Final Technical Report

Site Investigation and Evaluation of Remedial Alternatives for the
Wharton County Site, East Bernard, Texas

(RRC Site: 03-50213)

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1.0 EXECUTIVE SUMMARY

The Bureau of Economic Geology (BEG) investigated the Wharton County site near East Bernard, Texas (RRC Cleanup Code 03-50213) during a 6-month study from March through August of 1997. The Railroad Commission of Texas (RRC) designated the Wharton County site as a priority site under the abandoned oil-field program because of an unexplained source of methane that caused an explosion, fire, and injury at the Kramr residence near East Bernard, Texas. Previous RRC investigations included pressure testing of nearby natural gas pipelines and monitoring of gas vapors in the vicinity of the site by both RRC personnel and by consultants acting on behalf of a gas pipeline company. At the start of this investigation, details on how the explosion occurred had been determined, but the source of natural gas that had caused the explosion and its subsurface extent were unknown. Whether methane gas was still present in the subsurface at the Wharton site and the potential risk that would be posed by its presence also remained to be determined.

During this study we mapped out a plume of methane and other natural gas constituents in the subsurface below the Wharton site. The plume is in approximately the same position as a plume mapped out by a consultant in 1995, but it shows much lower methane concentrations. Maximum methane concentrations have fallen from more than 70 percent in 1995 to approximately 1 percent in August 1997. This decrease in concentration most likely reflects both venting to the atmosphere and natural attenuation of the contaminant gases.

The data and interpretations indicate that there is no ongoing source of natural gas contamination at the Wharton site. Because soil-gas concentrations have naturally fallen to below explosive levels, there is no immediate risk to safety of nearby residents.

We found no evidence of methane contamination between the site and nearby gas wells. The zero contamination line lies close to the site. Lack of lateral movement since 1995 implies that the plume probably did not move much before 1995, or at least during the 1993–1995 period.

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We cannot absolutely rule out the possibility of a natural gas seep, but in our opinion it is extremely unlikely. Natural gas in the region is produced from the Yegua Formation at a depth of approximately 8,000 ft.

In our opinion the evidence points to one or multiple leaks from a 100-psi pipeline, which were found soon after the explosion, as the most probable source of methane that caused the Kramr house to explode. Pressure in the pipeline would probably have been sufficient to force natural gas through cracks in the Beaumont clay into the underlying shallow sand, especially given the dry condition that existed at the time. This effect would have been enhanced if the leak had been directed downward. However, the pathway that eventually accumulated to explosive levels in the house could not be confirmed; all remnants of the house and septic system had been removed prior to this study.

Our remedial recommendation is to install six monitoring wells in the gas-charged sand layer and monitor methane gas concentrations for 2 yr. Quarterly monitoring for at least 2 yr will confirm whether residual natural gas concentrations remain below the lower explosive limit of methane (5 percent), even with ongoing seasonal climatic fluctuations.

2.0 INTRODUCTION

The Railroad Commission of Texas (RRC) has statutory responsibility under S.B. 1103 (72nd Legislature, 1991) for oversight of cleanup of abandoned oil-field sites throughout Texas. Since 1991, RRC personnel have identified and inventoried numerous sites as candidates for cleanup and have given priority to those sites that have had observable releases, that occur in ground-water recharge zones having high soil permeability, that lie near surface-water bodies or water-supply wells, or both, that have high public profile and that have received complaints, and that lie near population centers. Straightforward solutions for cleanup are readily apparent for many of the sites. At some sites, however, outlining cost-effective approaches to cleanup requires more complete information on the surface and subsurface extent of the contamination. For these priority sites, the Bureau of Economic Geology (BEG) is providing more extensive site investigations for

the RRC under interagency contract. The purpose of these investigations is to provide the required information for planning and executing the appropriate level of remediation.

The site of concern for this investigation is the Wharton County site near East Bernard, Texas (RRC Cleanup Code 03-50213), where in July 1993 the Kramr residence exploded owing to an accumulation of methane. On the basis of the potential for further risk of explosion and the lack of knowledge of the source of the gas contamination, this site was placed high on the priority list of RRC sites in need of remediation.

The principal tasks performed for this investigation included

(1) review of RRC files and previously compiled site data,

(2) determination of presence or absence of subsurface methane contamination,

(3) identification of the subsurface horizon in which the methane gas is contained,

(4) delineation of the lateral extent of methane contamination via drilling and measurement of borehole vapor concentrations,

(5) evaluation of risk-based options for site remediation, and

(6) preparation of cost estimates for the recommended cleanup options.

2.1 Site Description

The site is located in northeastern Wharton County, Texas, 2.5 mi southwest of the town of East Bernard at the intersection of County Road 205 and FM 1164 (fig. 2.1). The site consists of a 57,000 ft^2 (~1.3 acre) lot in a rural area bordered to the north and west by farm and pasture land. The land surface altitude in this area is approximately 120 ft above sea level, and average annual rainfall is 40 inches (U.S.D.A.-NRCS, 1997).

Primary land use in the area is rice farming or grazing of livestock. Production of natural gas, sulfur, and gravel are also important sources of income in Wharton County (Loskot and others, 1982). Bernard Prairie and Bernard West gas fields are located less than 5 mi to the northwest and southwest of the site, respectively (Solis, 1981). In addition, four natural gas wells, which have been plugged and abandoned, and two dry hole exploration borings appear on oil and gas lease

TEXAS

SAN BERNARD RIVER

East Bernard

Britt Branch

Caskids pipeline

Eastern pipeline

90 A

1164

60

273

205

Kramr house

Booster station

N

×   Pipeline leak

⬦   Dry hole

✳   Plugged and abandoned gas well
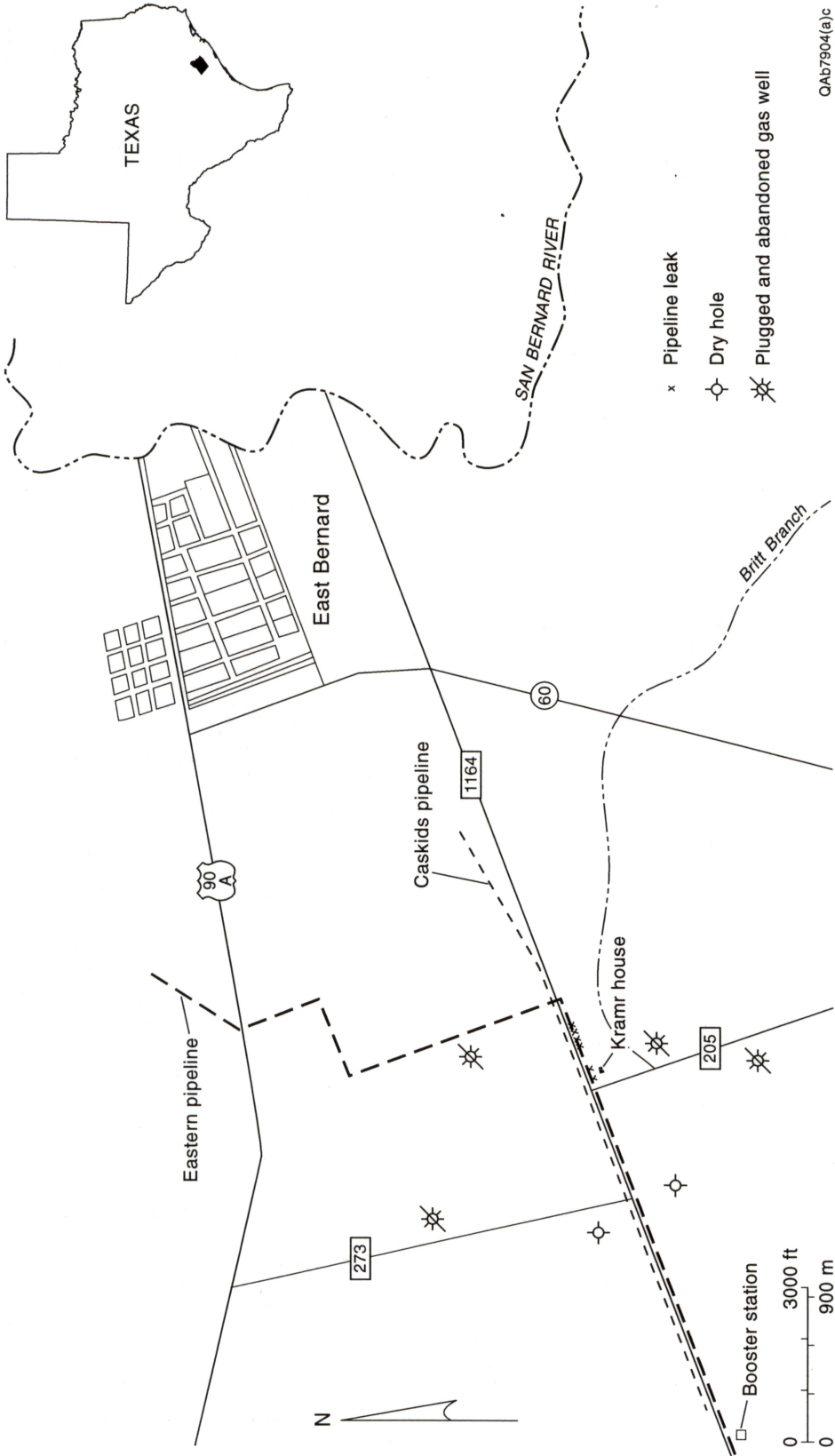
QAb7904(a)c

| 0 | 3000 ft |
| 0 | 900 m |

Figure 2.1. Location of the Wharton County site.

maps within 1 mi of the Kramr property. As of the mid 1970's, 2,367,884 million ft^3 of gas had been produced in Wharton County. Oil and gas lease maps show the primary production zone to be about 8,000 ft below ground level (bgl) in the Yegua Formation.

2.2 Site Geology

The Wharton County site is located on fluvial deposits of the ancestral Brazos River. Geologic units present at the surface near the site are clay, clayey sand, and silt layers of the Beaumont Formation (Barnes, 1974). The area underlying the site is mapped as dominantly clayey sand and silt of low to moderate permeability with moderate drainage. Depositional regimes represented include meanderbelt, levee, crevasse splay, and distributary sands. Finer grained portions of the Beaumont are also mapped within 1 mi of the site. The Beaumont clays, characterized by low permeability, high shrink–swell potential, poor drainage, and high plasticity, represent interdistributary, channel-fill, and fluvial overbank muds (Barnes, 1974). Throughout Beaumont terrain the surface is relatively flat and featureless. Concretions of calcium carbonate, iron, and manganese oxides are commonly seen in the zone of weathering.

