Site: Pine St.
Break: 3.4
Other: 463428

EPA CONTRACT NO. 68-W9-0036

EPA WORK ASSIGNMENT NO. 03-1L19

EPA Project Manager: Nancy Barmakian
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TECHNICAL MEMORANDUM

REVIEW OF PINE STREET CANAL SITE INFORMATION AND CONTAMINANT INFORMATION

PINE STREET CANAL SUPERFUND SITE
BURLINGTON, VERMONT

JUNE, 1990

Prepared by

METCALF & EDDDY, INC.

TASK 2

REVIEW OF SITE INFORMATION

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TASK 2 REVIEW OF SITE INFORMATION

2.0 Introduction

The purpose of Task 2 is to summarize the pertinent site information based on historical data and site investigations performed to date. This information includes a brief background of the site (including site history and ownership), a synopsis of the existing contaminant data, and a characterization of the ecological features of the Pine Street site. The approach to the biological assessment conducted by Metcalf & Eddy, Inc., involves a comparison of ecological characteristics at the Pine Street site to ecological characteristics at a similar reference site. This memorandum presents a general ecological overview of a potential reference site at Mallet's Creek. Future reconnaissance studies are intended to further evaluate and validate the suitability of the Mallet's Creek area as a reference site.

This Task also includes a brief discussion of "applicable or relevant and appropriate requirements" which may be pertinent to future remedial actions at the Pine Street site. Both federal and state regulations are discusses.

The Pine Street Canal site is an uncontrolled hazardous waste site located on the shore of Lake Champlain in Burlington, Vermont (Figure 1). The entire site covers approximately 60 acres,

