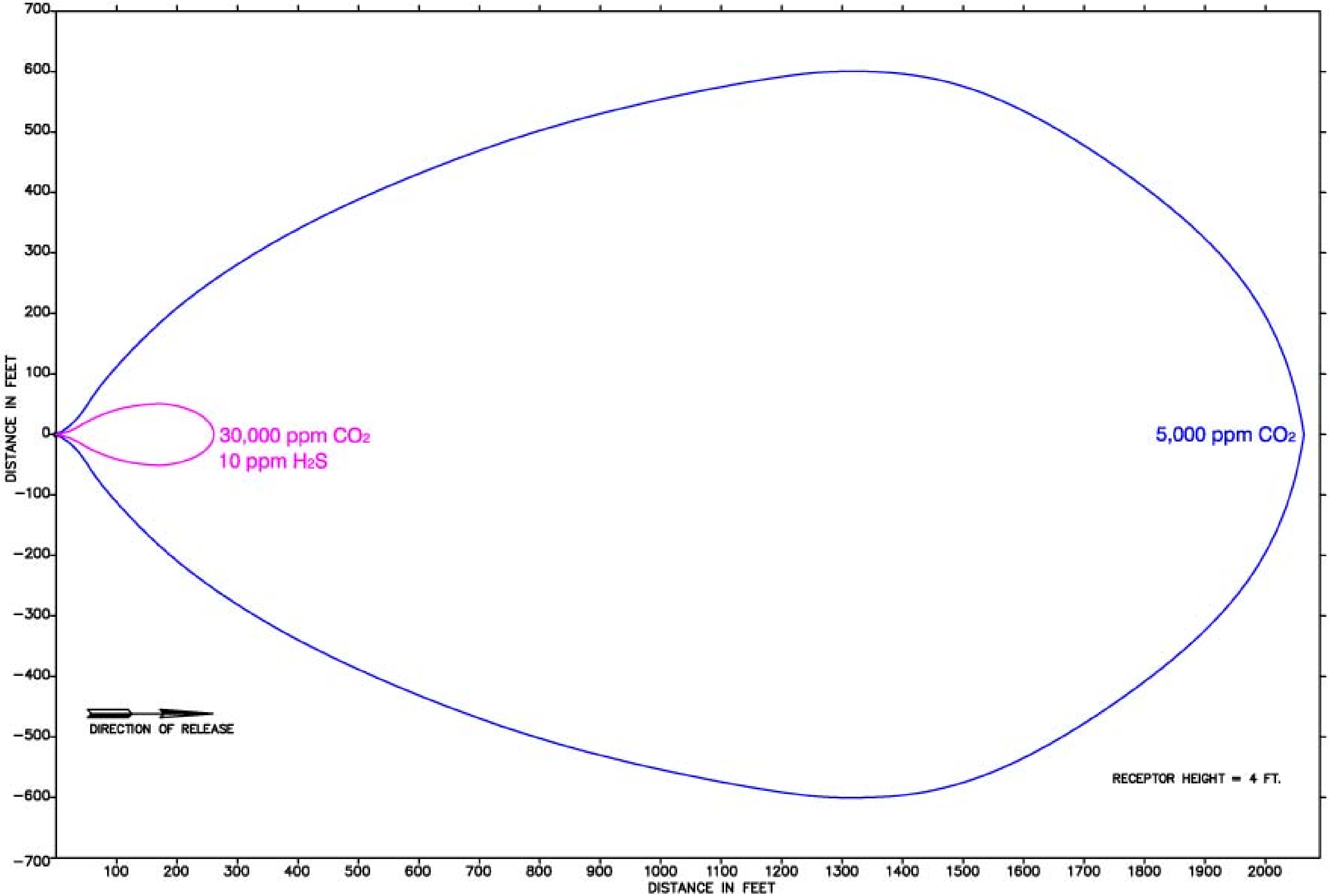
- • SOURCE AREA
- —5,000— 5,000 ppm CO_2 CONTOUR
- —30,000— 30,000 ppm CO_2 AND 10 ppm H_2S CONTOUR

CAMERON-COLE

FIGURE 14

SLAB MODEL OUTPUT
HORIZONTAL JET RELEASE 10 MMSCFD
3 INCH PIPE DIAMETER
HOWELL PETROLEUM

SCALE:	DATE:	DWG NO.
AS NOTED	8/5/05	1065-48

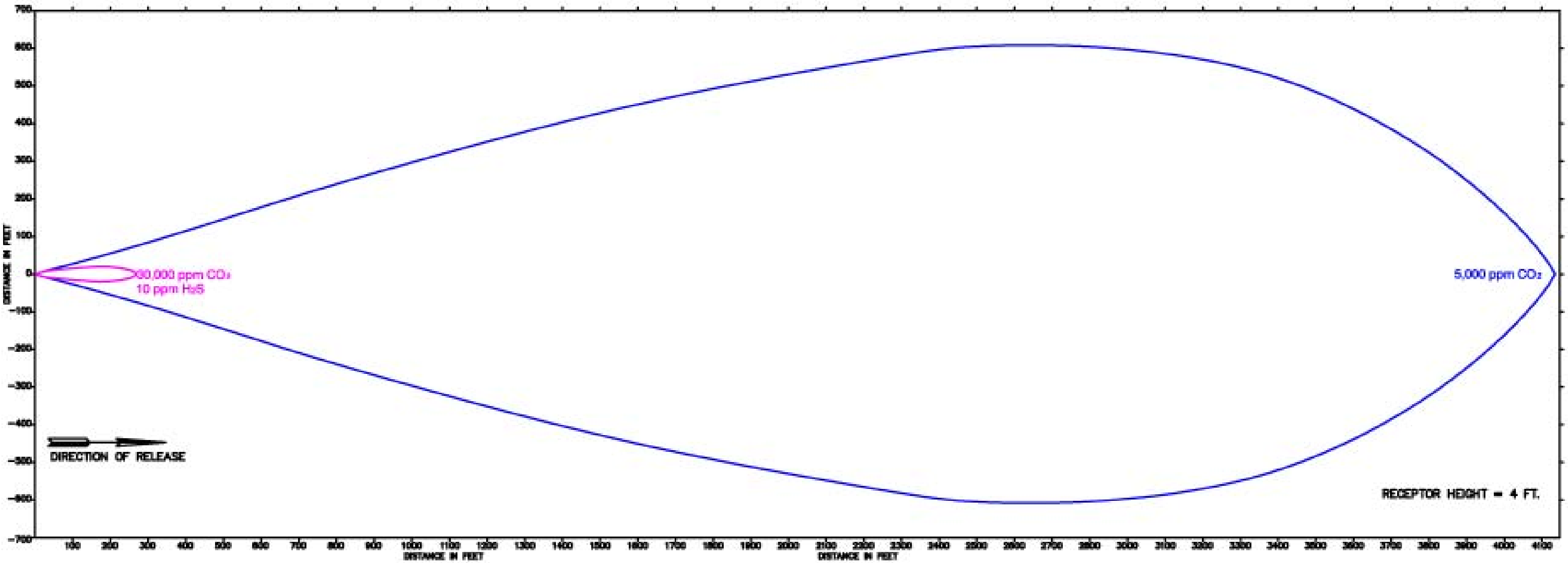


LEGEND

- • SOURCE AREA
- —5,000— 5,000 ppm CO_2 CONTOUR
- —30,000— 30,000 ppm CO_2 AND 10 ppm H_2S CONTOUR

CAMERON-COLE

FIGURE 15		
SLAB MODEL OUTPUT HORIZONTAL JET RELEASE 30 MMSCFD 6 INCH PIPE DIAMETER HOWELL PETROLEUM		
SCALE: AS NOTED	DATE: 8/5/05	DWG NO. 1065-49

