

Health Consultation

FORMER DELROC OIL REFINERY/WOODWIND LAKES
SUBDIVISION

HOUSTON, HARRIS COUNTY, TEXAS

EPA FACILITY ID: TXN000606661

FEBRUARY 23, 2007

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

You May Contact ATSDR Toll Free at
1-800-CDC-INFO

or

Visit our Home Page at: <http://www.atsdr.cdc.gov>

HEALTH CONSULTATION

FORMER DELROC OIL REFINERY/WOODWIND LAKES SUBDIVISION

HOUSTON, HARRIS COUNTY, TEXAS

EPA FACILITY ID: TXN000606661

Prepared By:

Texas Department of State Health Services
Under a Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

Table of Contents

Purpose and Statement of Issues.....	1
Background.....	1
Site Description and History.....	1
Community Health Concerns.....	1
Environmental Sampling.....	2
Public Health Implications.....	2
Introduction.....	2
Pathways Analysis.....	2
Determining Contaminants of Concern.....	3
Direct Contact with Media.....	4
Groundwater.....	4
Drinking Water.....	4
Sediment and Soil.....	5
Vapor Intrusion Pathway.....	6
Cancer Cluster Investigation.....	6
Birth Defects.....	7
Child Health Considerations.....	7
Conclusions.....	8
Recommendations.....	8
Public Health Action Plan.....	9
Authors, Technical Advisors, and Organizations.....	10
References.....	11
Certification.....	12
Appendix A: Acronyms and Abbreviations.....	13
Appendix B: Figure.....	14
Appendix C: Tables.....	15

Purpose and Statement of Issues

In response to a Texas Commission on Environmental Quality (TCEQ) request, the Texas Department of State Health Services (DSHS) evaluated the public health implications of exposure to environmental contaminants from the former Delroc Oil Refinery site. This site has been redeveloped as Section 3 of the Woodwind Lakes Subdivision in Houston, Texas. (Note: Appendix A lists abbreviations and acronyms used in this report).

Background

Site Description and History

The former Delroc Oil Refinery site (Delroc) is located on an approximately 5-acre site in Northwest Harris County (Figure). The refinery was in operation from 1955 through 1957 and processed crude oil. Aerial photographs indicate that between 1964 and 1970 the industrial infrastructure was removed, and the site appears to be a vacant tract of land until the 1990s. In the late 1990s, 32 homes were built on the site of Delroc as Section 3 of the Woodwind Lakes Subdivision (Section 3). No structural remnants of Delroc remain. Modifications to the land surface and drainage, including the construction of a major retention pond, occurred during construction of the subdivision. Rolling Fork Creek is located west of the site and receives stormwater discharge from the retention pond. Rolling Fork Creek flows south and discharges into White Oak Bayou, which ultimately flows into Buffalo Bayou [1].

In 2003, Chevron conducted a site investigation in Section 3 at the request of the Railroad Commission of Texas. Fourteen soil borings were advanced to 15 feet below ground surface (bgs) and analyzed for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), total petroleum hydrocarbons (TPH), and metals. Based upon TCEQ Texas Risk Reduction Program rules, it was determined that contaminants of concern did not present a risk to human health and no further investigation or action was needed [2].

In response to community concerns, the TCEQ conducted a Preliminary Assessment/Screening Site Inspection in Spring 2006 to determine if contaminants from Delroc were present in the groundwater, soil, and sediment at levels that may pose a threat to human health [1]. Using this data, DSHS provided technical assistance to TCEQ summarizing the public health implications associated with exposure to contaminants present in environmental media [3]. A detailed analysis is provided in this Health Consultation.

Community Health Concerns

Citizens living in Section 3 were concerned about the potential for adverse health effects from living on a former oil refinery. Community members were also concerned about a possible excess of cancer and birth defects.