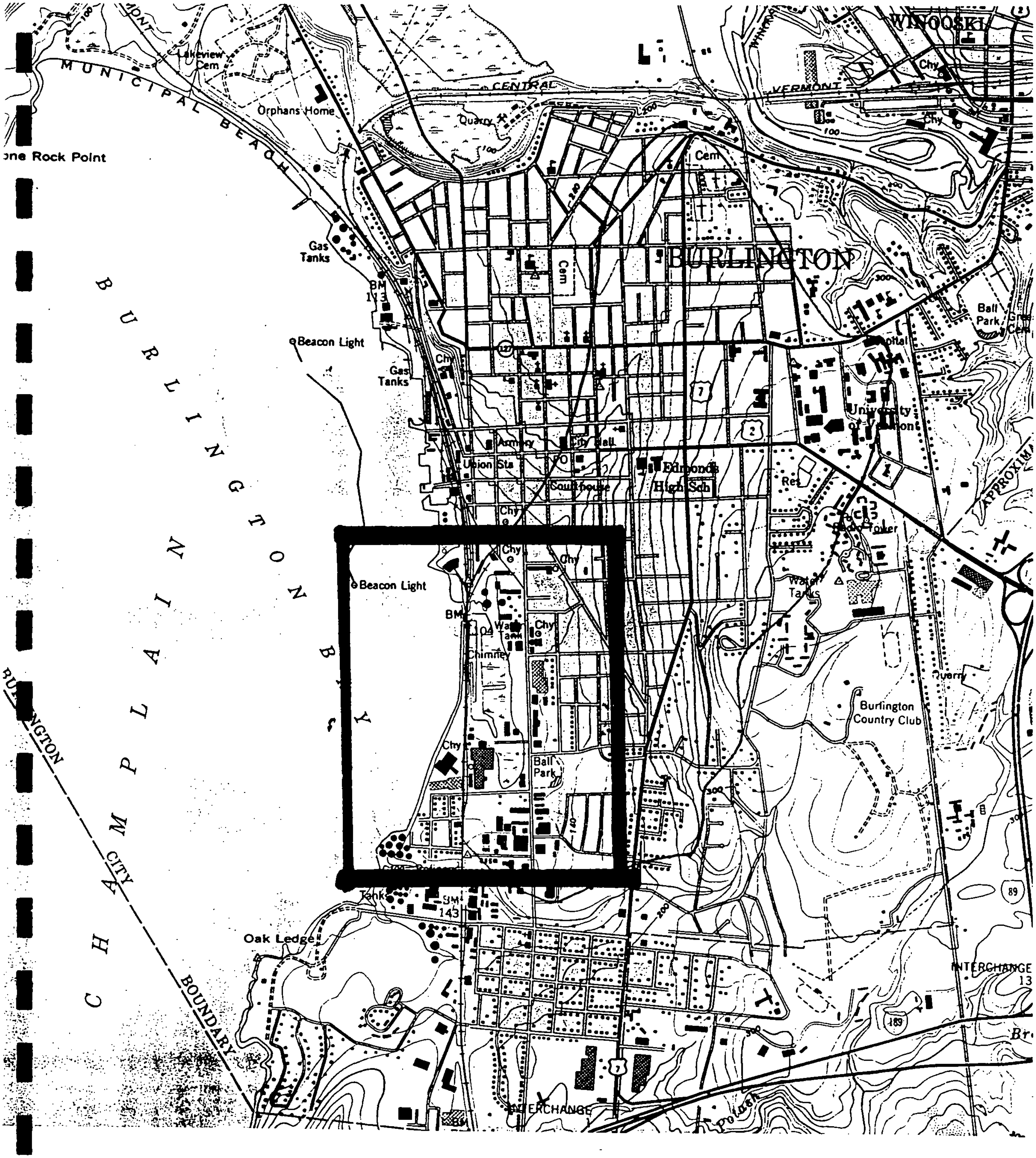

Figure 1. Location of the Pine Street Canal, Burlington, Vermont.

although the contamination appears to be concentrated in the canal itself and in the eleven acres of wetland surrounding it (PEER, 1989). The site is bounded by the Vermont Central Railroad to the west, Lakeside Avenue to the south, Pine Street to the east, and the property line of Ultramar Petroleum to the north. Access to the site is largely unrestricted by fences or other obstructions. Portions of the site have recent evidence of trash dumping, campfires, and fishing, indicating that the site is frequently used by local residents.

2.1 Site History

The following chronology of activities at the site was assembled by E & E (1982) from information provided by the Vermont Agency of Environmental Conservation (AEC), the Vermont Agency of Transportation (AOT), and the Vermont Department of Health.

The Pine Street Canal was constructed in the mid-1800s to provide shipping access to several sawmills and lumber yards located along Pine Street. Various piers and wharves were used by barges carrying lumber to and from the mills (PEER, 1989).

In 1908 the Burlington Gas Works moved from downtown Burlington to a location adjacent to the Pine Street Canal. The Gas Works then began to manufacture carburetted water gas at that location. In this process, heated coal is reacted with steam to produce carbon monoxide and hydrogen. Fuel oil is added to the hot gas, which increases the BTU value of the gas so it may be used for heating and other domestic and commercial uses. From 1908 to 1949 liquid waste materials from the plant were directly discharged to the canal, and solid wastes from the plant were disposed of in the wetlands. Waste materials consisted of emulsified tars and oils, tar sludges, and tar saturated wood chips. Following 1949, the heavy tar fractions of the waste material from the gasification plant were reclaimed and sold for use as roofing tar and asphalt (E & E, 1982).

In the 1960s production of petroleum gas from coal was largely abandoned in the U.S. because it could not compete economically with natural gas. Vermont Gas Systems (formerly Burlington Gas Works) ceased operations in 1966 and most likely dismantled the Pine Street coal gasification plant sometime before 1970. In 1966 a drainage ditch that ran from the coal gasification plant to the canal was plugged (E & E, 1982).

Fuel-oil distributors (Green Mountain Petroleum and Citizens Oil Company) have operated on the northern portion of the site since 1948. These distributors store oil in large cylindrical tanks on the site. At least one spill has occurred in the last decade as a result of improper oil transfer (PEER, 1989).