Because of the high shrink–swell capacity (high montmorillonite clay content) of Beaumont fine-grained sediments, the sediments can act as a low-permeability barrier to gas flow in wet conditions or become more permeable during dry conditions. Near-surface layers of Beaumont can also be more permeable in vegetated areas where root tubes/veins provide pathways for fluids.

According to U.S.D.A. Natural Resources Conservation Service (1997), soils that developed on Beaumont sediments in the vicinity of the Wharton site have the following characteristics:

(1) Soils are primarily fine sandy loam and are from 6 to 80 inches in thickness.

(2) The dominant clay in Beaumont soils is montmorillonite.

(3) Uncoated steel will be highly corroded when in contact with these soils.

(4) Hydrologic group characteristics include fine textures, slow infiltration rate, and high water table.

(5) Usual depth to the water table is 6 ft, except during dry periods such as typical summer months, when the water table is deeper than usual.

2.3 Site Hydrology

The Wharton site lies just north of Britt Branch, which flows into the present-day San Bernard River about 2 mi south of the town of East Bernard (fig. 2.1).

The Beaumont Formation comprises the uppermost unit of the upper Chicot aquifer, which extends from the surface to approximately 400 ft bgl in the vicinity of the Wharton site (Loskot and others, 1982). The Lissie Formation, which underlies the Beaumont, is the primary source of drinking water in Wharton County. Total depth of Chicot irrigation wells near the site is between 200 and 300 ft bgl; screened intervals are between 150 and 300 bgl (Loskot and others, 1982). Ground water in the Chicot aquifer is generally a hard to very hard calcium bicarbonate type. Beaumont and Lissie portions of the Chicot aquifer differ in hydraulic properties and ground-water composition (Dutton, 1994).

2.4 Site History

On June 22, 1993, at approximately 6 p.m., an explosion occurred at the residence of Frank Kramr, 2.5 mi southwest of East Bernard in Wharton County, Texas, resulting in a fire that destroyed the residence. Two natural gas pipeline easements, owned by Caskids Operating Company and Eastern Pipeline Company (EPL), parallel the adjacent FM 1164 on the north and south sides, respectively (fig. 2.1). Within several days of the explosion, a pipeline-survey crew found leaks in the EPL line where it crosses the north boundary of the Kramr property. Workers found elevated gas concentrations beneath the foundation of the Kramr house. High levels of subsurface gas were also found underneath and around the Dobias residence, approximately 100 ft to the northeast. The pipeline leaks were repaired and gas was vented from soil around the base of

the Dobias house. The pipeline was abandoned in December 1993. EPL monitored elevated soil gas concentrations in the vicinity through March 1996.

Past investigations into the source of the gas include borehole and soil gas investigations in the vicinity of the Kramr and Dobias houses, excavation and soil-gas monitoring along the EPL pipeline right-of-way, and investigations in the vicinity of plugged and producing oil and gas wells north and south of the homes.

A number of investigations of the Wharton site were completed immediately after the explosion; monitoring of subsurface gas concentrations continued through March 1996. Previous studies of the Wharton site include:

(1) investigative reports completed by the State Fire Marshall and the RRC Gas Utility Division;

(2) natural gas pipeline testing (EPL and Caskids Operating Company);

(3) field reports following numerous site visits by RRC personnel;

(4) studies conducted on behalf of EPL:

(a) Heath Consultants (CH&A and SPL Laboratories),

(b) Bagnell and Barber, Inc. (Soil Analytical Services, Inc. and Fesco Laboratories), and

(c) KEI Consultants, Inc. (SPL Laboratories); and

(5) a study conducted on behalf of the Kramr family by Sammy Russo of APR Consulting.

Conditions that contributed to the explosion of the Kramr house are documented in a report by the State Fire Marshall, an RRC Gas Utility Division LP-Gas Investigation Report, and letters prepared by the legal counsel of EPL. These reports and letters provide details on how the explosion occurred but do not indicate the source of accumulated subsurface natural gas.

The combination of conditions that led to the explosion of the Kramr house include:

(1) The explosion occurred just after Mr. Kramr turned down the thermostat on the central air-conditioning unit in the attic of the house.

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(2) The septic system of the Kramr house was vented into the attic rather than into the atmosphere.

(3) The septic tanks had been pumped out 3 weeks prior to the explosion, leaving liquid levels below the discharge pipes coming from the house.

(4) The EPL pipeline, which was found to be leaking, could have provided at least one source of flammable gas, the gas moving under pressure through cracks in the surficial clays into the underlying sand. The accumulation in the sand would have been enhanced by leaks in the bottom of the pipeline.

(5) The region was in a drought, thereby facilitating transport of gases through dry subsurface sediments.

(6) Natural gas in the soil was found to contain methane, ethane, propane, and other gases that could not have come from a septic tank or a landfill.

(7) The propane gas system supplying the house was also eliminated as a source.

One hypothesis is that combustible gases moved from the pipeline through the soil into the Kramrs' septic drain field then migrated into the septic tank and up the inlet pipes to accumulate in the attic. The gas ignited when the central air-conditioning unit in the Kramr house came on.

In November 1993, EPL abandoned its 4-inch-diameter 100-psi gas-gathering line and filled it with salt water. However, EPL agreed to continue monitoring soil-gas concentrations. According to EPL documentation, soil-gas readings continued to be in excess of detection limits of their Combustible Gas Indicator (CGI) through March 1996. At that time, they put in a request to the RRC to cease monitoring activities, arguing that because methane levels were still elevated, even though the pipeline had been shut down for several years, the EPL line was not the likely source of natural gas contamination.

3.0 METHODOLOGY

In March 1997, BEG began work on the Wharton County site (RRC Cleanup Code 03-50213) by discussing the project with RRC District 3 staff, reviewing site investigation files, and visually inspecting the Kramr property. We conducted onsite field work in two stages in May and August 1997. In May 1997 we focused on the area in the immediate vicinity of the former Kramr house by collecting 15 sediment cores and measuring in situ vapor concentrations (methane, carbon dioxide, and oxygen) in the resulting boreholes (A through P in fig. 3.1). During stage 2 field work in August 1997 we expanded our study area by measuring vapor concentrations in 20 additional boreholes (1 through 20 in figs. 3.1 and 3.2).

Stage 1 field work was designed to:

(1) determine whether methane was still present in the subsurface, and if so, to

(2) identify the depth at which elevated methane concentrations were detected, and

(3) delineate lateral extent of the plume.

The objectives of stage 2 field work were to:

(1) confirm the May 1997 gas-concentration measurements,

(2) obtain closure on the west and south edges of the methane plume observed during May field work,

(3) confirm that there are no elevated methane gas concentrations near the Dobias house (boreholes 18, 19, and 20 in fig. 3.1), and

(4) determine whether there were other potential sources of the natural gas contamination such as nearby oil and gas exploration borings and plugged gas wells (fig. 3.2).