Environmental Sampling

Data evaluated in this Health Consultation include groundwater, drinking water, soil, and sediment sample data collected by TCEQ in June 2006. Groundwater samples collected from two temporary monitoring wells (approximately 20 feet bgs) placed in the areas where above ground storage tanks had been located were analyzed for VOCs, SVOCs, pesticides, and polychlorinated biphenyls (PCBs). Drinking water samples were collected from four public water supply reservoir tanks (wells approximately 700 feet bgs) and one private water supply well (approximately 200 feet bgs) and were analyzed for VOCs, SVOCs, metals, pesticides, and PCBs. Eighteen soil samples collected from Section 3 (approximately 0 to 2 feet bgs, 4 to 6 feet bgs, and 15 to 18 feet bgs) were analyzed for VOCs, SVOCs, metals, pesticides, and PCBs. Five sediment samples (surface grab samples) collected from Rolling Fork Creek and White Oak Bayou were analyzed for VOCs and metals [1].

For this consultation, DSHS relied on the information provided in the referenced documents and assumed adequate quality assurance/quality control procedures were followed with regard to data collection, chain-of-custody, laboratory procedures, and data reporting.

Public Health Implications

Introduction

Exposure to chemical contaminants drives the Agency for Toxic Substances and Disease Registry (ATSDR) health consultation process. People may be adversely affected by chemicals only if exposure occurs; that is, they must come into contact with the chemicals or absorb the chemicals into their bodies. The presence of chemical contaminants in the environment does not always result in contact, and contact does not always result in the chemical being absorbed into the body. Thus, chemicals have the potential to cause adverse health effects only when people actually come into contact with them through a completed exposure pathway.

Pathways Analysis

The most common ways people come into contact with chemicals are by inhalation (breathing), ingestion (eating or drinking), or by dermal contact (contact with or absorption through skin) with a substance containing the contaminant. The exposure pathways of greatest concern for chemicals found in soil and sediment are incidental ingestion or by direct contact through the skin. For chemicals found in groundwater, we consider if people have private wells in the area of contamination or if contamination may migrate into the public water supply. Exposure pathways of concern are the ingestion of water as well as dermal contact and inhalation when water is used in the home (for example, showering and washing dishes). Whether adverse health effects are possible depends on: 1) the toxicological properties of the chemicals; 2) the manner in which the person contacts the chemical; 3) the concentration of the chemical; 4) how often the exposure occurs; 5) how long the exposure occurs; and 6) how much of the chemical is absorbed into the body during each exposure event.

Determining Contaminants of Concern

To determine the potential health risks associated with the contaminants found in the soil, sediment, and groundwater, we compared each contaminant detected with its media-specific health-based assessment comparison (HAC) value for non-cancer and cancer endpoints. These values are guidelines that specify levels of chemicals in specific environmental media (soil/sediment, air, and water) that are considered safe for human contact with respect to identified adverse health effects.

Non-cancer screening values are based on the ATSDR's minimal risk levels (MRLs)¹ or the United States Environmental Protection Agency's (EPA's) reference doses (RfDs)². Both of these are based on the assumption that there is an identifiable exposure threshold (both for the individual and for populations) below which there are no observable adverse effects. Therefore, MRLs and RfDs are estimates of daily exposures to contaminants that are unlikely to cause adverse non-cancer health effects even if exposure occurs for a lifetime.

For contaminants that are considered to be known human carcinogens, probable human carcinogens, or possible human carcinogens, cancer risk evaluation guides (CREGs) are calculated using EPA's chemical-specific cancer slope factors (CSFs) and an estimated excess lifetime cancer risk of one-in-one million persons exposed for a lifetime.

Standard assumptions for body weight (70 kg adult and 16 kg child), soil/sediment ingestion (100 mg/day for adults and 200 mg/day for a child), and water ingestion (2 L/day for adults and 1 L/day for a child) were used to calculate both non-cancer and cancer HAC values. Soil pica behavior (ingestion of more than 1 g of soil per day) may also occur in some children. The standard assumption for soil ingestion in pica children is 5,000 mg/day.