Between 1966 and 1975, a number of spills of oil-like material into the Pine Street Canal and Lake Champlain were reported to the U.S. Coast Guard and the Vermont Department of Water Resources. The causes of the spills were not identified. Possible sources of the spills include the Gas Works drainage ditch, the City of Burlington sanitary storm/sewer overflow, and other drainage culverts flowing into the canal from near the St. Johnsbury Trucking company. In 1969 the Vermont Department of Natural Resources recommended a tentative plan for remedial clean up of the site. Options for constricting the canal contaminants to the site included construction of a permanent metal boom or earthen barrier across the canal outlet. Complete removal of oil-saturated soil from the site was also suggested.

In 1972, in response to inquiries from the state Assistant Attorney General concerning drainage onto the site, the Burlington City Engineer and Superintendent of Streets reported that sanitary sewage from a paint-manufacturing plant on Lakeside avenue was leaching into the upstream wetlands south of the canal. Sanitary sewage from the St. Johnsbury Trucking Company was also found to be entering the canal (E & E, 1982).

In the summer of 1977, wetland property owned by the Whiting Company on the northern portion of the site was filled. In the process, approximately 1500 gallons of oily material was discharged into the turning basin.

From 1978 to 1980, the Vermont Agency of Transportation (AOT) and the Vermont Agency of Environmental Conservation (AEC) coordinated studies for the Environmental Impact Statement for the proposed Interstate 89 extension. The agencies concluded that between 150,000 and 200,000 cubic yards of organic material, much of which was contaminated, would have to be removed from the site and replaced with granular fill.

In 1981 the U.S. EPA conducted a site inspection of the Pine Street Canal. As a result of the inspection the site was given a Hazard Ranking Score of 34.64 and placed on the National Priority List (PEER, 1989). It is currently Vermont's top-priority Superfund site. Later in 1981 the Vermont AEC released an evaluation of the site that described an encapsulation and solidification treatment process for the coal-tar sludge. AEC concluded that the coal tar on the bottom of the canal was up to 10 feet thick and should be blanketed by an impermeable cover of bentonite clay. AEC recommended construction of a grout wall to contain contaminants in the Pine Street wetlands.

In 1985 EPA Region I conducted an emergency removal action at the site. Approximately 500 cubic yards (1,477 tons) of contaminated material were removed from Maltex pond (PEER, 1989). Seventeen potentially responsible parties (PRPs) were identified, including the City of Burlington, State of Vermont, manufacturing companies, utility companies, and individuals (see Attachment 1). Since the removal, the pond has been reestablished with native vegetation (Typha and Phragmites spp.).

2.2 Site Ownership (as of 1982)

The following ownership and residence patterns existed on the site in 1982. The southeast corner of the site was owned and occupied by the City of Burlington Electric Light Department. This parcel includes part of the site the former coal gasification plant. The undeveloped area in the south-central portion of the site was owned by the C.S. Blodgett Company and also includes portions of the former coal gasification plant site. The undeveloped area in the central portion of the site was owned by Christine E. Farrell. The north-central portion of the site, immediately southeast of the turning basin, was owned by Vermont Development Credit Corporation and leased by Green Mountain Industries, a furniture manufacturer. The parcel immediately east of the turning basing was owned by the Louis E. Farrell Estate and leased by the Pepsi Cola Bottling Company. The Citizens Oil Company owned and occupied the parcel immediately north of the Pepsi plant. The parcel immediately north of the turning basin was owned and occupied by Green Mountain Petroleum Co. The northwestern portion of the canal was owned by Herman E. Warner, who purchased the property with the intention of developing it into a marina.

2.3 Review of Contaminant Data

The major contributor to contaminants on the site was the coal gasification plant. Discharge from the plant resulted in organic contamination of ground water, surface water, sediment, and soil. Contamination has been found in all four of these media. The heaviest contamination has been observed in the area of the old gasification plant, the wetland, and the canal.