We originally planned to take stage 2 measurements under dry or drought conditions similar to those present at the time of the Kramr house explosion. However, during the summer of 1997, the area received an unusually high amount of rainfall.
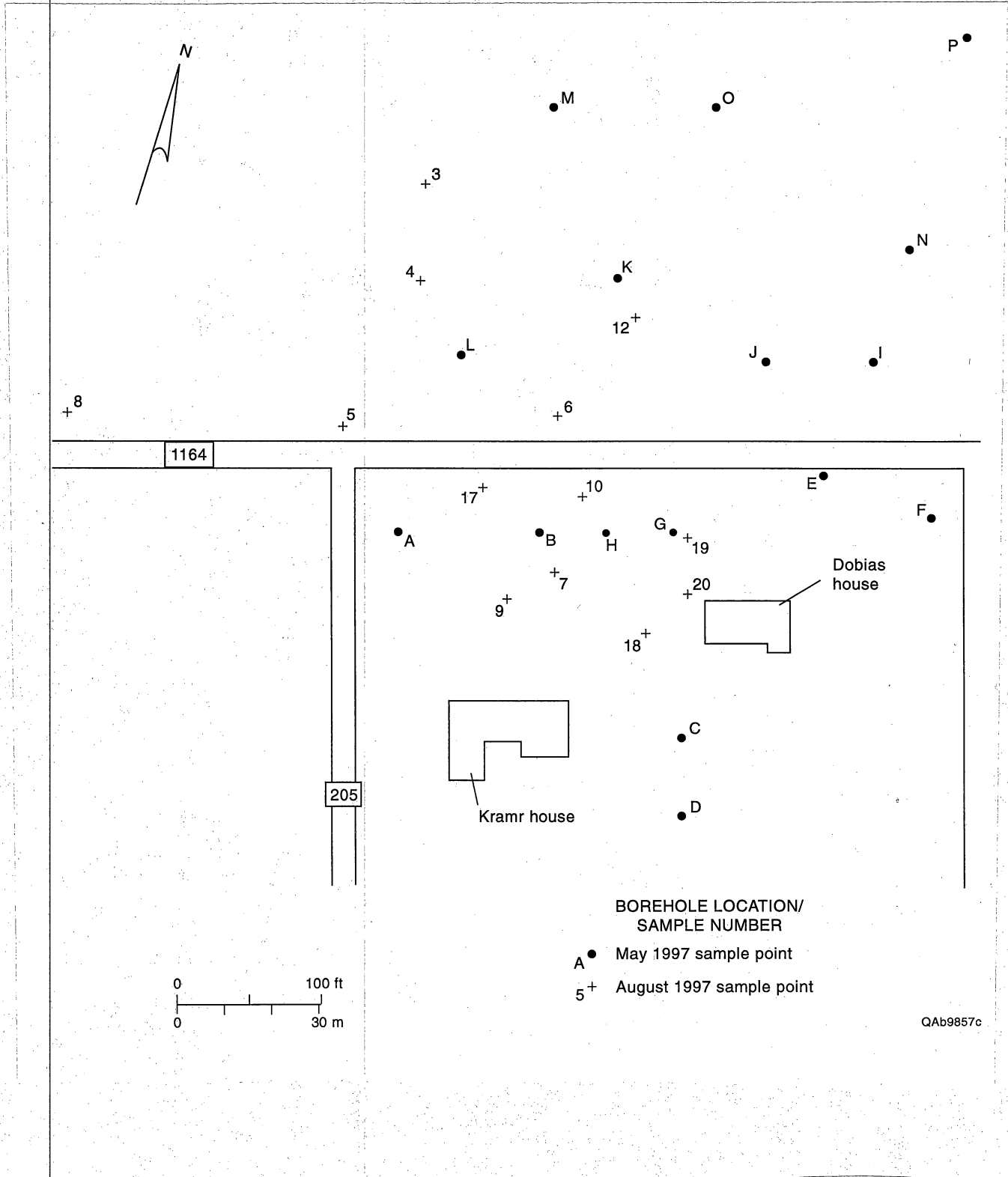
Figure 3.1. Boreholes drilled and sampled by BEG in the immediate vicinity of the Wharton site in May and August 1997. The area lies within the dashed rectangle shown in figure 3.2.
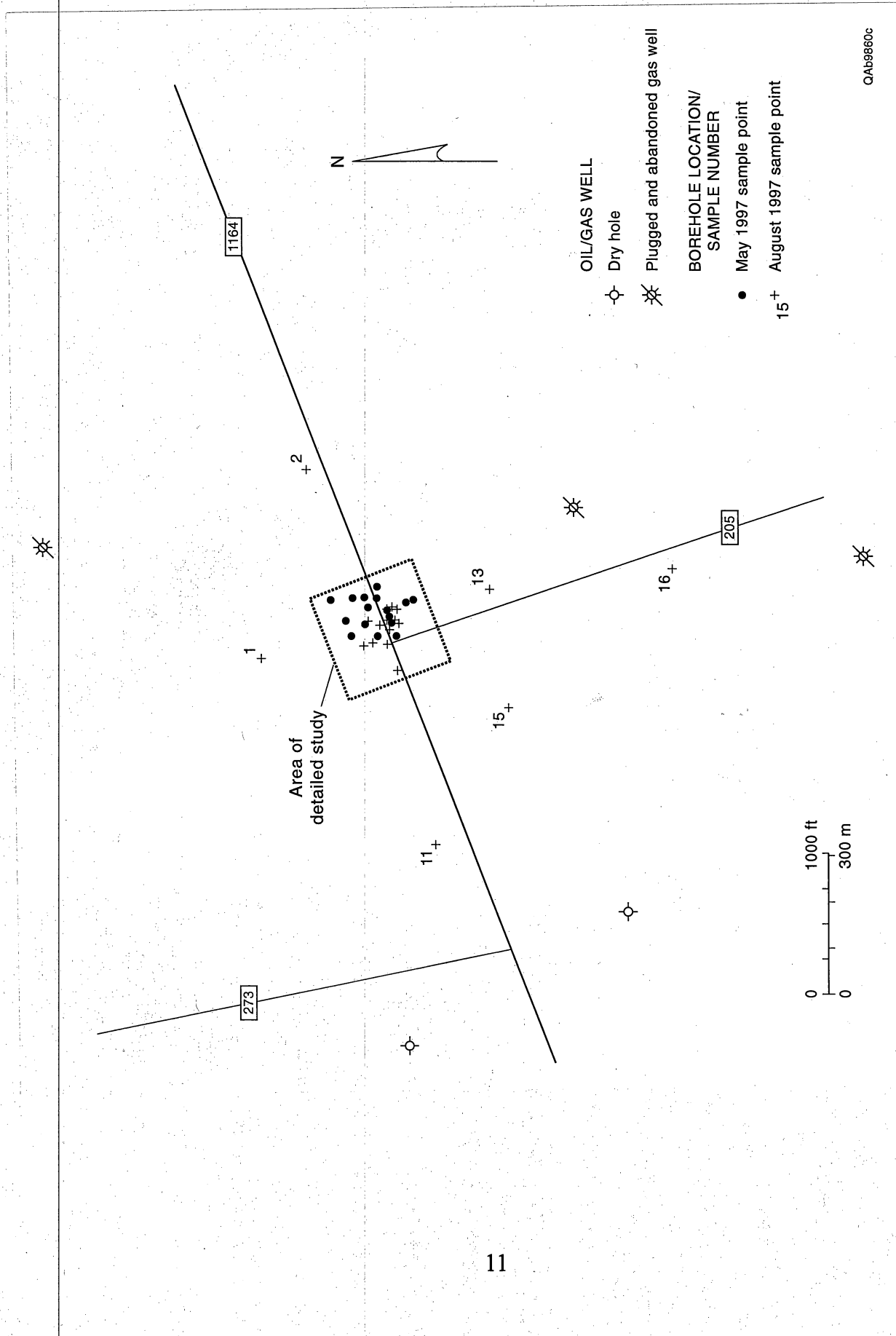
Figure 3.2. Boreholes drilled and sampled by BEG between the Wharton site and nearby gas wells in May and August 1997.

OIL/GAS WELL

-◇- Dry hole

✳ Plugged and abandoned gas well

BOREHOLE LOCATION/
SAMPLE NUMBER

● May 1997 sample point

15 + August 1997 sample point

QAb9860c

Area of
detailed study

11

N

3.1 Drilling

We used a Giddings soil-probe rig to push core samples and auger boreholes for vapor measurements. The rig was used to push a 1 5/8-inch-diameter split-barrel sampler in 3-ft increments to a depth of approximately 12 ft bgl. We were unable to utilize the direct-push method and collect core samples below this point.

Below 12 ft we drilled with 3-ft lengths of 2 1/4 -inch-diameter augers. By switching from direct-push to auger methods of drilling and by anchoring the portable rig with angled screw-in-type anchors, we were able to reach a maximum depth of 21 ft bgl.

The onsite geologist described in detail the first few cores obtained at the site. Subsequent cores were briefly described to confirm similarity of subsurface material and ensure that we were measuring borehole vapors in the same lithologic interval. The drilling crew plugged all boreholes at the end of each day by backfilling with cuttings and topping off with hydrated bentonite powder. We plotted locations of stage 1 borings by measuring distances from a known point using a fiberglass tape and compass. Stage 2 locations were plotted by using output from a total station laser-guided surveying instrument.

3.2 Borehole Vapor Measurement

After completing the borehole, we measured methane, carbon dioxide, and oxygen vapor concentrations using a portable infrared gas analyzer connected to a soil vapor probe suspended in the borehole and collected samples for onsite gas chromatographic (GC) analysis of light-end hydrocarbons.

The specific procedure we followed was to

(1) prepare the soil-gas sampling probe with an appropriate length of 0.25-inch-diameter virgin tygon tubing and collect a vapor sample blank;

(2) push or auger to the total depth of the borehole;

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(3) cover the borehole opening with high-density polyethylene to trap vapors as soon as the core tube or augers were withdrawn;

(4) determine the presence or absence of ground water;

(5) lower the soil-vapor probe to the total depth of the borehole then retract it by 1 ft;

(6) purge the tubing with a 50-cc plastic, gas-tight syringe;

(7) sample borehole vapors for GC analysis using a 5-cc glass, gas-tight syringe; and

(8) measure methane, carbon dioxide, and oxygen levels in the borehole using a Lantech GA-90 infrared gas analyzer. This instrument was factory calibrated by Landfill Control Technologies as of January 12, 1997. The instrument is designed to be calibrated annually.

We profiled methane concentrations in selected boreholes (6, 7, 12, and 17 on fig. 3.1) by taking methane readings every 3 ft to total depth. Total depths of the profile boreholes were 21 ft bgl. In all other locations we metered methane concentrations at one or two shallow-depth intervals and at total depth. These borehole depths ranged from 12 to 16 ft depending on stratigraphy and auger refusal.

Both The University of Texas at Austin, Department of Geological Sciences (UT DGS) (stages 1 and 2), and Transglobal Environmental Geochemistry (TEG) of Marion, Texas (stage 2 only), provided onsite GC services. The UT DGS machine is an SRI GC 8610. The machine has two detectors: (1) an FID (flame ionization detector) and a TCD (thermal conductivity detector) and (2) a Hayesep Q column. This column gives very good separations of aliphatic gases and some light aromatic compounds. Hydrogen gas was used as the carrier gas, and the flow rate was set to 30 mL/min, which gives approximately 30 min of run time up to the toluene component in the gas sample. Gas components are separated according to their retention time, which is determined by the partition coefficients of the gas components between the carrier phase and the column surface material phase.

Calibrations were accomplished by either (1) analyzing at least three different gas concentrations for a calibration curve or (2) analyzing the same gas concentration at least three

times. The calibration was accepted when the standard deviation fell within 5 percent error. Machine performance was checked by running blank or standard samples, or both, at the beginning of the runs, between the runs, and at the end of the runs.

Sample analysis was performed by injecting 1 cc of gas sample through a built-in sampling loop. The sampling loop allows the machine to take and hold only 1 cc of gas sample from the injection port; at least 50 cc of gas sample was acquired and injected to the sampling loop. At least 250 cc of fresh air was injected to the sampling loop after each run to purge any possible gas residues to avoid any possible carry-over contamination.

TEG provided a mobile laboratory to collect and analyze vapor samples for TPH and C1-C6 hydrocarbons using EPA Method 8015. A Shimadzu GC-14A (with FID detector) was used in conjunction with a DB-5 1.5-μm, megabore capillary column for TPH and an Altech alumina-packed column for C1-C6 analyses. The GC was calibrated three times each day using external standard techniques according to a hexane gas standard. A minimum of three gas concentration standards (for example, 110, 440, and 1100 ppmv methane) were run during each calibration; if percent relative standard deviation was less than 20 percent, then the average response factor could be used for calibration. No sample preparation was necessary for analysis of soil vapors.

4.0 RESULTS AND DISCUSSION

The following sections document our delineation of subsurface contamination at the Wharton site. The information presented provides a basis for inferring the source of natural gas contamination and for recommending remedial solutions.

4.1 Sediments

We found the silty-clay and -sand sediments at the Wharton site to have a fairly uniform thickness and distribution. In general, the top 2 ft is composed of silt to fine-grained sandy soil. This is underlain by 4 to 6 ft of poorly bedded, mottled silty clay that is typical of Beaumont

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Formation sediments. Numerous vertical cracks containing root fibers commonly exhibit iron-staining. The clay shrinks and cracks upon drying. The base of the silty clay grades into an underlying sand that varies in clay and silt content (table 4.1). Depth to the base of the clay layer could not be determined in boreholes where core was not collected (n/a on table 4.1). In several of the boreholes, we did not advance the boring deep enough to encounter the base of the clay interval (n/e on table 4.1). All of the elevated gas concentrations detected during this study were found within the sand layer underlying the silty clay. We encountered shallow ground water in very few of the boreholes (table 4.1).