Polycyclic aromatic hydrocarbons (PAHs) are a group of more than 100 different chemicals (including benzo[a]pyrene or BaP) that are generally found in the environment as mixtures, not as single compounds. Because BaP is perhaps the most toxicologically significant PAH, it was used as a surrogate to assess the potential health risks associated with PAHs in soil and sediment. Individual PAH concentrations were converted to BaP toxic equivalents (TEQ) using established toxicity equivalency factors (TEFs, Table 1). For the two PAHs detected in drinking water, we used ATSDR screening values for analysis.

Standard HAC values to assess the potential health risks associated with the presence of carbazole and methylcyclohexane in soil and sediment were not available. A CREG value of 35 mg/kg was derived for carbazole using the Oak Ridge National Laboratories Risk Assessment

¹ An MRL is a contaminant specific exposure dose below those which might cause adverse health effects in the people most sensitive to such chemical-induced effects. MRLs generally are based on the most sensitive chemical-induced end point considered to be of relevance to humans.

² An RfD is an estimate (with a level of uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive groups) that is likely to be without appreciable risk of deleterious effects during a lifetime.

Information System's CSF [4] for carbazole. For methylcyclohexane, we used the EPA Region 9 Preliminary Remediation Goal [5] screening value for residential soil of 2,600 mg/kg.

The exposure assumptions used to establish these screening levels are conservative with respect to protecting public health; as a result, actual exposures are likely to be lower than those used to calculate the screening values. Exceeding a screening value does not mean that a contaminant represents a public health threat; rather, it suggests that the contaminant warrants further consideration. Assessing the public health significance of contaminants that exceed their respective screening levels involves reviewing and integrating relevant toxicological information with plausible exposures. We may estimate the magnitude of the public health significance by comparing the estimated exposures to identified "no observed" and "lowest observed" adverse effects levels (NOAELs and LOAELs) in animals and to known effect levels in humans, when available. We assess the public health significance of contaminants that exceed screening values by reviewing and integrating relevant toxicological information with reasonable maximum exposure scenarios.

Direct Contact with Media

Groundwater

Shallow groundwater (approximately 20 feet bgs) in the Section 3 area is not used for drinking or other household purposes. Therefore, there is **no public health hazard** associated with the direct contact with shallow groundwater.

Drinking Water

Dibromochloromethane exceeded the CREG in one public water supply well utilizing the Evangeline Aquifer. Estimated exposure doses were calculated for preschool children, elementary school children, teenagers, and adults using standard assumptions for body weight (16 kg preschool child, 30 kg elementary school child, 50 kg teenager, and 70 kg adult), water intake rate (1 L/day preschool child, 1.5 L/day elementary school child, and 2 L/day teenager and adult), and the maximum dibromochloromethane concentration (0.82 µg/L). Estimated exposure doses were well below the chronic MRL for dibromochloromethane (0.09 mg/kg/day). This MRL was derived by dividing the LOAEL (40 mg/kg/day, based upon the appearance of fatty change in the liver) by an uncertainty factor of 300 to account for use of a LOAEL, animal to human extrapolation, and human variability. The risk for cancer due to exposure to dibromochloromethane over a lifetime was calculated by evaluating cancer risk over life stages and summing these risks. The lifetime risk of developing cancer was estimated to be 2.4×10^{-6} . Qualitatively, we would interpret this as a no increased lifetime risk for developing cancer.

Iron exceeded EPA's secondary drinking water standards in one public water supply well, however, secondary drinking water standards are based upon aesthetic quality of water (taste, odor, staining) and are not indicators of a potential health threat. All other contaminants in both the public and private drinking water supplies were below the detection limit or, if detected,

below the screening value. Based on this information, there is **no apparent public health hazard** from direct contact with drinking water. Drinking water data are presented in Table 2.

Sediment and Soil

Aluminum and vanadium in soil exceeded their respective environmental media evaluation guides (EMEGs) for intermediate duration of exposure (15 days to 1 year) for children exhibiting pica behavior. However, concentrations of these metals were within the ranges of normal background levels for this part of the United States [6] and below levels that have been shown to cause adverse health effects. Arsenic in most soil and sediment samples exceeded the CREG; however, the CREG is below background levels. Based upon ATSDR guidance, the recommended soil/sediment HAC value for arsenic is 20 mg/kg (chronic EMEG child). No soil or sediment samples exceeded this HAC value. Therefore, we do not expect aluminum, arsenic, or vanadium in the soil to pose a health risk to children or adults.