2.3.1 Results of Past Studies

Several attempts have been made to characterize the extent of contamination on the site. The first major investigation was undertaken in the late 1970's by E.C. Jordan, as part of comprehensive site surveys in preparation of the I-89 extension environmental impact statement. Numerous soil borings, test pits, and monitoring wells were placed within the proposed highway right of way. Twenty-one PVC monitoring wells were installed in eleven locations.

From 1978 to 1980 the Vermont AOT and AEC performed analytical tests of soils and groundwater. Soil borings indicated coal tar contamination in the two boreholes nearest the old coal gasification plant. In 1981 VT DEC performed sampling of water in the turning basin and detected less than 10 ppb of phthalate, esters, anthracene, and saturated hydrocarbons. The maximum on-site contaminant values indicated in past studies are in Tables 1 through 4, originally presented in PEER (1989). No air sampling has been conducted on the site.

In 1982 Ecology and Environment, Inc. conducted a survey of the site and collected water samples from the canal and from Maltex pond and soil samples from several sealed boring cores. These water and soil samples were to be analyzed for organic and volatile compounds. The most recent investigations of contamination at the Pine Street Site were conducted by PEER, Inc. in the fall of 1989. Most analytical results of these investigations were unavailable for review at the time this report was prepared, however.

2.3.2 Recent Investigations

2.3.2.1 Surface Water

Characterization of the extent of contamination to surface waters is important because waterborne contaminants potentially lead to the greatest number of receptors. During periods of heavy runoff, surface flow over the site may carry contaminants into the canal and into Lake Champlain, which serves as the drinking water source for the City of Burlington.

Spills of oils and other materials into the canal and subsequently into Lake Champlain have occurred infrequently since the abandonment of the coal gasification plant in the late 1960s. On

TABLE 1
MAXIMUM CONCENTRATION OF CONTAMINANTS
DETECTED IN SURFACE WATER
PINE STREET CANAL SITE

Parameter	Max. on Site	AWQC[1]	MCL[2]
Volatile Compounds:			
Chloroform	7.6	1.9E-1 (c)	100
Dichloromethane	31	1.9E-1 (c)	
1,1,1-Tricholoroethane	20	18,400 (t)	200
Trans-1,2 dichloroethene	1.0		
Base/Neutral Compounds:			
Bis(2-ethylhexyl)phthalate	D	15,000 (t)	
Diethyl phthalate	22	350,000 (t)	
Di-n-butylphthalate	25	34,000 (t)	
Di-n-octylphthalate	D		
M-nitrosodimethylamine	D		
Acid Compounds:			
2-Methylphenol	23		

All concentrations reported in PPB
D = Detected

NOTES:

[1] Ambient Water Quality Criteria (AWQC) developed under the Clean Water Act. The criteria in this table are for human protection from cancer (10E-6) based on ingestion of organisms and drinking water (c) or are based on human toxicity (t).

[2] Maximum Contaminant Levels (MCL) developed under the Safe Drinking Act.

Source: PEER, 1989.

TABLE 2
MAXIMUM CONCENTRATION OF CONTAMINANTS DETECTED IN SEDIMENT
PINE STREET CANAL SITE

Parameter	Concentrations (ppb dry weight)
Volatile Compounds:	
Benzene	760
Ethylbenzene	770
Dicholoromethane	170
Trichlorofluoromethane	5
Toluene	39
Acetone	69
o-Xylene	320
Polychlorinated Biphenyls:	
PCB-1260	210
Total PCBs	3,200
Acid Compounds:	
2,4,5-Trichlorophenol	D
Pentachlorophenol	D
4-Methylphenol	950
Base/Neutral Compounds:	
Acenaphthene	10,000
Fluoranthene	24,000
Isophorone	480
Naphthalene	35,000
Bis(2-ethylhexyl)phthalate	3,500
Di-n-butyl phthalate	420
Diethyl phthalate	760
Benzo(a)anthracene	970
3,4-Benzofluoranthene	1,900
Benzo(k)fluoranthene	1,900
Chrysene	1,400
Acenaphthylene	D
Anthracene	400
Benzo(g,h,i)perylene	920
Fluorene	400
Phenanthrene	19,000
Indeno(1,2,3-ed)pyrene	920
Pyrene	13,000
Benzoic acid	2,100
Benzo(a)pyrene	370
N-nitrosodiphenylamine	D