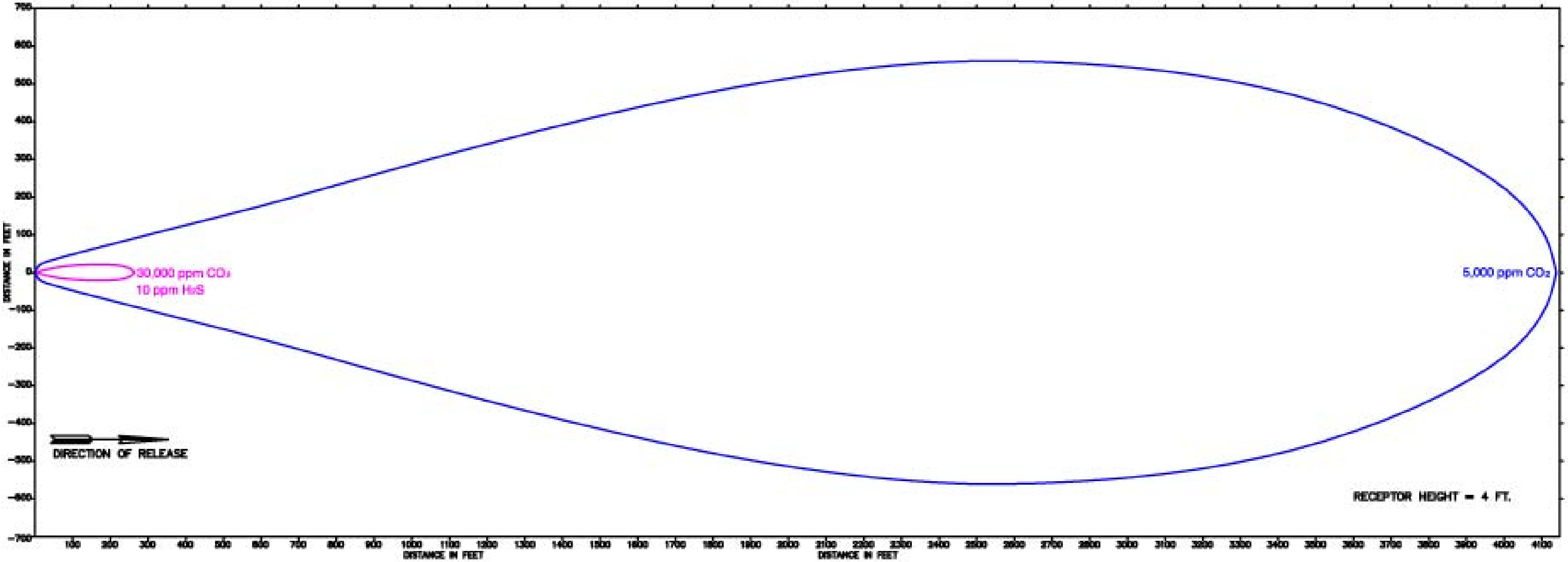


LEGEND

- • SOURCE AREA
- —5,000— 5,000 ppm CO_2 CONTOUR
- —30,000— 30,000 ppm CO_2 AND 10 ppm H_2S CONTOUR

CAMERON-COLE

FIGURE 16		
SLAB MODEL OUTPUT HORIZONTAL JET RELEASE 250 MMSCFD 12 INCH PIPE DIAMETER HOWELL PETROLEUM		
SCALE: AS NOTED	DATE: 8/5/05	DWG NO. 1065-50

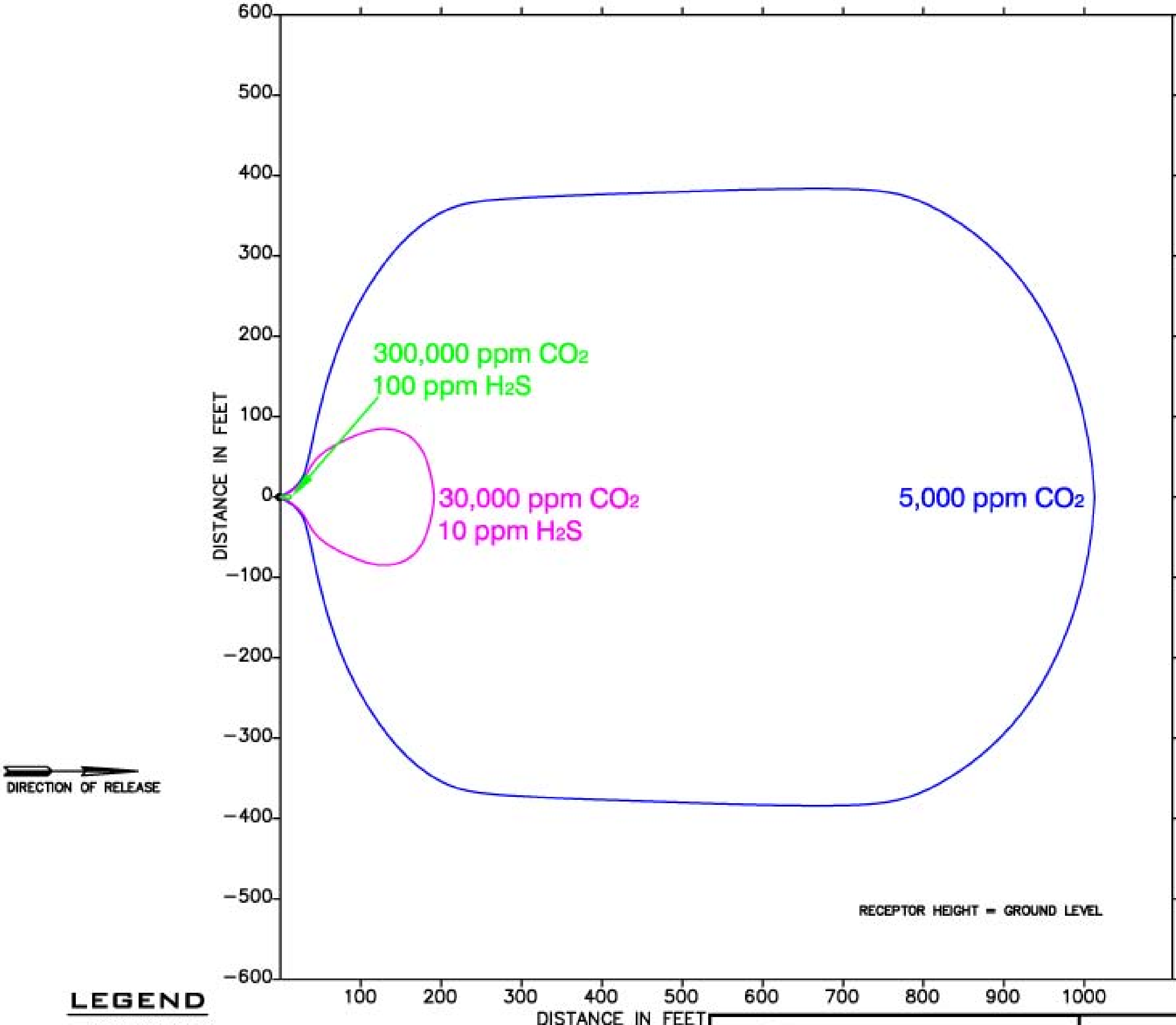


LEGEND

- • SOURCE AREA
- —5,000— 5,000 ppm CO_2 CONTOUR
- —30,000— 30,000 ppm CO_2 AND 10 ppm H_2S CONTOUR

CAMERON-COLE

FIGURE 17		
SLAB MODEL OUTPUT HORIZONTAL JET RELEASE 290 MMSCFD 16 INCH PIPE DIAMETER HOWELL PETROLEUM		
SCALE: AS NOTED	DATE: 8/5/05	DWG NO. 1065-51