BaP was used as a surrogate to assess the relative toxicity of PAHs in sediment and soil. Using our standard exposure scenario (16 kg child ingesting 200 mg of soil/sediment per day) and the soil/sediment sample with the highest BaP TEQ (1.35 mg/kg), the estimated exposure dose of PAHs was 0.00002 mg/kg/day. Although no MRL or RfD has been derived for PAHs, there are LOAELs and NOAELs available [7]. An intermediate NOAEL of 1.3 mg/kg/day was observed for mice exposed to BaP. The LOAEL (2.6 mg/kg/day) is based upon the appearance of gastric tumors. There currently are no studies available that evaluate chronic exposures. Systemic effects occurred at much higher exposure doses in acute and intermediate duration exposures [7]. The estimated exposure dose of PAHs in soil and sediment is several orders of magnitude below the NOAEL and LOAEL for BaP; therefore, we do not expect exposure to PAHs in the soil and sediment to result in adverse health effects.

BaP, along with several other PAHs, has been classified by the EPA as a "probable human carcinogen" [7]. This classification is based on animal data where repeated BaP administration in numerous strains of at least four species of rodents and several primates has been associated with increased incidence of total tumors and of tumors at the site of exposure [7]. Human data specifically linking BaP, or any of the other PAHs, to a carcinogenic effect are lacking. Although lung cancer has been found in humans who had received exposure to various mixtures of PAHs known to contain BaP – including cigarette smoke, roofing tar, and coke oven emissions – it is not possible to conclude from this information that BaP, or any other of the PAHs, is the responsible agent [7].

The risk for cancer due to lifetime exposure to PAHs was calculated by evaluating cancer risk over life stages and summing these risks. Estimated exposure doses were calculated for preschool children, elementary school children, teenagers, and adults using standard assumptions for body weight (16 kg preschool child, 30 kg elementary school child, 50 kg teenager, and 70 kg adult), soil/sediment intake rate (200 mg/day preschool child, 150 mg/day elementary school child, and 100 mg/day teenager and adult), and the maximum BaP TEQ concentration (1.35

mg/kg). The lifetime risk of developing cancer was estimated to be 2.6×10^{-5} . Qualitatively, we would interpret this as a no apparent increased lifetime risk for developing cancer.

All other contaminants were below the detection limit or, if detected, below the screening value. Based on this information, there is **no apparent public health hazard** from direct contact with soil and sediment. Soil and sediment data are presented in Tables 3 and 4.

Vapor Intrusion Pathway

One exposure route of potential concern when volatile substances are detected in soil or shallow groundwater is whether or not these subsurface contaminants may intrude into indoor air. Vapor intrusion is the term used to describe this phenomenon in which volatile compounds in the subsurface (soil or shallow groundwater) migrate into overlying buildings and affect indoor air quality.

The vapor intrusion pathway was analyzed using EPA guidance [8]. For sites in which soil and shallow groundwater may contain volatile substances, EPA recommends using soil gas data to evaluate the vapor intrusion pathway. Soil gas data were not available for this site, so shallow groundwater data were used. Some volatile substances that have the potential to migrate into overlying buildings were detected in the two shallow groundwater samples in Section 3. Estimated values of two of these (benzene and ethylbenzene) were at levels that could potentially affect indoor air quality; however, as these are estimated values it is difficult to determine if the true concentrations for these contaminants are at levels that may affect human health. Additionally, attenuation factors associated with this site are unknown and these attenuation factors significantly affect the degradation of petroleum products. Because of the estimated values of contaminants, the unknown attenuation factors, and the lack of soil gas data, the vapor intrusion pathway poses an **indeterminate public health hazard**. We recommend further investigation into this pathway of potential concern.