D = detected

Source: PEER, 1989.

TABLE 3
MAXIMUM CONCENTRATION OF CONTAMINANTS
DETECTED IN SOIL
PINE STREET CANAL SITE

	Depth in feet			
Parameter	0-5	10-15	15-20	30
Volatiles (ppb):				
Benzene	59,000	65,000	57,000	28,000
Ethylbenzene	110,000	180,000	43,000	40,000
Methylene Chloride		<1,000	3,800	<1,000
Toluene	74,000	110,000	52,000	60,000
Pesticides (ppb):				
Aldrin				140
Dieldrin				500
Heptachlor				140
Base/Neutral Compounds (ppb):				
Acenaphthene	71,000	300,000	130,000	91,000
Fluoranthene	28,000	140,000	82,000	79,000
Naphthalene	540,000	1,000,000	840,000	400,000
Benzo(a)anthracene	34,000	66,000	83,000	39,000
Benzo(a)pyrene	16,000	49,000	44,000	37,000
3,4-Benzofluoranthene	10,000	23,000	34,000	25,000
Benzo(k)fluoranthene	10,000	23,000	34,000	25,000
Chrysene	34,000	66,000	83,000	39,000
Acenaphthylene	10,000	170,000	130,000	170,000
Anthracene	140,000	740,000	590,000	620,000
Benzo(g,h,i)perylene		trace		
Fluorene	48,000	180,000	170,000	140,000
Phenanthrene	140,000	740,000	590,000	620,000
Indeno(1,2,3-ed)pyrene	trace	trace		trace
Pyrene	40,000	140,000	120,000	83,000

Source: PEER, 1989.

TABLE 4
MAXIMUM CONCENTRATION OF CONTAMINANTS
DETECTED IN GROUND WATER
PINE STREET CANAL SITE

Parameter	Max Onsite	Clean Water Act AWQC[1]	Safe Drinking Water Act MCL[2]	Safe Drinking Water Act MCL Goal	Vermont Primary Ground Water Quality Standards Enforcement Standard	Vermont Primary Ground Water Quality Standards Preventive Action Limit	Vermont Drinking Water Quality Regulations
Volatile Compounds:							
Benzene	3,900	6.7E-1(c)	5	0	5.0	0.5	
Bromodichloromethane	6	1.9E-1(c)	100[3]				100
Chloroform	50	1.9E-1(c)	100[3]				100
Cyclopentane	D						
Dichloromethane	17				5.0	0.5	
Ethylbenzene	13,000	2,400(t)		680[4]	680	340	
Pentane	D						
Toluene	6,500	15,000(t)		2,000[4]	2,420	1,210	
1,1,2,2-Tetrachloroethane	5	1.7E-1(c)					
1,1,1-Trichloroethane	2	19,000(t)	200	200	200	100	
Trichlorofluoromethane	2	1.9E-1 (c)					
Total Trihalomethanes	56	1.9E-1(c)	100[3]				100
Xylenes	15,000			440	200		
Base/Neutral Compounds:							
Acenaphthene	27,000	3.1E-3(c)					
Acenaphthylene	88,000						
Anthracene	350,000						
Benzo(b) fluoranthene	19,000	3.1E-3(c)					
Benzo(k) fluoranthene	58,000	3.1E-3(c)					
Benzo(a)pyrene	60,000	3.1E-3(c)					
Chrysene	94,000	3.1E-3(c)					
Fluoranthene	140,000	42(t)					
Fluorene	260,000	3.1E-3(c)					
Naphthalene	710,000						
Pyrene	160,000	3.1E-3(c)					