LEGEND

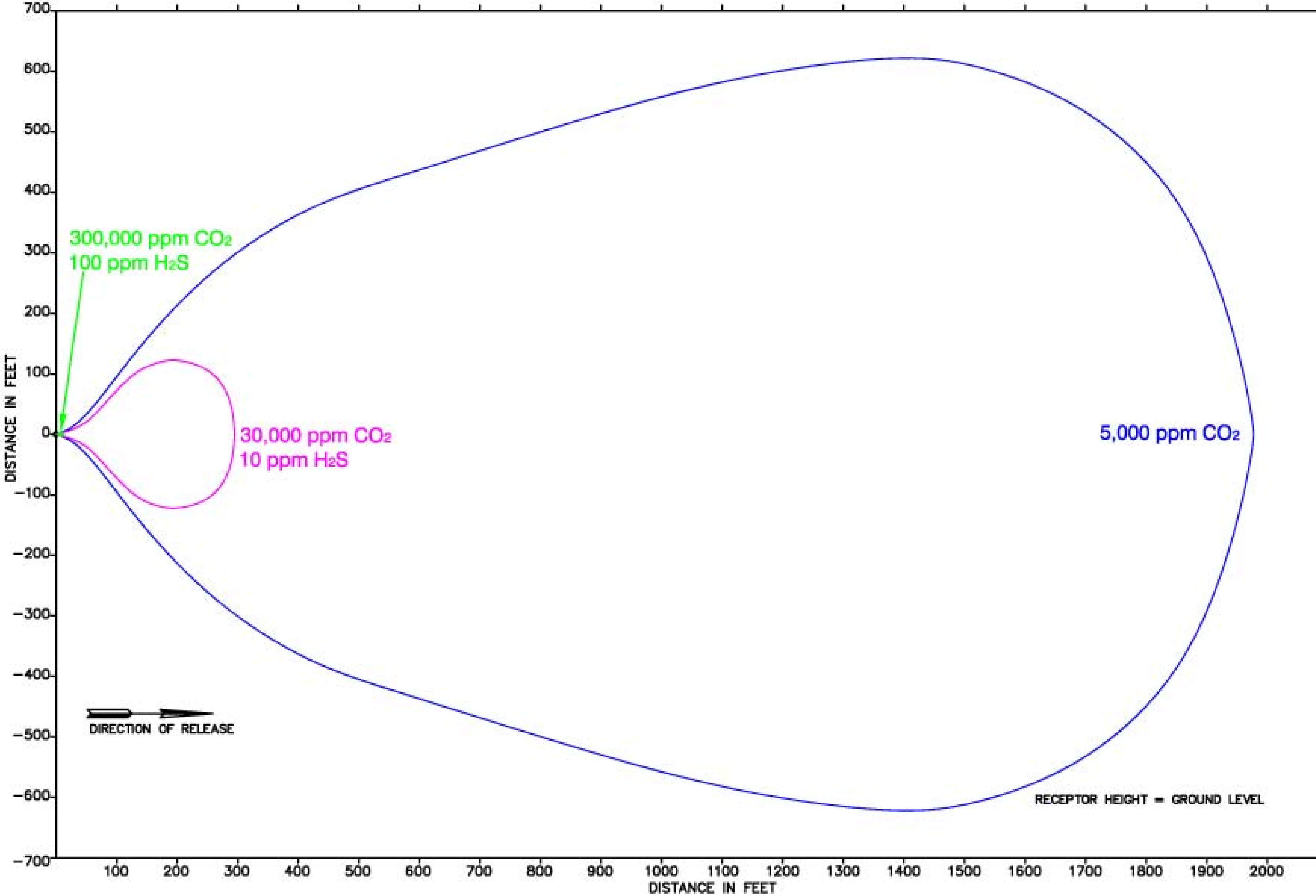
- • SOURCE AREA
- —5,000— 5,000 ppm CO_2 CONTOUR
- —30,000— 30,000 ppm CO_2 AND 10 ppm H_2S CONTOUR
- —300,000— 300,000 ppm CO_2 AND 100 ppm H_2S CONTOUR

CAMERON-COLE

FIGURE 18

SLAB MODEL OUTPUT
HORIZONTAL JET RELEASE 10 MMSCFD
3 INCH PIPE DIAMETER
HOWELL PETROLEUM

SCALE:	DATE:	DWG NO.
AS NOTED	8/5/05	1065-52

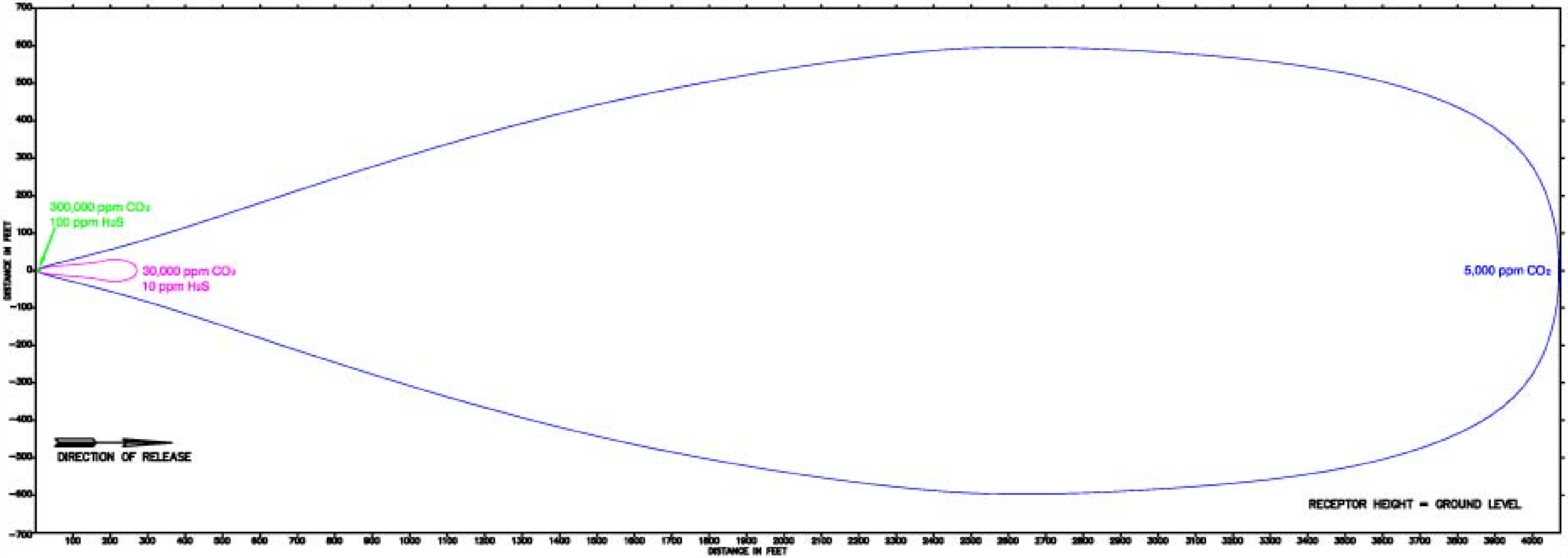


LEGEND

- • SOURCE AREA
- —5,000— 5,000 ppm CO_2 CONTOUR
- —30,000— 30,000 ppm CO_2 AND 10 ppm H_2S CONTOUR
- —300,000— 300,000 ppm CO_2 AND 100 ppm H_2S CONTOUR

CAMERON-COLE

FIGURE 19		
SLAB MODEL OUTPUT HORIZONTAL JET RELEASE 30 MMSCFD 6 INCH PIPE DIAMETER HOWELL PETROLEUM		
SCALE: AS NOTED	DATE: 8/05/05	DWG NO. 1065-53

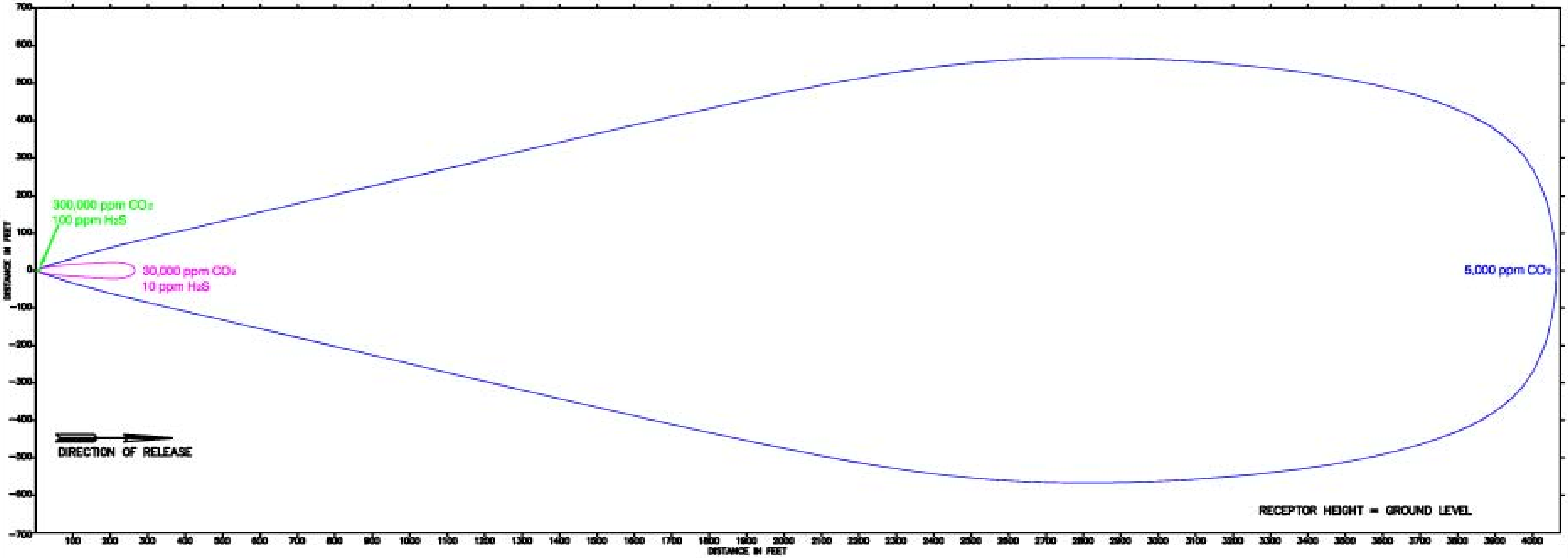


LEGEND

- • SOURCE AREA
- 5,000 — 5,000 ppm CO_2 CONTOUR
- 30,000 — 30,000 ppm CO_2 AND 10 ppm H_2S CONTOUR
- 300,000 — 300,000 ppm CO_2 AND 100 ppm H_2S CONTOUR