Cancer Cluster Investigation

Citizens living in Section 3 were concerned about a possible excess of cancer among residents of the subdivision. Although it is not possible to determine if a particular cancer is caused by environmental or other risk factors, the Texas Cancer Registry conducts cancer cluster investigations to determine if there is an excess of cancer in an area or population. In these investigations, the number of observed cases is compared to what would be expected based on the state cancer rate. The analysis of incidence data for zip code 77040, Houston, Texas, from January 1, 1995 through December 31, 2003, found the following cancers to be within expected ranges in both males and females: prostate, breast, lung, colon and rectum, bladder, kidney and renal pelvis, liver and intrahepatic bile duct, non-Hodgkin's lymphoma, brain/central nervous system, selected leukemia subtypes, oral cavity and pharynx, nasopharynx, nose and nasal cavity, larynx, esophagus, corpus and uterus, ovary, cervix, bones and joints, thyroid, Hodgkin's lymphoma, myeloma, testis, and stomach [9].

Birth Defects

Citizens living in Section 3 were concerned about a possible excess of birth defects among residents of the subdivision. The Texas Birth Defects Registry evaluated the occurrence of 48 specific types of birth defects among deliveries during 1999 through 2003 to women who lived in zip code 77040 at the time of delivery. The prevalence data were compared to prevalence data for Texas during the same time period. None of the types of birth defects examined were elevated among residents in that area compared to Texas overall. Additionally, for half of the types of birth defects examined, no cases were reported during this time period. The number of infants and fetuses with any birth defects was lower among residents of this area compared to Texas overall [10].

Child Health Considerations

In communities faced with air, water, or food contamination, children could be at greater risk than are adults from certain kinds of exposure to hazardous substances. A child's lower body weight and higher intake rate result in a greater dose of hazardous substance per unit of body weight. Sufficient exposure levels during critical growth stages can result in permanent damage to the developing body systems of children. Children are dependent on adults for access to housing, for access to medical care, and for risk identification. Consequently, adults need as much information as possible to make informed decisions regarding their children's health.

We evaluated whether children living in Section 3 would be likely to be exposed to site contaminants at levels of health concern. We evaluated the potential risk to children by using conservative exposure scenarios – scenarios where the exposures are likely to be much higher than those children might actually experience. These evaluations were included in each discussion section.

Conclusions

1. Shallow groundwater in the area is not used for drinking or other household purposes. Therefore, there is **no public health hazard** associated with direct contact with groundwater in the area of the former Delroc Oil Refinery.
2. Dibromochloromethane exceeded the CREG in one public water supply system sample. However, estimated exposure doses were below the MRL, and there was no increased risk for developing cancer due to exposure to the levels of dibromochloromethane measured in that public water supply. Therefore, there is **no apparent public health hazard** from direct contact with drinking water.
3. Although several metals exceeded screening values in the soil and sediment, concentrations of these metals were within the ranges of normal background levels for this part of the United States and below levels that have been shown to cause adverse health effects.

BaP was used as a surrogate to assess the relative toxicity of PAHs in sediment and soil. Estimated exposure doses for BaP TEQs were well below the NOAEL and LOAEL for BaP, and there was no apparent increased risk for developing cancer due to exposure to PAHs.

Therefore, there is **no apparent public health hazard** from direct contact with soil and sediment.

4. Based upon the data reviewed in this document, direct contact with media at the former Delroc Oil Refinery poses **no apparent public health hazard** for residents of Section 3 of the Woodwind Lakes Subdivision.
5. Because of a lack of data, the vapor intrusion pathway poses an **indeterminate public health hazard**.
6. The Texas Cancer Registry found the occurrence of specific cancers in the area to be within expected ranges based upon state cancer rates.
7. The Texas Birth Defects Registry found no elevations in the occurrence of birth defects compared to Texas overall.

Recommendations

We recommend the TCEQ conduct soil gas analysis in Section 3 to fully assess the vapor intrusion pathway.