4.2 Natural Gas Contamination

The maximum methane concentration we detected with the GC was 1.63 percent by volume of air at a depth of 15 ft bgl in borehole 6 (table 4.2; fig. 4.1). The highest methane values are located along both the north and south sides of FM 1164 in the immediate vicinity of the Kramr property (figs. 4.1 and 4.2). The location of the elevated methane is consistent with that measured during studies previously conducted by the RRC and those conducted on behalf of EPL. This is the same general location where local residents noted areas of stressed vegetation prior to the Kramr house explosion in 1993. This information, communicated to BEG personnel during the May 1997 field work, is contained in RRC District 3 personnel daily field records. We did not observe any areas of stressed vegetation during this study. Our offsite sampling was sufficient to rule out nearby gas wells and dry holes as potential sources of the contamination. For example, measurements taken in boreholes located outside of the detailed study area and toward the nearby oil and gas wells all yielded zero values for methane (fig. 4.2).

The methane values shown in figures 4.1 and 4.2 are all taken from analyses using the UT DGS GC. Both the UT and TEG GC runs gave consistent and comparable gas-concentration results. We are confident that, judging from this good correlation, the gas chromatographic data are the most accurate values to use in our assessment of the extent of methane contamination present at

Table 4.1 Borehole information.

Boring	Date drilled	Core collected (Y/N)	Depth to clay/ sand interface (ft bgl)	Depth to ground water (ft bgl)	Total depth (ft bgl)
A	05/07/97	Y	8	n/e	18
B	05/07/97	Y	8	n/e	15
C	05/07/97	Y	11.1	n/e	12
D	05/08/97	Y	10.8	n/e	12
E	05/08/97	Y	8.0	n/e	12
F	05/08/97	Y	8.6	n/e	12
G	05/08/97	N	n/a	n/e	9
H	05/08/97	N	n/a	n/e	9
I	05/08/97	Y	n/e	n/e	7
J	05/08/97	Y	n/e	n/e	9
K	05/08/97	Y	n/e	n/e	6.5
L	05/09/97	Y	8.3	n/e	9
M	05/09/97	Y	8.7	n/e	9
N	05/09/97	Y	n/e	5.6	6
O	05/09/97	Y	9.6	n/e	12
P	05/09/97	Y	n/e	n/e	7
1	08/13/97	Y	9.8	n/e	12
2	08/12/97	Y	9.1	n/e	12
3	08/13/97	Y	8.8	n/e	12
4	08/13/97	N	n/a	n/e	16
5	08/13/97	N	n/a	n/e	12
6	08/11/97	N	n/a	n/e	21
7	08/11/97	N	n/a	n/e	21
8	08/13/97	Y	8.0	n/e	12
9	08/13/97	N	n/a	n/e	16
10	08/13/97	N	n/a	n/e	16
11	08/13/97	Y	8.8	n/e	12
12	08/13/97	N	n/a	n/e	20
13	08/13/97	Y	9.1	n/e	12
15	08/13/97	N	n/a	n/e	12
16	08/13/97	Y	8.5	n/e	12
17	08/12/97	N	n/a	n/e	21
18	08/12/97	N	n/a	n/e	12
19	08/12/97	N	n/a	n/e	12
20	08/12/97	N	n/a	n/e	12

n/e: not encountered; n/a: not applicable.

Table 4.2. Borehole vapor measurements taken using gas chromatograph (GC) and infrared gas analyzer (meter).

Borehole	Depth (ft)	Date	GC Methane (%)	GC CO₂ (%)	Meter Methane (%)	Meter CO₂ (%)	Meter O₂ (%)
A	9	05/07/97	0.00	11.40	0.00	13.90	3.70
B	9	05/07/97	1.16	10.99	3.30	9.60	3.40
C	12	05/07/97	0.00	0.17	n/m	n/m	n/m
D	12	05/08/97	0.00	5.09	0.00	6.60	11.50
E	12	05/08/97	n/m	6.44	0.00	8.10	11.30
F	12	05/08/97	0.00	6.44	0.00	8.10	10.60
H	9	05/08/97	1.31	9.20	4.70	11.30	1.30
I	7	05/08/97	0.00	8.21	0.00	10.60	6.90
J	9	05/08/97	0.00	9.38	0.00	12.20	2.80
K	6.5	05/08/97	0.01	9.25	0.00	13.80	2.60
L	9	05/09/97	1.59	7.47	5.60	10.80	1.70
M	9	05/09/97	0.00	5.96	0.10	7.10	10.80
N	5.6	05/09/97	0.00	0.25	0.00	2.30	17.60
O	12	05/09/97	0.00	7.76	0.00	6.90	10.80
P	6	05/09/97	n/m	n/m	n/m	n/m	20.60
1	9	08/13/97	n/m	n/m	0.00	5.00	15.00
	12		n/m	n/m	0.00	3.50	15.30
2	12	08/12/97	n/m	n/m	0.00	4.80	6.00
3	6	08/13/97	n/m	n/m	0.00	0.30	11.20
	9		n/m	n/m	0.00	8.10	7.90
	12		n/m	n/m	0.00	8.20	7.20
4	8	08/13/97	n/m	n/m	0.50	5.80	11.10
	12		n/m	n/m	1.30	9.20	4.50
	16		0.74	9.39	1.90	11.30	0.40
4*	12	08/13/97	0.80	n/m	n/m	n/m	n/m
	16		0.90	n/m	0.50	9.70	6.60
5	8	08/13/97	0.52	10.92	0.80	11.70	0.70
	12		0.70	n/m	0.00	n/m	n/m
5*	12	08/13/97	n/m	n/m	0.00	n/m	n/m
6	3	08/11/97	0.53	6.78	3.00	n/m	n/m
	6		n/m	n/m	10.90	n/m	n/m
	9		n/m	n/m	11.70	n/m	n/m
	12		1.63	11.38	12.00	n/m	n/m
	15		n/m	n/m	11.80	n/m	n/m
	18		1.61	12.55	11.90	n/m	n/m
7	3	08/11/97	n/m	n/m	0.00	n/m	n/m
	6		n/m	n/m	0.00	n/m	n/m
	9		n/m	n/m	0.00	n/m	n/m
	12		n/m	n/m	0.00	n/m	n/m
	15		n/m	n/m	0.00	n/m	n/m
	18		n/m	n/m	0.00	n/m	n/m
8	9	08/13/97	n/m	n/m	0.00	5.50	14.40
	12		n/m	n/m	0.00	6.30	13.10
9	12	08/13/97	n/m	n/m	0.10	11.40	0.70
	16		0.18	11.27	0.40	13.00	1.00
9*	16	08/13/97	0.23	n/m	n/m	n/m	n/m
10	12	08/13/97	n/m	n/m	7.40	11.40	0.70
	16		1.26	10.44	8.80	11.80	0.30
10*	16	08/13/97	1.65	n/m	n/m	n/m	n/m
11	9	08/13/97	n/m	n/m	0.00	0.30	19.90
	12		n/m	n/m	0.00	0.10	13.80
12	8	08/13/97	n/m	n/m	0.80	9.50	6.50
	12		n/m	n/m	1.50	12.60	1.70
	16		0.42	11.21	1.80	13.00	1.00
	20		n/m	n/m	2.30	13.50	0.50
12*	16	08/13/97	0.62	n/m	n/m	n/m	n/m
13	9	08/13/97	n/m	n/m	0.00	7.00	15.10
	12		n/m	n/m	0.00	6.30	13.80
15	9	08/13/97	n/m	n/m	0.00	45.00	15.10
	12		n/m	n/m	0.00	5.20	14.50
16	12	08/13/97	n/m	n/m	0.00	4.00	15.10
17	3	08/12/97	n/m	n/m	2.10	0.00	n/m
	6		n/m	n/m	4.00	6.00	n/m
	9		n/m	n/m	6.80	9.00	1.30
	12		n/m	n/m	6.80	11.50	1.70
	15		n/m	n/m	7.70	11.10	0.90
	18		n/m	n/m	6.20	11.70	2.40
	21		1.13	8.43	n/m	10.30	n/m
18	12	08/12/97	n/m	n/m	0.00	9.00	6.50
19	12	08/12/97	n/m	n/m	0.00	11.40	3.20
20	12	08/12/97	n/m	n/m	0.00	9.80	6.00