CAMERON-COLE

FIGURE 20		
SLAB MODEL OUTPUT HORIZONTAL JET RELEASE 250 MMSCFD 12 INCH PIPE DIAMETER HOWELL PETROLEUM		
SCALE: AS NOTED	DATE: 8/5/05	DWG NO. 1065-54



LEGEND

- • SOURCE AREA
- —5,000— 5,000 ppm CO_2 CONTOUR
- —30,000— 30,000 ppm CO_2 AND 10 ppm H_2S CONTOUR
- —300,000— 300,000 ppm CO_2 AND 100 ppm H_2S CONTOUR

CAMERON-COLE

FIGURE 21		
SLAB MODEL OUTPUT HORIZONTAL JET RELEASE 290 MMSCFD 16 INCH PIPE DIAMETER HOWELL PETROLEUM		
SCALE: AS NOTED	DATE: 8/5/05	DWG NO. 1065-55

APPENDIX A

Carbon Dioxide Dispersion Test at 12WC2NE14

CO_2 dispersion Test at 12WC^{2}NE14

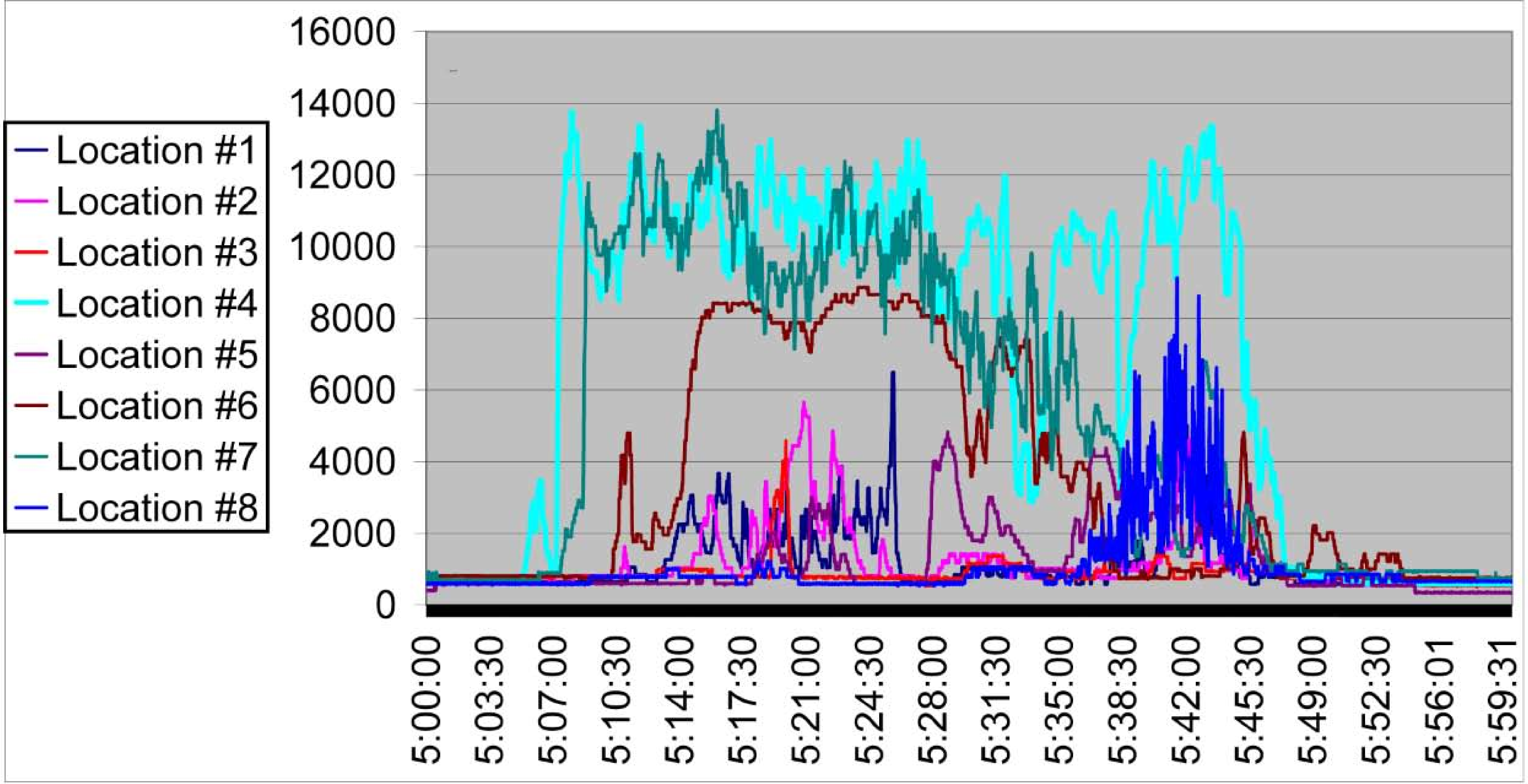
The purpose of this dispersion test is to validate and field test our dispersion modeling. The test conditions need to be worst case scenario, calm day, low lying area (draw), and a high volume release (relatively speaking) (8MM). The test will be performed early morning (between 5 and 6 am) as to not affect field personnel. The well will be WAG'd 24hrs prior to the test to allow any water in the system to be cleared. If water isn't cleared from the system hydrates or ice may form. Below is the procedure for performing the test.

- Set RTU's (8) to record dispersion data (CO_2 concentration in PPM)
  - Calibrate and program RTU's to gather data once per second - Allan
- Stroke 12NE14 choke to the closed position and leave RTU in local
- Shut well head gate valve
  - Using the 1" bleeder located on the flow "T" bleed off the pressure between the choke and the well head gate
- Make up hard line and fittings from well head to ~ 60' from well head running to the east **– SEE HAND SKETCH**
  - Fittings
    - 2 – 90º swivels with 1502 hammer unions
    - 3 – jts of 2" XH hard line with 1502 hammer unions
    - 1- bean choke with 1" bean
    - 1 – 2 3/8" perforated sub
  - Make up
    - On the 2" full port wire line valve thread in a 2" XH nipple with a 1502 wing half
    - Install a 2" 90º swivel
    - Install a short section (~10') of 2" XH hard line
    - Install a 2" 90º swivel
    - Install two (2) twenty (20) foot sections of hard line
      - Hard line will be installed on top of three (3) cement blocks and chain/boomered down
      - There should be one block located on the back side of the ground level 90º swivel
    - Install the bean choke
    - Install a 2" X 2 3/8" HP swage
    - Install a 2 3/8" perforated sub open ended
- Set up well (12NE14) RTU for test
  - Capture rate and pressure every 30 sec – 1 min
  - Set well head set point to 1000 psi
  - Set rate over ride to 8MM
- Start the eight (8) RTU's gathering data
- Open the 2" full port wire line entry valve
- Notify affected personnel that the test is about to commence - DEM