Public Health Action Plan

Actions Completed

1. The DSHS evaluated contaminant data from soil, sediment, and groundwater samples collected in June 2006 from the former Delroc Oil Refinery/Woodwind Lakes Subdivision.
2. Texas Cancer Registry completed analysis of cancer incidence data for zip code 77040, Houston, Texas, from January 1, 1995 through December 31, 2003.
3. Texas Birth Defects Registry completed analysis of birth defect prevalence data for zip code 77070, Houston, Texas during 1999 through 2003.

Actions Planned

The DSHS will review soil gas data when it becomes available.

Authors, Technical Advisors, and Organizations

Report Prepared by

Carrie M. Bradford, MS, PhD

Toxicologist

DSHS Health Assessment & Toxicology Program

Susan Prosperie, MS, RS

Manager

DSHS Exposure Assessment & Surveillance Group

John F. Villanacci, PhD, NREMT-I

Principal Investigator/Manager

DSHS Environmental & Injury Epidemiology and Toxicology Branch

Jennifer Lyke

Regional Representative

ATSDR Region 6

George Pettigrew, PE

Senior Regional Representative

ATSDR Region 6

Jeff Kellam

Environmental Health Scientist

Division of Health Assessment and Consultation

Cooperative Agreement Program Evaluation Branch

References

1. Texas Commission on Environmental Quality. Preliminary Assessment/Screening Site Inspection Workplan. Delroc Oil Refinery, Houston, Harris County, Texas. July 2006.
2. Railroad Commission of Texas. Site Investigation Report. Woodwind Lakes Section 3, Houston Texas. September 2003.
3. Correspondence. Carrie Bradford, Toxicologist, Texas Department of State Health Services to Robert Musick, Project Manager, Texas Commission on Environmental Quality. November 2, 2006.
4. The Risk Assessment Information System. Toxicity and Chemical-Specific Factors Data Base. Carbazole. Available at http://risk.lsd.ornl.gov/cgi-bin/tox/TOX_9801. Last accessed May 24, 2006.
5. Environmental Protection Agency Region 9. Preliminary Remediation Goals. Available at <http://www.epa.gov/region09/waste/sfund/prg/index.html>.
6. Agency for Toxic Substances and Disease Registry. Public Health Assessment Guidance Manual. 1992.
7. Agency for Toxic Substances and Disease Registry. Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs). Atlanta: US Department of Health and Human Services. August 1995.
8. Environmental Protection Agency. Office of Solid Waste and Emergency Response Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance). 2002. Available at <http://www.epa.gov/correctiveaction/eis/vapor.htm>.
9. Texas Cancer Registry. Texas Department of State Health Services. Summary of Investigation into the Occurrence of Cancer, Zip Code 77040, Houston, Harris County, Texas, 1995-2003. December 20, 2006.
10. Electronic Correspondence. Mary Ethen, Epidemiologist, Texas Birth Defects Registry, Texas Department of State Health Services. January 9, 2007.
11. Nisbet ICT and LaGoy PK. Toxic Equivalency Factors (TEFs) for Polycyclic Aromatic Hydrocarbons (PAHs). Regulatory Toxicology and Pharmacology. 16: 290-300 (1992).

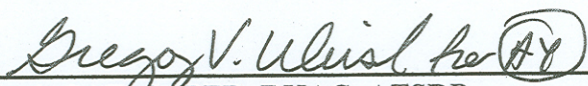
Certification

This public health consultation on Former Delroc Oil Refinery/Woodwind Lakes Subdivision, Houston, Harris County, Texas was prepared by the Texas Department of State Health Services under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methods and procedures existing when the time the public health consultation was initiated. Editorial review was completed by the Cooperative Agreement partner.



Technical Project Officer, CAT, CAPEB, DHAC, ATSDR

The Division of Health Assessment and Consultation, ATSDR, has reviewed this public health consultation and concurs with its findings.