n/m: not measured

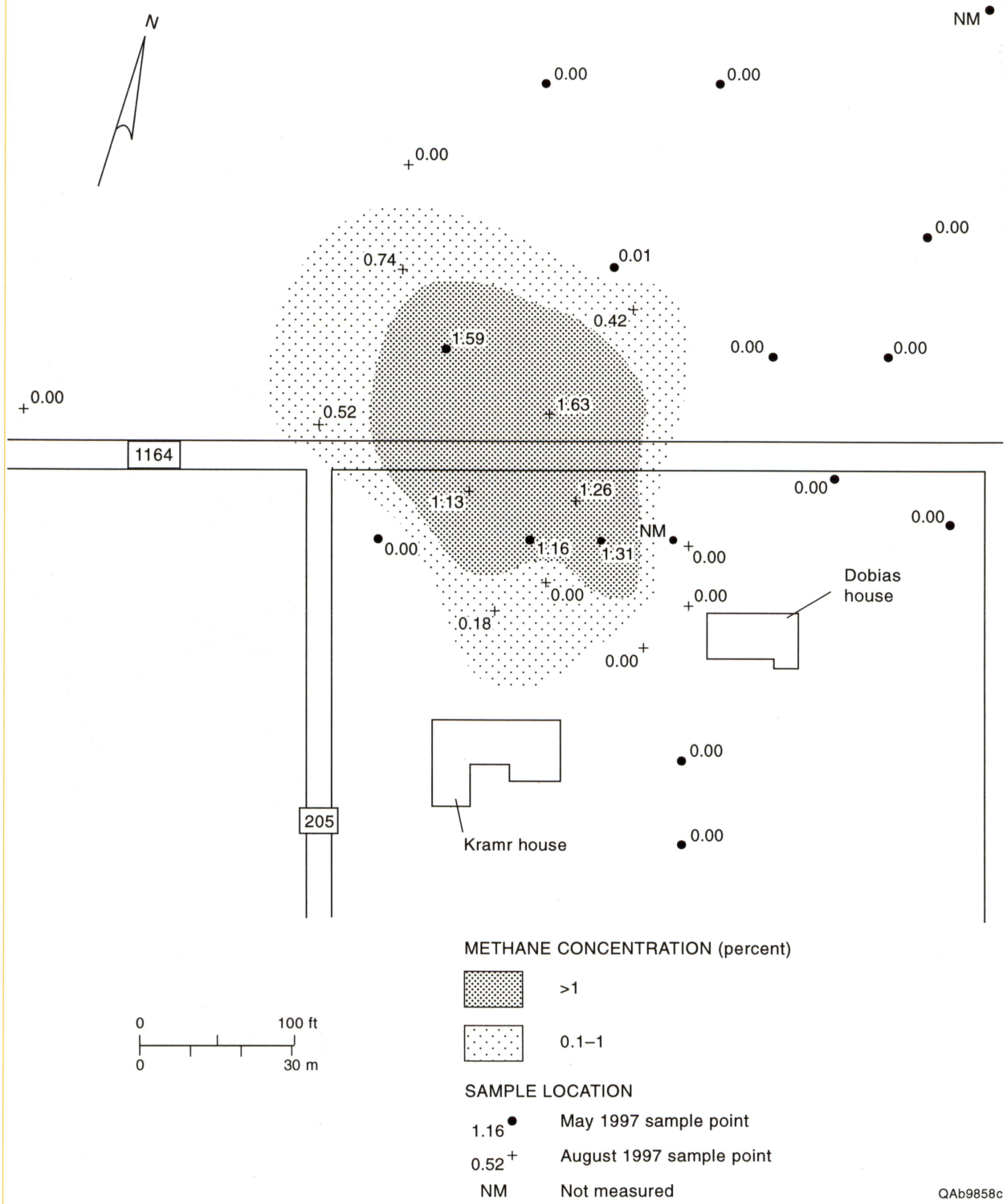* GC analyses by TEG; all others by UT

Figure 4.1. Detailed view of borehole methane concentrations measured by BEG in May and August 1997.
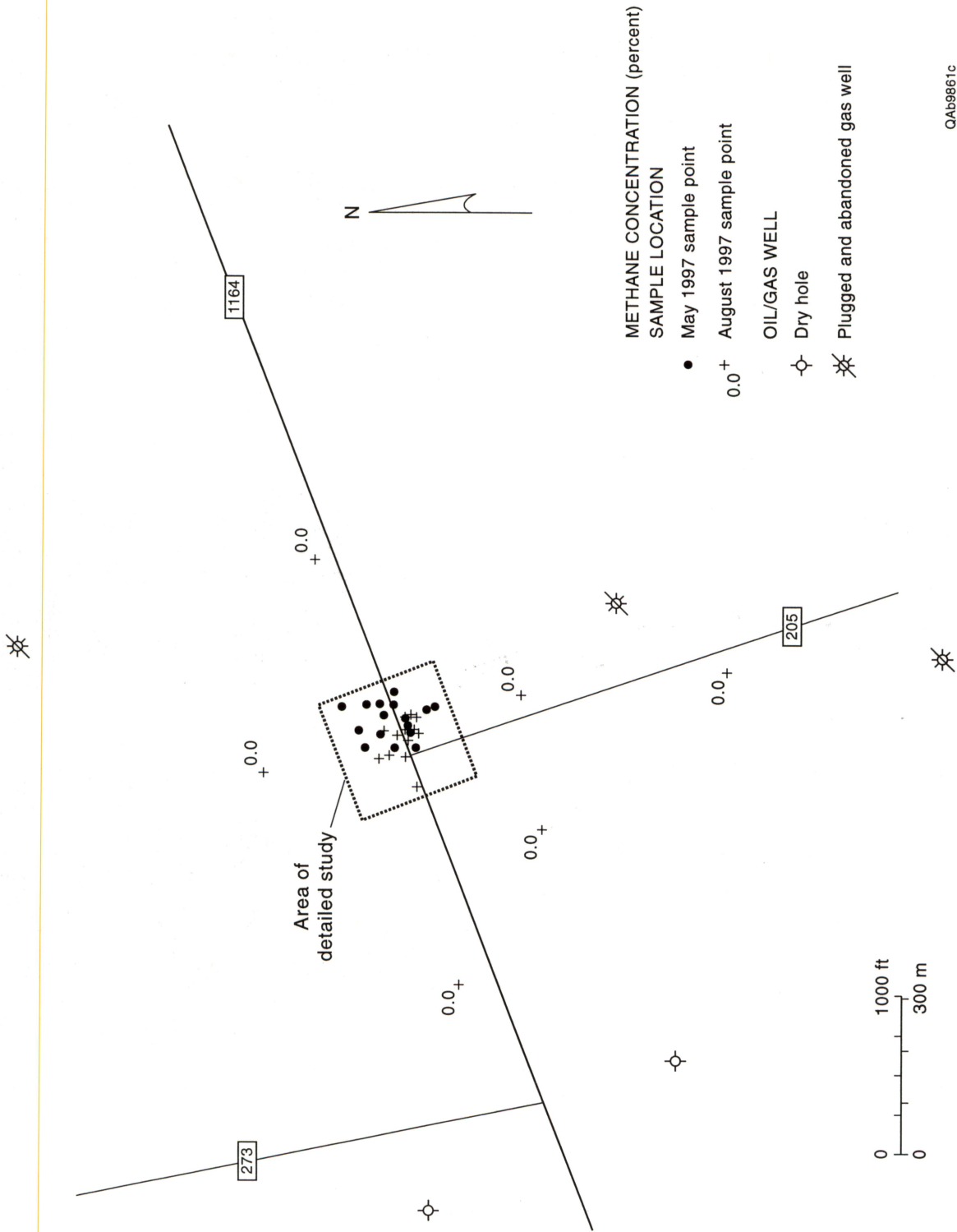
Figure 4.2. Regional view of borehole methane concentrations measured by BEG in May and August 1997.

the Wharton site. Methane values measured by the Lantech GA-90 were all consistently higher than those measured by either the UT DGS or TEG gas chromatographs (table 4.2); however, we do still consider this type of meter to be good for use as a screening tool for methane measurement. The discrepancy between measurement methods increases with increasing gas concentration.

Methane was not the only hydrocarbon gas detected in the borehole vapors. In table 4.3 we show concentrations of C1 through C5 hydrocarbons measured by GC (values from both the UT DGS and TEG gas chromatographs). Typical natural gas exhibits a small ethane:methane ratio. For example, the natural gas standard used in calibration has an ethane:methane ratio of approximately 0.1. The ethane:methane ratio in vapors collected in boreholes in which significant concentrations:methane were detected were all approximately 0.1 (table 4.3).

Chromatograms of the natural gas standard (STD-NGM) and the C1 through C5 gases detected in borehole 6 are very similar (fig. 4.3). The voltage response for the natural gas standard (fig. 4.3a) is much higher than for the vapors measured in borehole 6 because of differences in C1 through C6 concentrations between the standard and the sample (fig. 4.3). The important point is that the vapors from borehole 6 exhibit a typical natural gas signature. The similarity in chromatogram patterns and ethane:methane ratios indicate that the subsurface methane contamination present at the Wharton site is due to some type of natural gas leak. This fact implies that sewer gas from the Kramr septic system is not the source of methane gas measured at the site. However, the septic system could have and, most likely, provided a pathway along which the explosive gases traveled from the subsurface and collected in the attic of the residence.

Carbon dioxide values measured by both the UT DGS GC and the Lantech GA-90 are similar (table 4.2). Carbon dioxide commonly occurs in the vadose zone because of microbial degradation of organic material. According to Jury and others (1991), concentrations of carbon dioxide in clayey soils rarely reach more than 0.5 percent; however, this background value is strongly dependent upon the amount of organic material in the soil zone. Values within the contaminated zone at the Wharton site, however, are approximately 10 percent or greater (table 4.2; fig. 4.4), significantly above background.

Table 4.3. Natural gas constituent concentrations.

Borehole	Depth (ft)	Date	Time	Methane (ppmv)	Ethane (ppmv)	Propane (ppmv)	Isobutane (ppmv)	n-Butane (ppmv)	Isopentane (ppmv)	n-Pentane (ppmv)	CO_2 (%)
B	9	05/07/97	15:01:38	11559.94	743.65	597.28	180.56	50.07	85.36	n/d	10.99
H	9	05/08/97	15:34:04	13098.53	991.82	780.27	234.81	73.87	128.49	4.07	9.20
L	9	05/09/97	08:11:39	15944.16	1239.57	588.99	179.34	18.08	71.69	n/d	7.47
4	16	08/13/97	14:37:28	7447.85	991.52	49.58	39.61	56.27	29.36	37.03	9.39
4*	12	08/13/97	n/m	8000	680	12	8	n/m	3	n/m	n/m
	16	08/13/97	n/m	9000	780	14	8	n/m	6	n/m	n/m
5	12	08/13/97	16:41:33	5245.36	835.25	2.71	33.92	n/d	11.69	12.79	10.92
5*	12	08/13/97	n/m	7000	638	n/d	n/d	n/m	n/d	n/m	n/m
6	6	08/11/97	18:20:01	5294.70	837.77	n/d	n/d	n/m	n/d	n/m	6.78
	15	08/11/97	18:43:36	16261.99	2052.25	1053.25	271.62	151.22	461.65	n/d	11.38
	21	08/11/97	19:28:14	16144.92	2107.22	1058.60	329.97	88.49	188.62	n/d	12.55
9	16	08/13/97	18:24:04	1808.65	142.61	67.57	36.58	16.56	20.52	7.59	11.27
9*	16	08/13/97	n/m	2300	185	74	9	n/m	n/d	n/m	n/m
10	16	08/13/97	19:11:15	12578.38	1423.11	463.30	223.21	55.92	120.44	3.74	10.44
10*	16	08/13/97	n/m	16500	1340	500	69	n/m	n/d	n/m	n/m
12	16	08/13/97	19:45:01	4204.16	349.35	170.75	92.55	30.49	54.46	n/d	11.21
12*	16	08/13/97	n/m	6200	518	233	41	n/m	n/d	n/m	n/m
17	21	08/13/97	13:45:12	11288.99	1217.58	321.48	150.15	61.23	72.09	28.71	8.43