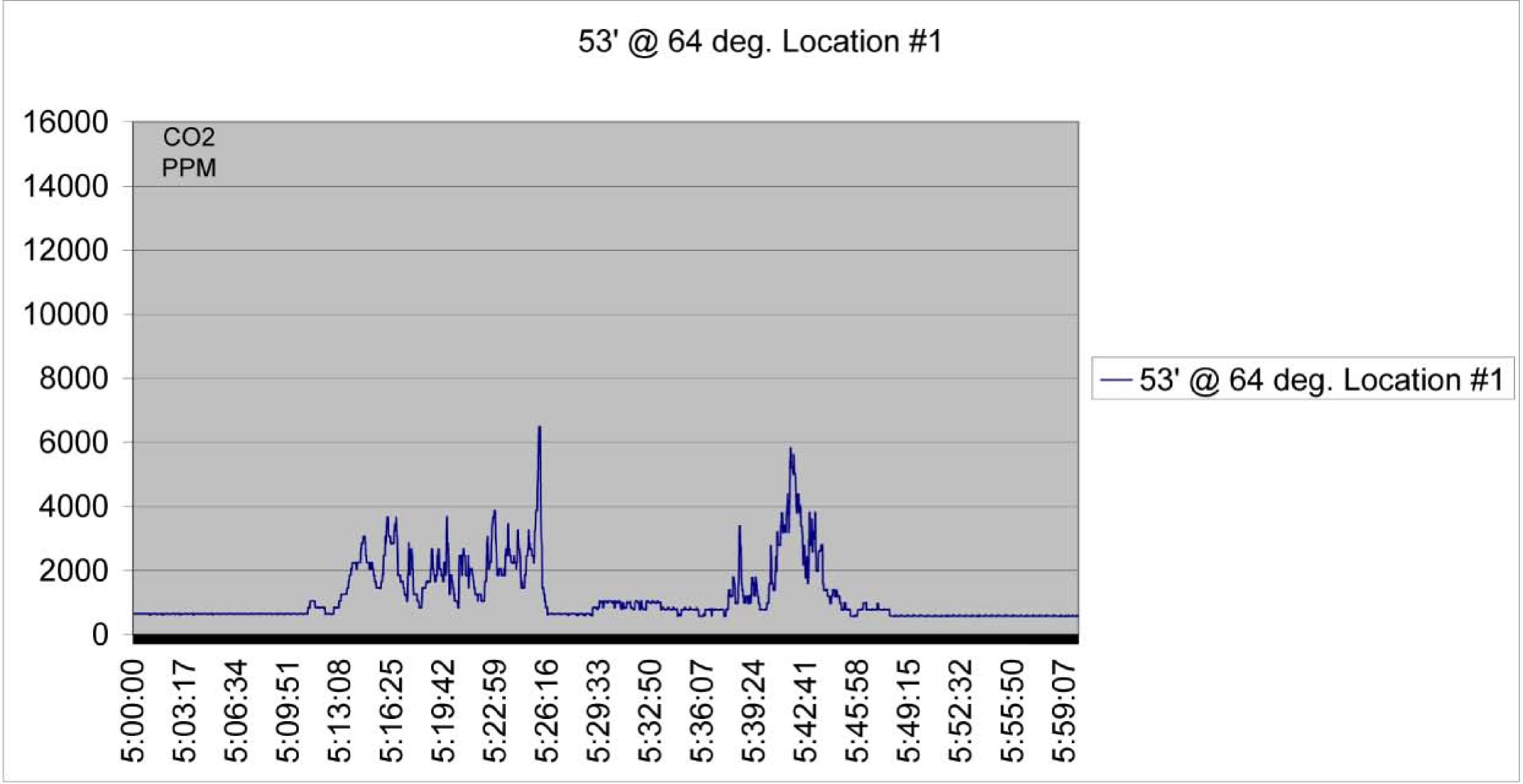
    - BJV will be monitoring the test from the office in case the test needs shut down
- Put RTU in auto and clear the area
    - Monitor from a distance preferably cross wind and up hill
    - Stay in contact with BJV in the office monitoring CASE
        - If for any reason the test needs shut down BJV will do so using the CASE host
            - Reasons can include but are not limited to
                - Hard line plugging from the formation of dry ice
                - The hard line starts to rise off of the ground
                - The hard line starts to move from side to side/ front to back
                - Leaking fittings
                - Completion of the test
- Duration of the test will be twenty (20) to thirty (30) minutes
    - **CAUTION**
        - H_2S and CO_2 gas will be present
        - Extreme cold temperatures will be present
        - Dry Ice may form
        - High pressures will be present
- Notify affected personnel of the completion of the test – DEM
- BJV will change the set points from CASE and notify when the well status indicates the choke is closed
- Once the well is shut in
    - Put RTU in local
    - Close the 2” FP, WL entry valve
    - Break all fittings apart
    - Open the well head gate valve
    - Reset the well RTU to normal injection control set points
    - Put the well RTU in auto
    - Gather all data points from the eight (8) RTU
        - Put in excel format
- Attachments
    - Hand Sketch
    - Map of 12NE14 with approximate RTU locations
    - Map with out 12NE14 but with exact RTU location