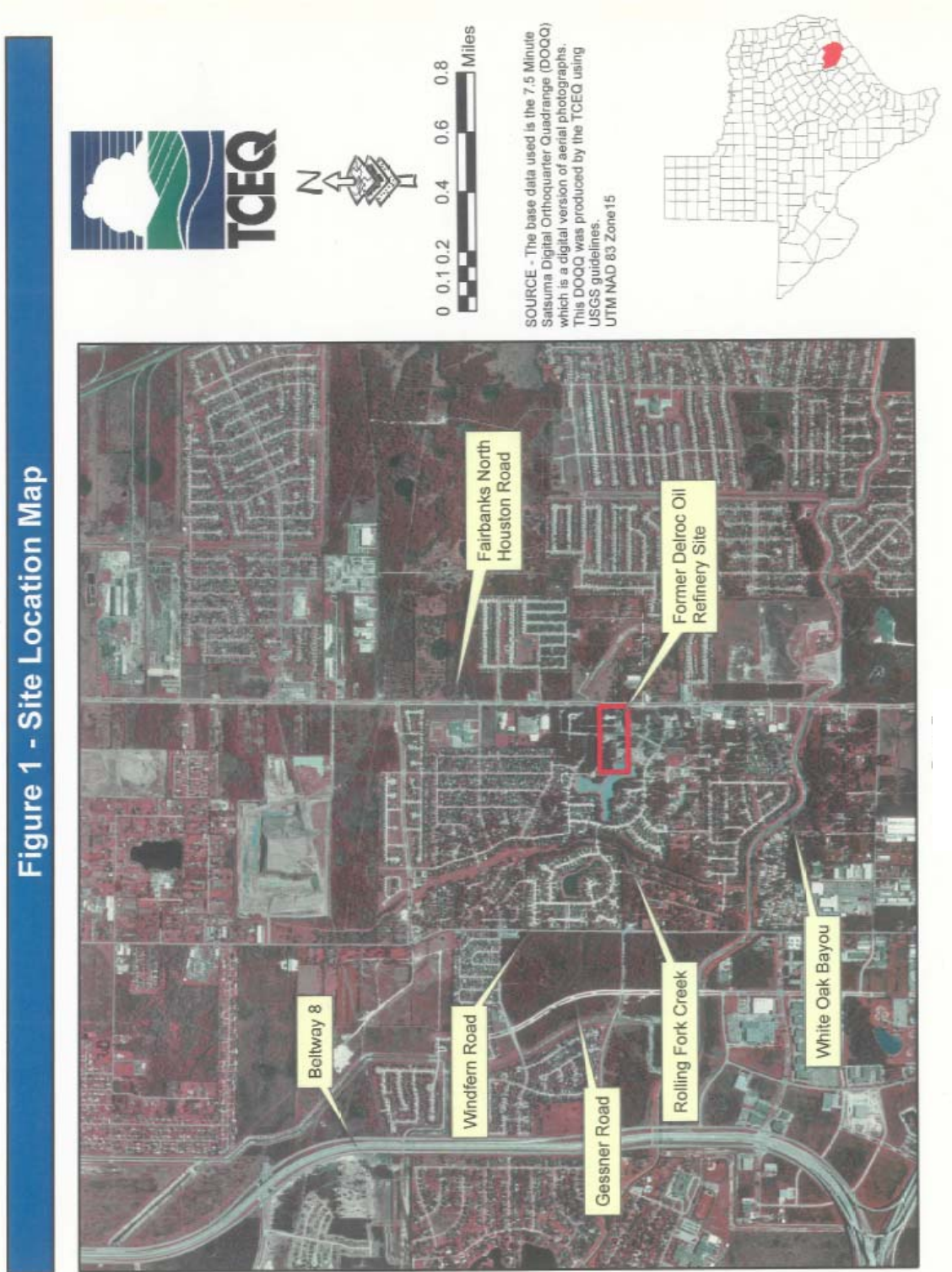
Team Lead, CAT, CAPEB, DHAC, ATSDR

Appendix A: Acronyms and Abbreviations

ATSDR	Agency for Toxic Substances and Disease Registry
BaP	benzo[a]pyrene
bgs	below ground surface
CREG	Cancer Risk Evaluation Guide
CSF	Cancer Slope Factor
Delroc	former Delroc Oil Refinery Site
DSHS	Texas Department of State Health Services
EMEG	Environmental Media Evaluation Guide
EPA	Environmental Protection Agency
g	gram
HAC	Health-Based Assessment Comparison
kg	kilogram
L/day	liters per day
LOAEL	Lowest Observable Adverse Effect Level
mg	milligram
mg/day	milligram per day
mg/kg	milligram per kilogram
mg/kg/day	milligram per kilogram per day
MRL	Minimal Risk Level
NOAEL	No Observable Adverse Effect Level
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
RfD	Reference Dose
Section 3	Section 3 of the Woodwind Lakes Subdivision
SVOC	Semivolatile Organic Compound
TCEQ	Texas Commission on Environmental Quality
TEF	Toxic Equivalency Factor
TEQ	Toxic Equivalent
TPH	Total Petroleum Hydrocarbon
µg/L	microgram per liter
VOC	Volatile Organic Compound

Appendix B: Figure

Figure. Location of former Delroc Oil Refinery in Houston, Harris County, Texas [1].



Appendix C: Tables

Table 1. Toxic Equivalency Factors (TEF) for PAHs [11].

PAH	TEF
Acenaphthene	0.001
Acenaphthylene	0.001
Anthracene	0.01
Benzo(a)anthracene	0.1
Benzo(a)pyrene (BaP)	1
Benzo(b)fluoranthene	0.1
Benzo(g,h,i)perylene	0.01
Benzo(k)fluoranthene	0.1
Chrysene	0.01
Dibenzo(a,h)anthracene	5
Fluoranthene	0.001
Fluorene	0.001
Indeno(1,2,3-cd)pyrene	0.1
2-Methylnaphthalene	0.001
Naphthalene	0.001
Phenanthrene	0.001
Pyrene	0.001

Table 2. Contaminants that exceeded HAC values in drinking water samples. All other compounds were below the detection limit or, if detected, below the HAC value.