n/d: not detected; n/m: not measured
* analyses by TEG; all others by UT.
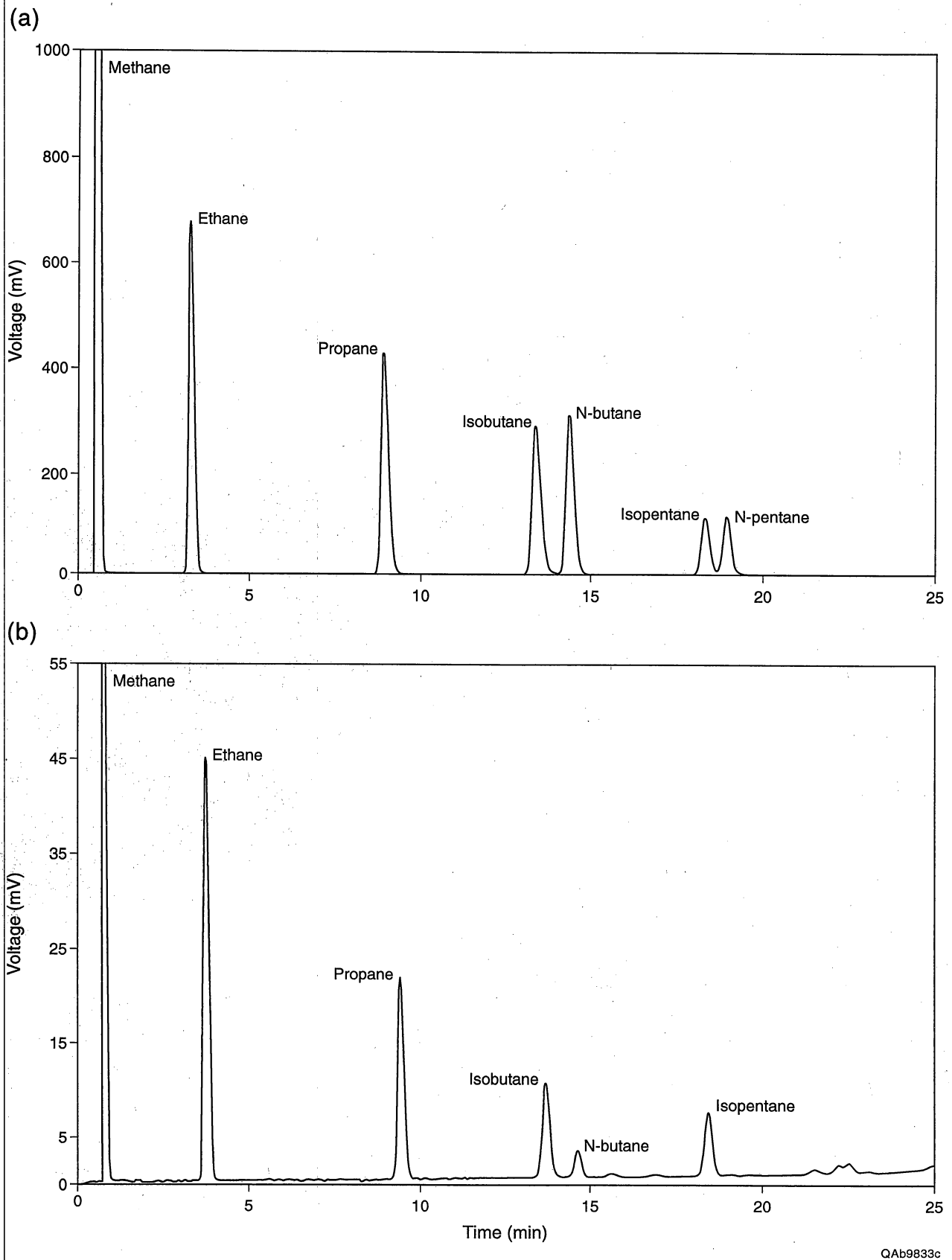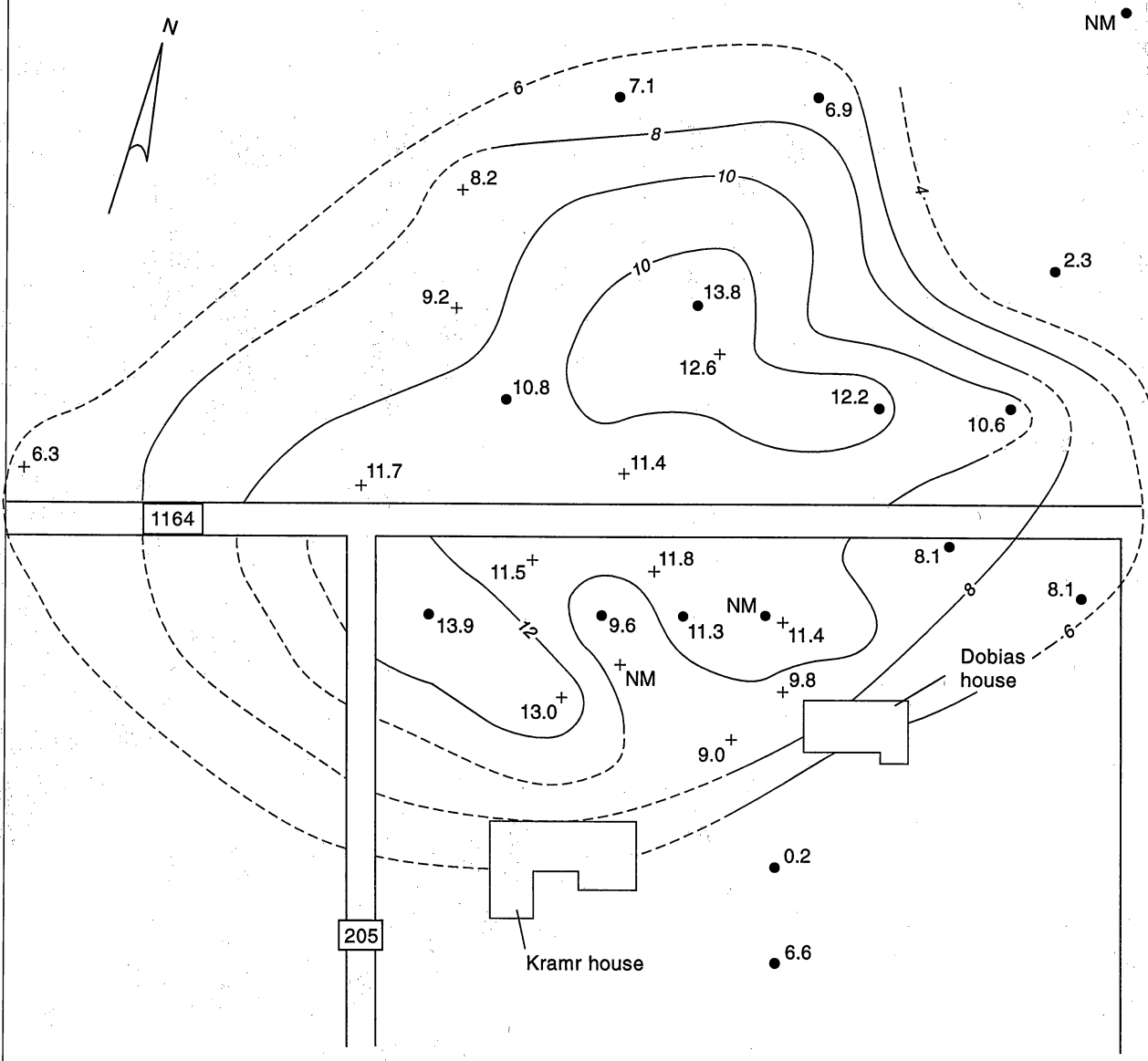ppmv: parts per million vapor

Figure 4.3. Chromatograms of (a) natural gas standard and (b) Warton site from borehole vapor sample 6.

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Figure 4.4. Percent carbon dioxide measured in borehole vapor samples in May and August 1997. Results also listed in table 4.2.

Background oxygen concentrations in soil gas were above 10 percent, but measured values at the site were as low as 0.7 percent (table 4.2; fig. 4.5). In comparison, atmospheric oxygen is approximately 21 percent. Zones of elevated carbon dioxide (fig. 4.4) and decreased oxygen (fig. 4.5) concentrations are coincident with the zone of increased methane (fig. 4.2).

Methane generation can occur by both inorganic and organic processes. It can volatilize from crude oil and can also be generated biogenically during microbial degradation of natural gas. Breakdown of organic material is an oxygen-consuming process that can result in the formation of a reducing environment; carbon dioxide is also generated during the degradation of organic material. The reactions are catalyzed by microbes that occur naturally in the subsurface (Drever, 1988). This process, known as natural attenuation, has most likely been taking place at the Wharton site. Bacterial oxidation and bacterial fermentation are represented by the following two generalized reactions:

Bacterial oxidation: $CH_2O + O_2 \longrightarrow CO_2 + H_2O$

Bacterial fermentation: $2C_{organic} + 2H_2O \longrightarrow CH_4 + CO_2$.
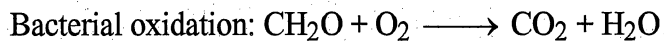
Elevated carbon dioxide and depressed oxygen values measured at the Kramr site suggest that oxidation and fermentation have effected a partial reduction in methane.