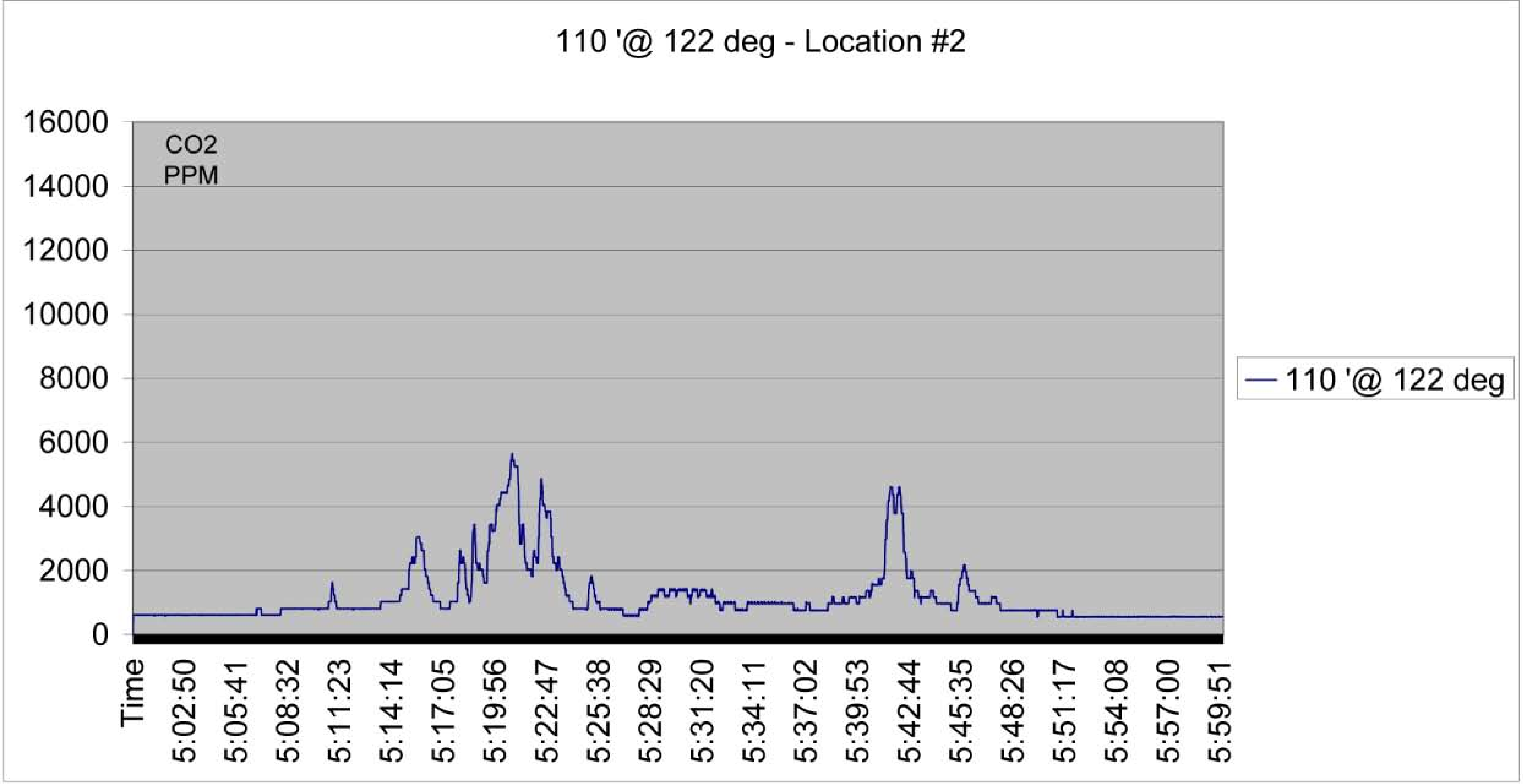
APPENDIX B

Carbon Dioxide Dispersion Test – Monitoring Results

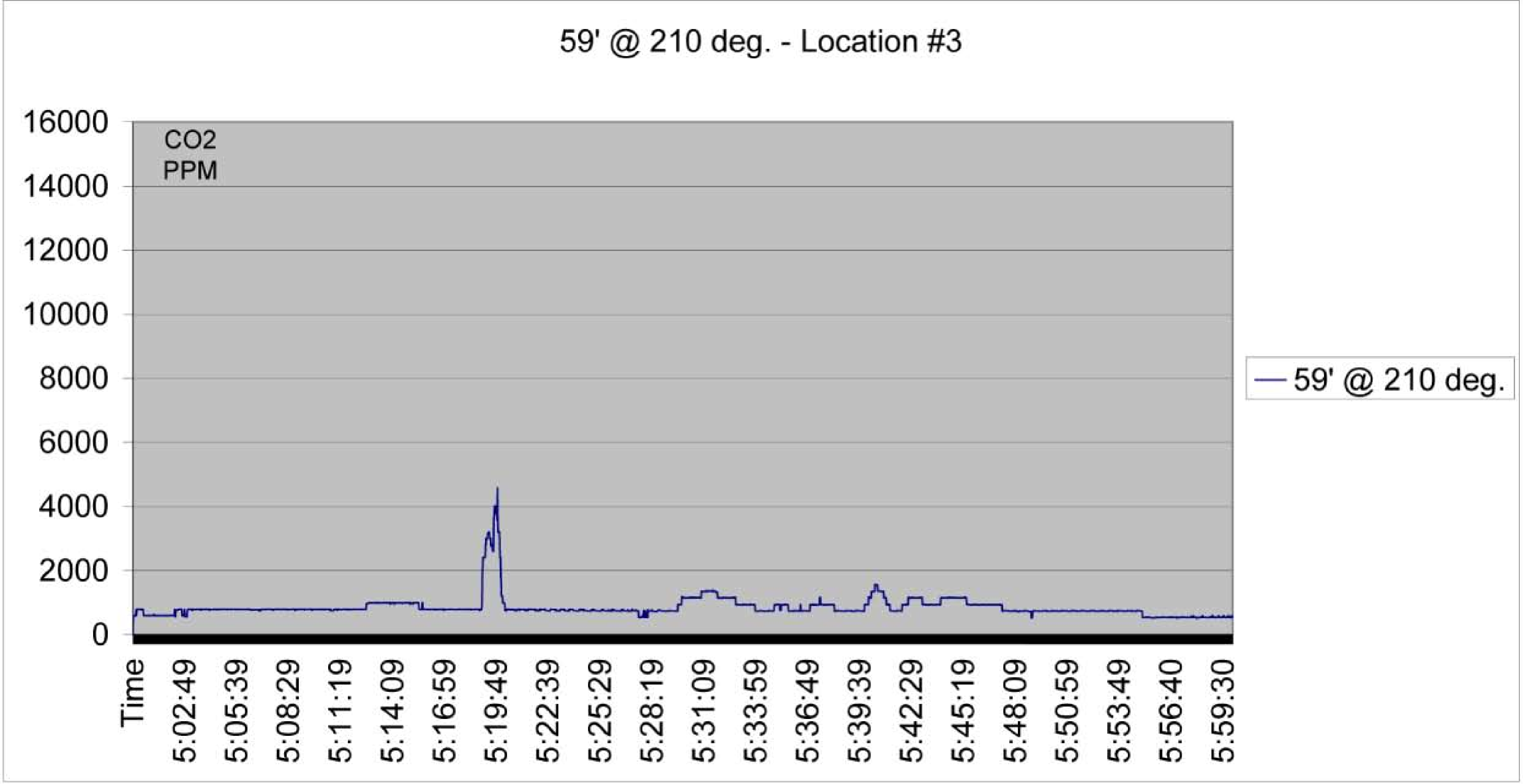


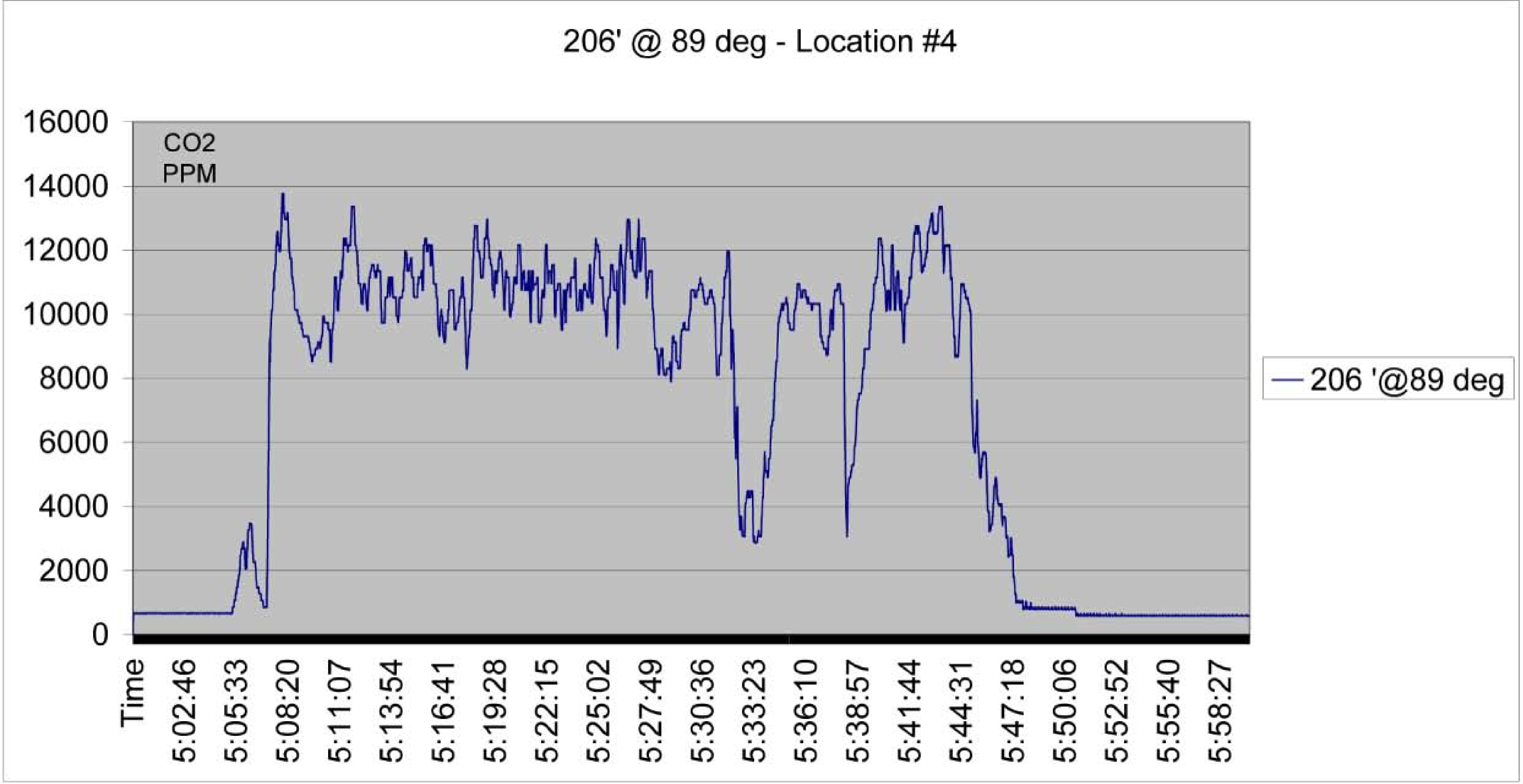
16000
14000
12000
10000
8000
6000
4000
2000
0
Location #1
Location #2
Location #3
Location #4
Location #5
Location #6
Location #7
Location #8
5:00:00
5:03:30
5:07:00
5:10:30
5:14:00
5:17:30
5:21:00
5:24:30
5:28:00
5:31:30
5:35:00
5:38:30
5:42:00
5:45:30
5:49:00
5:52:30
5:56:01
5:59:31


53' @ 64 deg. Location #1
CO2
PPM
16000
14000
12000
10000
8000
6000
4000
2000
0
5:00:00
5:03:17
5:06:34
5:09:51
5:13:08
5:16:25
5:19:42
5:22:59
5:26:16
5:29:33
5:32:50
5:36:07
5:39:24
5:42:41
5:45:58
5:49:15
5:52:32
5:55:50
5:59:07
53' @ 64 deg. Location #1