Contaminant	Concentration Range (µg/L)	# Detected/ # Samples Collected	# Samples that exceed HAC value	HAC value (µg/L)
Dibromochloromethane	ND-0.82	1/8	1	0.4 (CREG)
Iron	ND-348	2/6	1	300 (EPA Secondary Standard) ^a

ND – Not Detected

^a EPA Secondary Standards are based upon the aesthetic quality of drinking water and are not indicators of a potential public health threat.

Table 3. Contaminants that exceeded HAC values in soil samples. All other compounds were below the detection limit or, if detected, below the HAC value.

Contaminant	Concentration Range (mg/kg)	# Detected/ # Samples Collected	# Samples that exceed HAC value	HAC value (mg/kg)
Aluminum	1,740-12,700 ^a	18/18	12	4,000 (intermediate EMEG pica child)
Arsenic	ND-9.5 ^a	15/18	15	0.5 (CREG) ^b 20 (chronic EMEG child)
BaP TEQ	ND-1.35	5/18	5	0.1 (CREG)
Vanadium	2.1-19 ^a	18/18	14	6 (intermediate EMEG pica child)

ND – Not Detected

^a Contaminant concentrations are within the ranges of background concentrations for this area [6].

^b The CREG for arsenic in soil (0.5 mg/kg) is below background levels, so the recommended soil CV is 20 mg/kg.

Table 4. Contaminants that exceeded HAC values in sediment samples. All other compounds were below the detection limit or, if detected, below the HAC value.

Contaminant	Concentration Range (mg/kg)	# Detected/ # Samples Collected	# Samples that exceed HAC value	HAC value (mg/kg)
Arsenic	ND-4.1 ^a	2/5	2	0.5 (CREG) ^b 20 (chronic EMEG child)
BaP TEQ	ND-1.29	1/5	1	0.1 (CREG)

ND – Not Detected

^a Contaminant concentrations are within the ranges of background concentrations for this area [6].

^b The CREG for arsenic in soil (0.5 mg/kg) is below background levels, so the recommended soil CV is 20 mg/kg.