5.0 REMEDIAL EVALUATION

The scope of work for this project included evaluation of feasible remediation alternatives and recommendation of an appropriate approach for remediation of the Wharton site. Site-specific conditions considered in evaluating remedial alternatives included mitigation of potential environmental impacts and cost effectiveness of different methods. The remedial options we consider here fall into the categories of no action, passive venting, and extraction. Because methane levels are below the lower explosive limit and pose no immediate danger, no action should be taken at this time to further lower gas concentrations, but we recommend that soil-methane concentration be monitored quarterly for 2 yr to ensure that concentrations do not increase on a
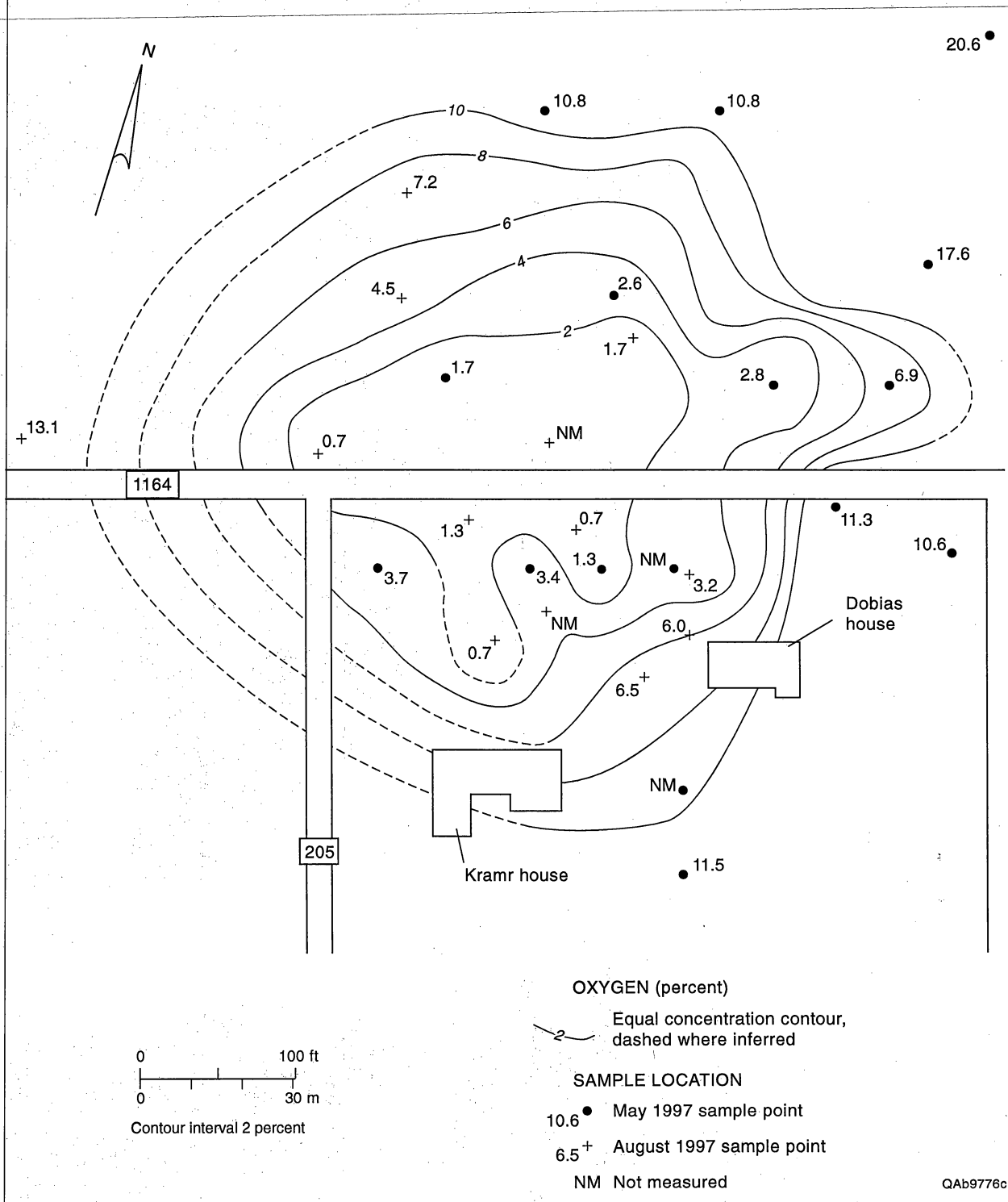
Figure 4.5. Percent oxygen measured in borehole vapor samples in May and August 1997. Results also listed in table 4.2.

seasonal cycle. These data should suffice to document site closure if, as we expect, methane concentrations remain low or continue to decline.

5.1 Summary of Wharton Site Conditions

The issue of concern at the Wharton site is elevated concentrations of methane in the subsurface. The subsurface levels measured using gas chromatography now range from 0 to 1.63 percent. Methane is explosive within the range of 5 to 15 percent at typical atmospheric oxygen levels. The area where elevated methane levels were noted is approximately 170 ft $\times$ 200 ft and extends to the north and south of FM 1164. Our site investigation concluded that there is not an ongoing source for methane. The source may be residual but now is discontinued. The subsurface methane levels measured during our site investigation do not pose an immediate safety risk.

A map of methane concentrations measured in selected boreholes in March and April 1994 shows a semicircular plume about 500 ft in diameter centered near the corner of FM 1164 and County Road 205. A map of these contoured values superimposed on results of our borehole vapor survey (fig. 5.1) shows a coincident area of elevated methane but with present concentrations greatly reduced from those measured in 1994. On the basis of the decrease in measured methane concentrations between 1994 and 1997 and indications that natural degradation has taken place, we are confident that there is no longer an active source of methane in the vicinity of the Wharton County site. However, one problem with making a direct comparison of KEI and BEG methane measurements is that we do not know the methodology used by KEI. For example, we do not know the depth at which they measured methane concentrations or whether they used a portable meter or GC methods to measure concentrations of methane and other natural gas constituents.

5.2 Remedial Options

In this section, we evaluate remedial alternatives for the elevated levels of natural gas (methane) delineated during the site assessment. One remedial alternative is no action. Other
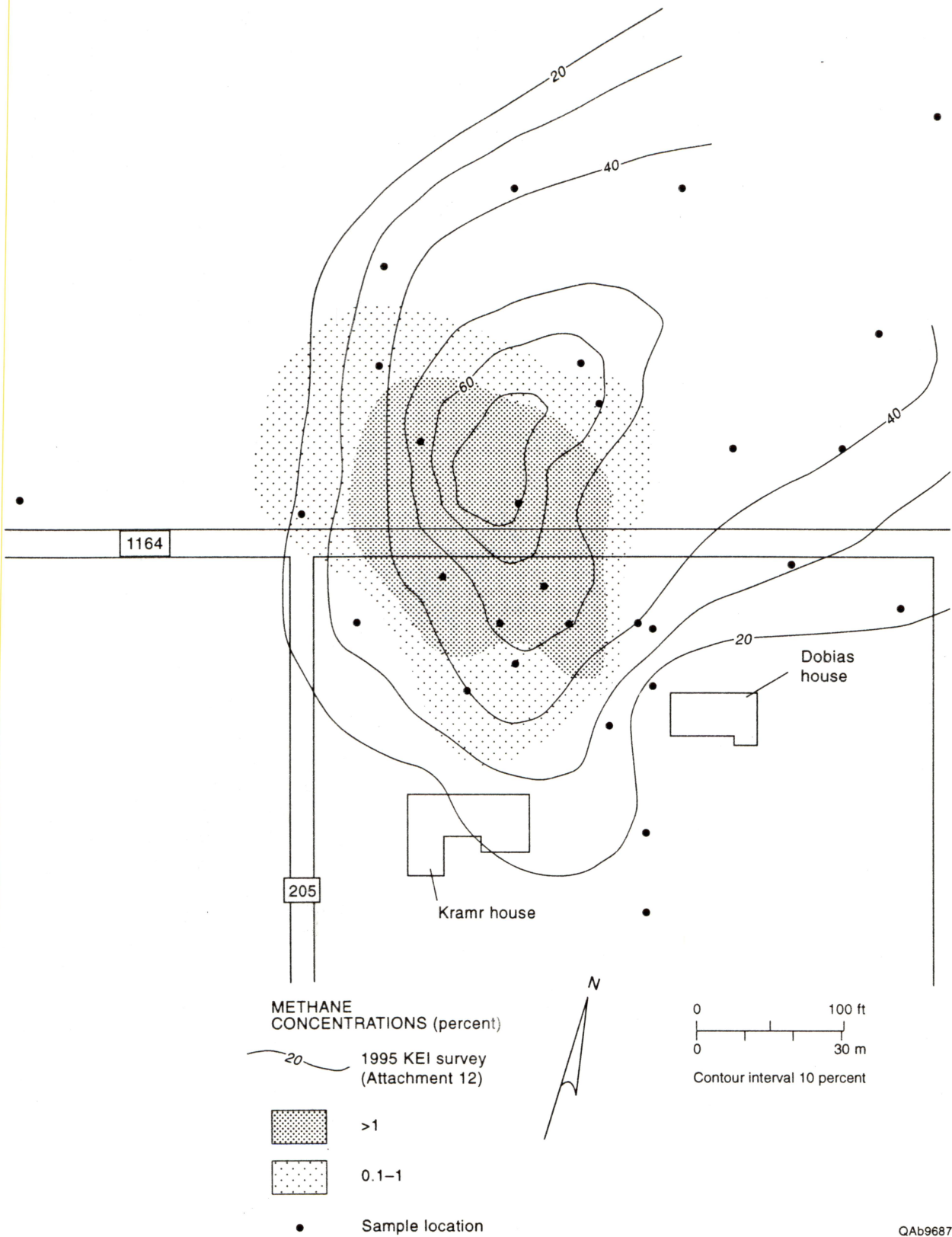
Figure 5.1. Inferred extent of methane contamination.

remedial alternatives evaluated include continued periodic monitoring, encouraging natural biodegradation, passive gas venting, and soil-gas-vapor extraction.

5.2.1 No Action

Methane levels have apparently decreased from more than 70 percent to less than 2 percent between 1995 and 1997, according to a comparison between KEI survey data and our site assessment (fig. 5.1). Under a no-action alternative, the existing conditions would remain unaltered by remedial actions. Gas concentration would continue to decrease, but some uncertainty exists as to how long it will take for methane to decrease to background levels. Because the site's file history indicates fluctuations in the levels of methane since the incident, and because of the potential severe consequences associated with undetected elevated methane levels, we do not recommend the no-action alternative.

5.2.2 Continued Periodic Monitoring

The maximum level of methane detected in the subsurface at the Wharton site during our site investigation is 1.6 percent, or 33 percent of the lower explosive limit (LEL) of methane (borehole 6). Site records and KEI data indicate higher levels of methane detected in the past. The decrease in subsurface methane levels is probably because of venting to the atmosphere, microbial degradation, and some dispersion. File data suggest, however, that there have been fluctuations in methane concentration while the overall level has been decreasing. Such fluctuations might reflect seasonal effects due to variations in precipitation and soil-moisture content, changes in the water table, or differences in measuring technologies.

Periodic monitoring of the subsurface methane level over different seasons could confirm that soil-gas levels do not ever approach the lower explosive limit of methane. If consistently low levels of methane are confirmed, no further remedial action with respect to soil gas would be necessary.

Conversely, systematic monitoring of the Wharton site would allow detection of any significant increase in subsurface methane level and would allow for remedial steps to be taken if necessary.

One monitoring option would be to perform sequential subsurface soil-gas surveys at the site on a periodic basis. Repeated mobilization and probing for soil-gas measurements, however, would not be cost effective. Another function of a monitoring program would be to remove uncertainties in evaluating the subsurface methane levels; the inherent uncertainties present in any intrusive investigative method may overshadow the results of a program that monitors conditions through existing measuring points.

Another monitoring option would be to install soil-gas monitoring points at the Wharton site. This option would provide for consistent subsurface measurement points and eliminate many of the variables associated with other methods. This option would also provide a monitoring system capable of documenting a decrease or increase in subsurface methane levels at particular locations with time. Regardless of whether above-ground or at-grade well completions are used, some precautions are needed to avoid damage to the wells and to facilitate locating and accessing the wells at each visit.

5.2.3 Natural Biodegradation Encouragement

Elevated methane and carbon dioxide and decreased oxygen levels measured in the subsurface suggest that natural biodegradation of the methane is ongoing. Oxygen is generally a limiting factor in bioremediation, and the rate of natural biodegradation can often be encouraged by supplementing oxygen supply to the subsurface. Reduced oxygen levels were noted in the site assessment in an area coincident with the one where elevated methane levels were measured. Injection of air into the subsurface would probably encourage natural biodegradation of the subsurface methane. However, due to the low levels of methane measured at the Wharton site and the relatively slow rate at which biodegradation occurs, it may be difficult to assess a definite benefit from increasing the subsurface oxygen concentration at this site.