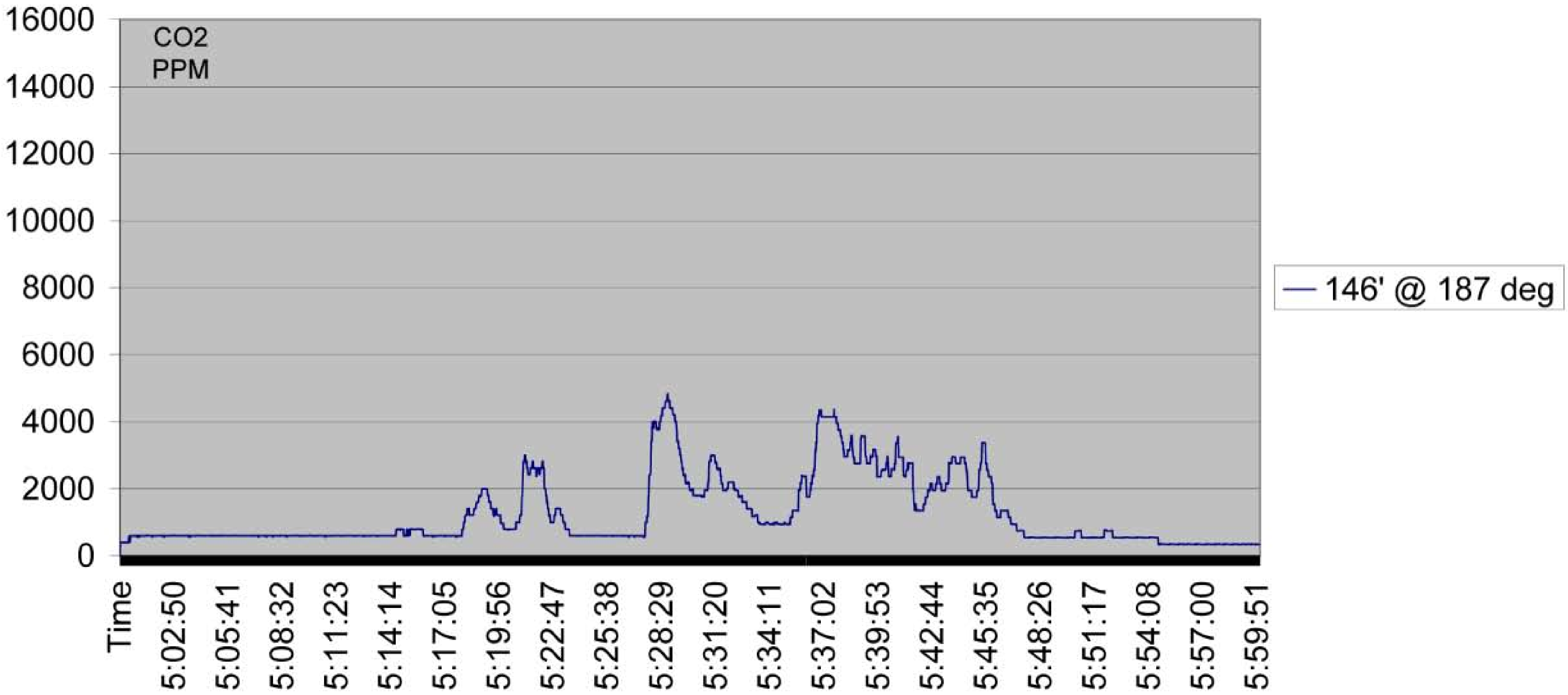


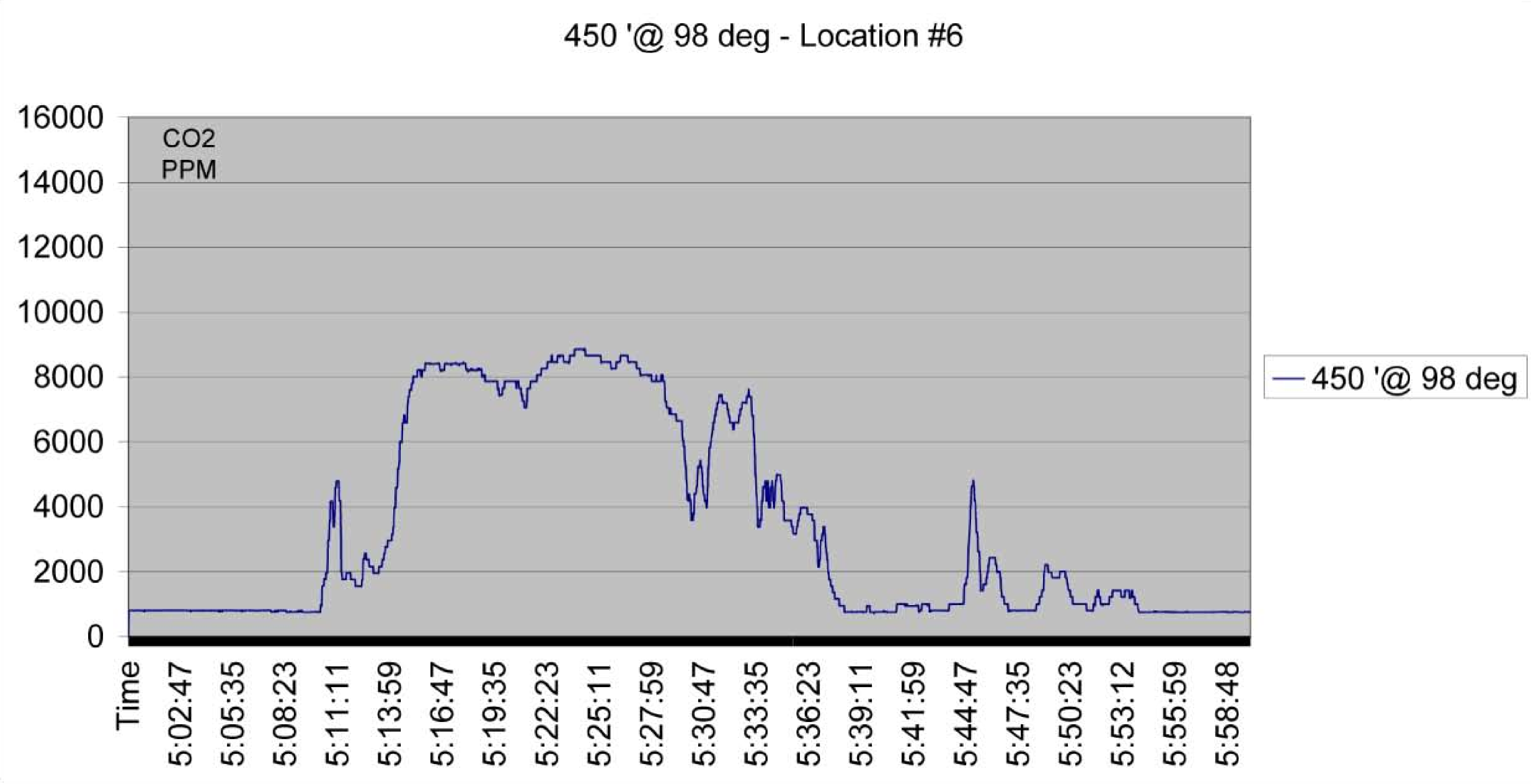
110 '@ 122 deg - Location #2
CO2
PPM
16000
14000
12000
10000
8000
6000
4000
2000
0
Time
5:02:50
5:05:41
5:08:32
5:11:23
5:14:14
5:17:05
5:19:56
5:22:47
5:25:38
5:28:29
5:31:20
5:34:11
5:37:02
5:39:53
5:42:44
5:45:35
5:48:26
5:51:17
5:54:08
5:57:00
5:59:51
110 '@ 122 deg


59' @ 210 deg. - Location #3
CO2
PPM
16000
14000
12000
10000
8000
6000
4000
2000
0
Time
5:02:49
5:05:39
5:08:29
5:11:19
5:14:09
5:16:59
5:19:49
5:22:39
5:25:29
5:28:19
5:31:09
5:33:59
5:36:49
5:39:39
5:42:29
5:45:19
5:48:09
5:50:59
5:53:49
5:56:40
5:59:30
59' @ 210 deg.