5.2.4 Passive Gas Venting

A passive gas-venting system might be used to discharge methane to the atmosphere, thereby reducing subsurface methane levels. Because the concentrations of methane in the subsurface at the Wharton site are low, and if monitoring of the subsurface gas levels continues, passive gas venting might be appropriate. One disadvantage to a passive-gas venting system is lack of drive for venting and the required relative close spacing of the vents. Passive drive is rarely sufficient to decrease subsurface gas concentrations in a timely manner when an air-treatment apparatus is required. Prior to subsurface gases being passively vented, environmental regulations that govern venting of pollutants (methane) into the atmosphere may require registration for a standard air permit exemption (30 TAC 106.533).

5.2.5 Soil-Gas-Vapor Extraction System

Soil-gas or soil-vapor extraction systems (SVE's) are technologies frequently used for in situ remediation of sites contaminated by leaky petroleum storage tanks. In soil-gas extraction systems, clean air is drawn through a zone of contaminated soil; contaminants desorb from the soil and are removed, along with the exhausted air. Continued flushing with clean air can significantly reduce methane concentration in soil (U.S. EPA, April 1991). A basic soil-gas extraction system consists of extraction wells or trenches or both in conjunction with an air blower or vacuum pump. Treatment of discharge air to separate moisture and remove contaminants is typically required.

SVE systems are commonly used for remediation of sites with significant levels of soil-gas contaminants or where the subsurface contamination contains highly volatile constituents. Whereas an SVE system is a feasible option at the Wharton site, the low levels and the small area where methane gas was measured may not require or justify this level of remediation.

5.3 Remedial Recommendations

We recommend establishing a soil-gas monitoring plan that includes taking soil-gas measurements on a quarterly basis for a period of 2 yr to measure seasonal fluctuations in methane levels (if present) and to confirm that soil-gas levels do not approach the lower explosive limit of methane. If consistently low levels of methane are confirmed, no further remedial action with respect to the soil gas will be necessary and the site should be closed. Conversely, systematic monitoring of the Wharton site would provide for the detection of any increase in subsurface methane levels and allow appropriate remedial steps to be taken at that time. However, we do not expect methane concentrations would remain much above our recently measured levels for very long.

We recommend the installation of six gas monitoring wells as indicated in figure 5.2. These wells will provide for consistent subsurface gas monitoring and remove many of the uncertainties associated with other methods. The wells will consist of 20 ft of 2-inch-diameter PVC pipe installed to a depth of 17.5 ft (2.5 ft stick-up). The targeted depth will allow measurement of gas in the sandy layer, while hopefully remaining above the water table. The wells will be screened (perforated casing) in the lower 10 ft, and the annulus will be filled with granular material to approximately 5 ft bgl. The remaining annular space will be filled with a cement and bentonite grout mixture to provide a seal at the surface. The gas-monitoring plug would be capped and locked. This system will provide for consistent monitoring of subsurface gas concentrations.

An advantage to these soil-gas monitoring wells is the flexibility of converting them to another remedial option if necessary, depending on site-monitoring results. For example, replacing a well cap with a venting apparatus would easily convert the monitoring wells to soil-gas vents, provided no regulatory restrictions apply. Similarly, the wells could be connected by surface piping and attached to a vacuum extraction system if future site conditions warranted an active approach to reducing subsurface methane levels.
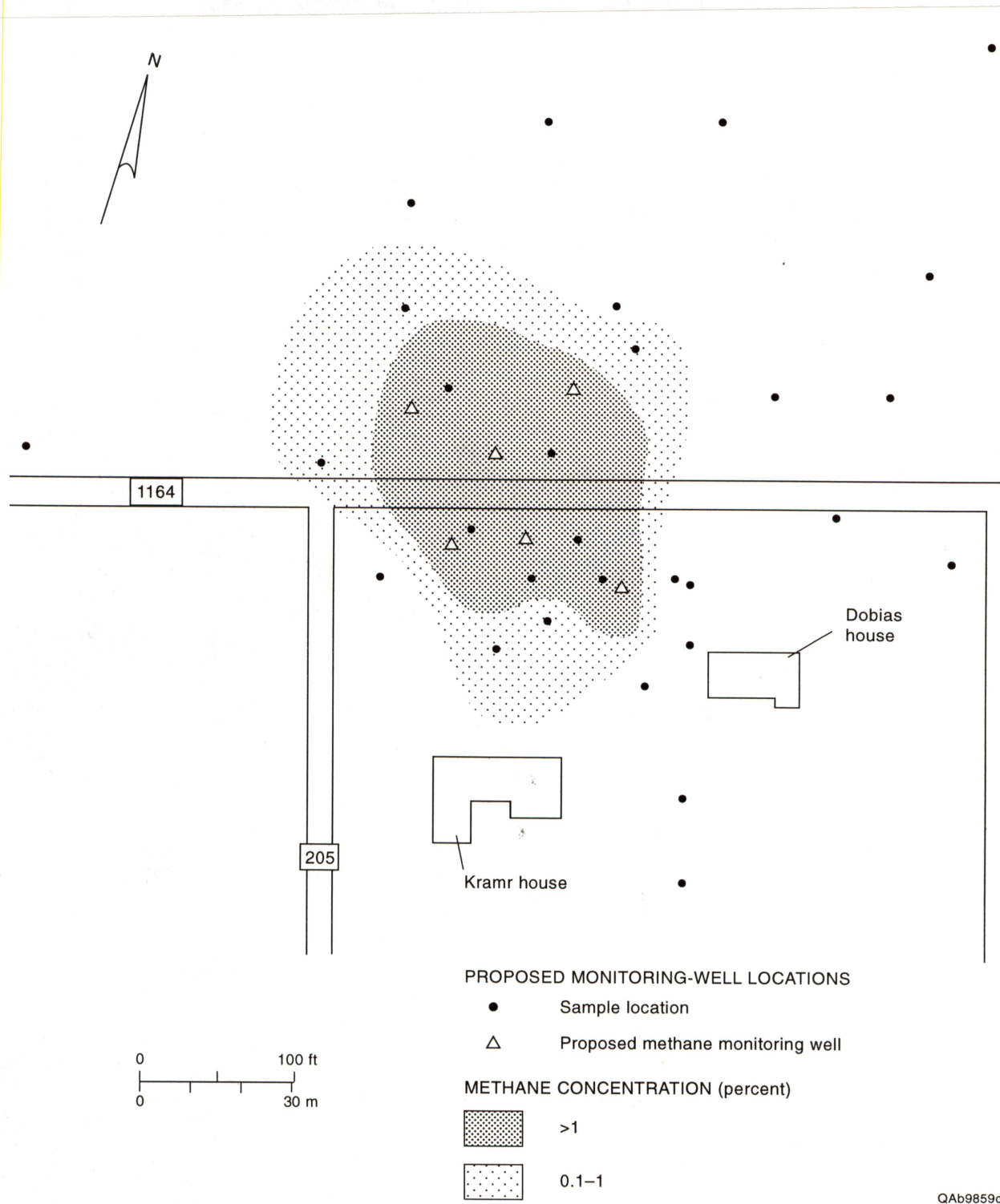
Figure 5.2. Proposed methane monitoring-well locations for the Wharton site.

Monitoring will most likely be required on a weekly basis during the first month of operation and on a quarterly basis thereafter. Monitoring should consist of vapor-concentration measurements by a methane meter (Lantech GA-90 infrared gas analyzer) used as a screening tool. If an increase in methane concentrations is seen over those measured during this study, additional samples should be taken for confirmatory analysis by GC. A confirmatory GC analysis would (1) ensure that the methane meter was functioning properly and (2) measure the relative abundance of the longer chain hydrocarbons (that is, ethane, propane, butane). Detection of longer chain hydrocarbons in addition to methane would help to discern the source of elevated methane concentrations. The monitoring results should be evaluated to determine the appropriateness of continued monitoring and whether conversion of the monitoring wells to another remedial option is required. For example, if methane concentrations increase to 75 percent of the LEL (3.75 percent CH_4), we will most likely recommend that the monitoring wells be converted to gas-extraction wells.

6.0 CONCLUSIONS

The maximum methane concentration we detected at the Wharton site using gas chromatography was 1.63 percent by volume of air (33 percent of the lower explosive limit) at a depth of 15 ft bgl. Throughout our study we found slightly elevated methane, ethane, propane, and butane concentrations only in the immediate vicinity of the Kramr property and along both the north and south sides of FM 1164. In addition, our offsite sampling was sufficient to rule out nearby gas wells and dry holes as potential sources of contamination. Regardless of the exact source of elevated methane, we conclude that it is no longer active and that there are no other ongoing sources.

The distribution of elevated gas concentrations, similarity in chromatogram patterns, and ethane:methane ratios of natural gas standards and samples collected onsite indicate that the subsurface methane contamination present at the Wharton site is due to some type of natural gas leak and does not represent an accumulation of sewer gas from the Kramr septic field. We

concluded that the most likely source was a 100-psi natural gas pipeline that was found to be leaking soon after the Kramr house exploded on June 23, 1997. Reasons supporting these conclusions include:

(1) the absence of an offsite source of methane, the plume's remaining in a relatively fixed location since originally detected, and a zero-concentration methane contour between the site and offsite gas wells;

(2) the narrow and relatively fixed position of the highest methane contamination just to the north of the Kramr property and coincident with the location of the EPL pipeline right-of-way in both 1995 and 1997 and the reduction in methane levels from above 70 to just above 1 percent between 1995 and 1997;

(3) the ethane:methane ratios measured at the site during this study, which indicate natural gas as opposed to sewer gas; and

(4) reports of stressed vegetation along the pipeline right-of-way during the time in which the pipeline was in operation and the subsequent recovery of vegetation since the pipeline was taken out of service.

Cracks in the Beaumont clay probably provided the pathway along which natural gas was introduced into the sand layer underlying the pipeline. This same pathway would have allowed natural venting of the gas to the atmosphere and a subsequent decrease in gas concentration in the plume. Elevated carbon dioxide and decreased oxygen measured during our site investigation suggest that natural attenuation of the gas contamination has also taken place. These factors, combined with the fact that contaminant levels are below the lower explosive limit of methane, lead us to conclude that no immediate remediation other than continued monitoring of methane levels at the Wharton site is warranted.

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