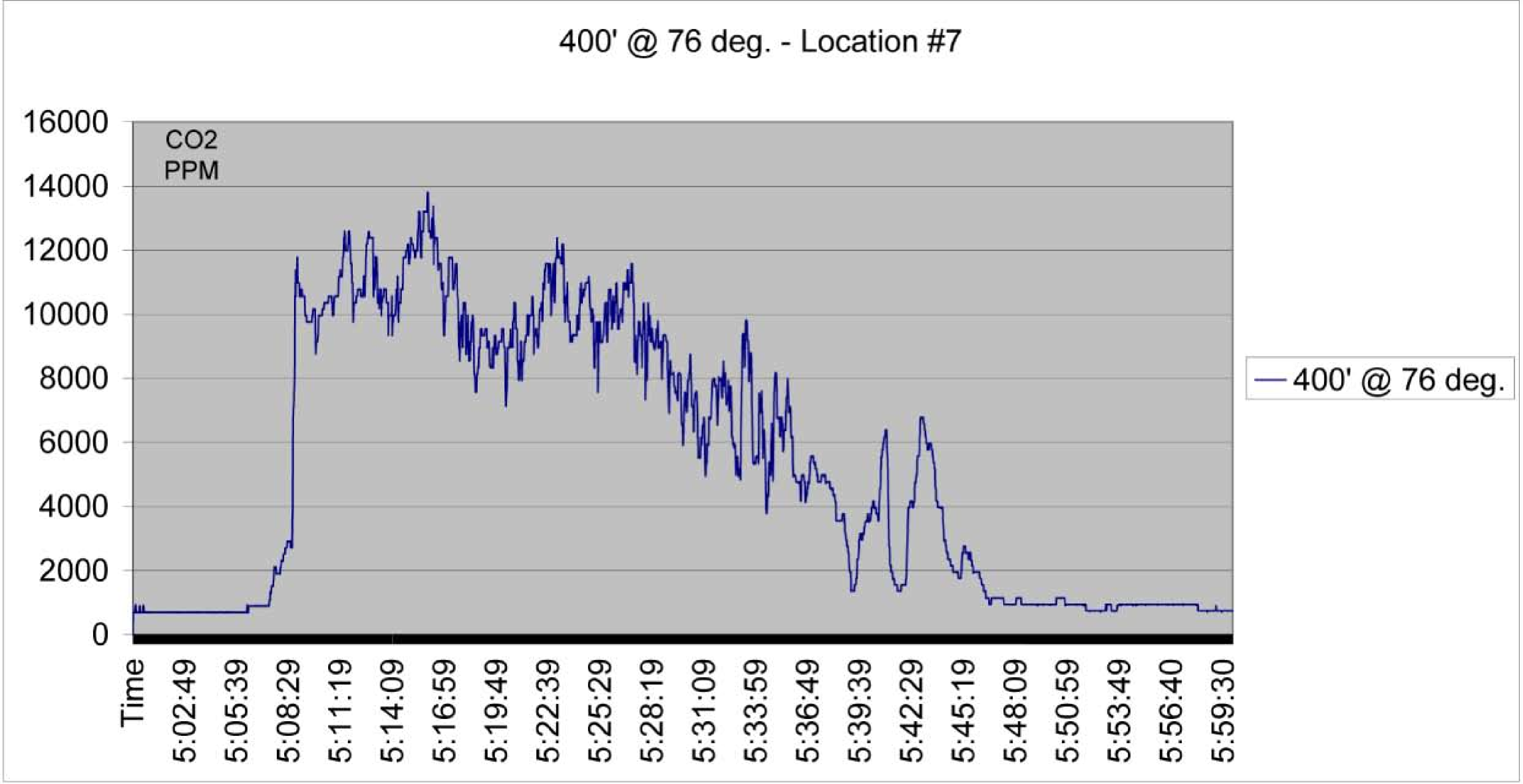

206' @ 89 deg - Location #4
CO2
PPM
16000
14000
12000
10000
8000
6000
4000
2000
0
Time
5:02:46
5:05:33
5:08:20
5:11:07
5:13:54
5:16:41
5:19:28
5:22:15
5:25:02
5:27:49
5:30:36
5:33:23
5:36:10
5:38:57
5:41:44
5:44:31
5:47:18
5:50:06
5:52:52
5:55:40
5:58:27
206 '@89 deg

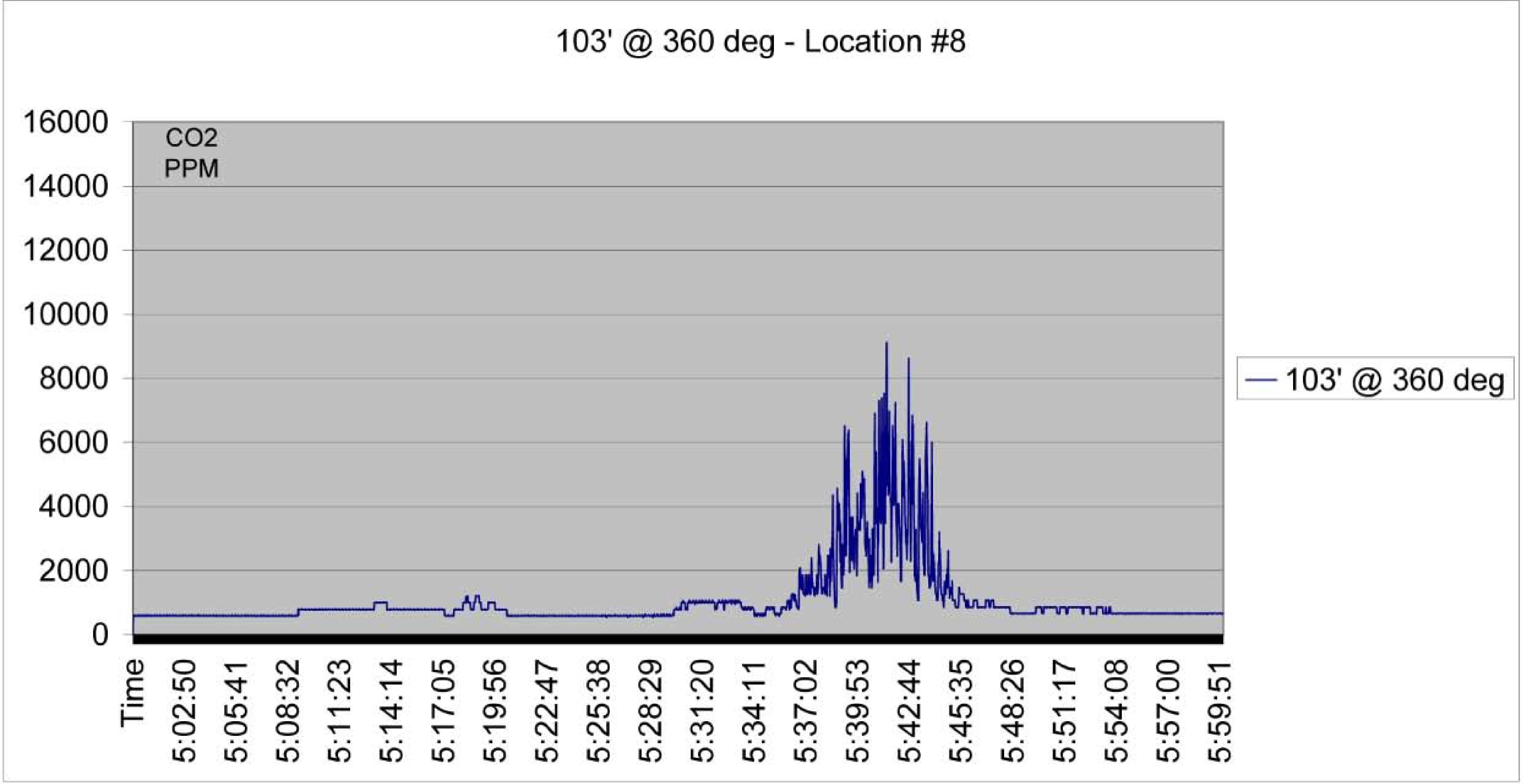
146' @ 187 deg - Location #5





450 '@ 98 deg - Location #6
CO2
PPM
16000
14000
12000
10000
8000
6000
4000
2000
0
Time
5:02:47
5:05:35
5:08:23
5:11:11
5:13:59
5:16:47
5:19:35
5:22:23
5:25:11
5:27:59
5:30:47
5:33:35
5:36:23
5:39:11
5:41:59
5:44:47
5:47:35
5:50:23
5:53:12
5:55:59
5:58:48
450 '@ 98 deg


400' @ 76 deg. - Location #7
CO2
PPM
16000
14000
12000
10000
8000
6000
4000
2000
0
Time
5:02:49
5:05:39
5:08:29
5:11:19
5:14:09
5:16:59
5:19:49
5:22:39
5:25:29
5:28:19
5:31:09
5:33:59
5:36:49
5:39:39
5:42:29
5:45:19
5:48:09
5:50:59
5:53:49
5:56:40
5:59:30
400' @ 76 deg.



103' @ 360 deg - Location #8
CO2
PPM
16000
14000
12000
10000
8000
6000
4000
2000
0
Time
5:02:50
5:05:41
5:08:32
5:11:23
5:14:14
5:17:05
5:19:56
5:22:47
5:25:38
5:28:29
5:31:20
5:34:11
5:37:02
5:39:53
5:42:44
5:45:35
5:48:26
5:51:17
5:54:08
5:57:00
5:59:51
103' @ 360 deg