All results reported in PPB

D = Detected

NOTES:

[1] Ambient Water Quality Criteria (AWQC) developed under the Clean Water Act. Quantitatively assess levels of pollutants in water which will ensure water quality adequate to support a specified use. The criteria in this column are for human protection from cancer (10E-6) based on ingestion of drinking water (c) or from toxicity (t).

[2] Maximum Contaminant Levels (MCL)

[3] MCL Values for Bromodichloromethane, Chloroform (Trichloromethane), and Trichlorofluoromethane are expressed as Total Trihalomethanes (100 ppb).

[4] MCLGs for Ethylbenzene, Toluene, and Xylene are proposed and not finalized.

Source: PEER, 1989.

several occasions site inspections have revealed the presence of an oil sheen on the canal; at times a visible sheen could be produced by walking on the wetlands along the shore of the canal (PEER, 1989a). In 1981 the Vermont AEC performed water sampling in the turning basin and determined the presence of trace amounts of organic contaminants, including breakdown products of PAHs. Of the ten compounds detected in site surface waters, only two (chloroform and trans-1,2 dichloroethane) are assigned values for freshwater acute or chronic toxicity in the EPA Quality Criteria for Water (EPA, 1986) For both chloroform and trans-1,2 dichloroethane, values listed in the Criteria are lowest observable effect levels (LOEL). Data was insufficient to develop formal criteria. Detected concentrations of both chloroform and trans-1,2 dichloroethane were well below the acute and chronic exposure LOELs for aquatic life.

One adverse human health effect from exposure to canal waters has been documented. A person who reported falling into the turning basin apparently developed a rash and became ill. No follow up observations were recorded (PEER, 1989).

The southern portion of the site has periodically received discharges from a sanitary sewer outfall. Discharge into the southern end of the canal by sewer outfalls is evident in 1972 aerial photos.

The most recent water sampling program was conducted by PEER in 1989. According to the results of these samples, there are significant levels of inorganics and relatively low levels of volatiles and semi-volatiles in onsite surface waters. These results indicate that surface waters do not appear to retain volatiles and that the semi-volatiles present are relatively insoluble in water. Adjacent Lake Champlain waters do not appear to contain elevated levels of toxic compounds, although low levels of volatiles and semi-volatiles were detected (PEER, 1990a).

2.3.2.2 Ground Water

The most recent investigations of soil contamination were conducted by PEER, Inc. in 1989, although most analytical results were not available during the preparation of this report. Coal tar residue was visually observed in 13 of 23 soil borings. The areas exhibiting coal tar residues correspond closely to the former coal gasification complex, the area west of the plant, and the southern portion of the canal (PEER, 1990c). According to investigations by E & E (1982), groundwater underlying the site contains elevated levels of benzene, toluene, and ethylbenzene, three aromatics present in fossil fuels. These compounds do not appear in samples of the surface water samples, however. The presence of these three compounds in ground water but not in surface water suggests that the compounds have volatilized from surface waters (E & E, 1982).

2.3.2.3 Sediments

Many of the semi-volatiles and inorganics at the Pine Street Canal are likely to accumulate in sediments because semi-volatiles and inorganics generally have a high rate of adsorption onto sediments. A number of sediment samples have been analyzed, both in the canal and in Lake Champlain. The most recent sampling was performed by PEER, Inc. in 1989. All sediments sampled in the canal were dark black, malodorous, and left a sticky residue on sampling equipment. When disturbed, the sediments released emulsified oils, floating oils, and what appeared to be methane bubbles (PEER, 1990a).

According to PEER (1990a), the highest concentrations of organics and semi-volatiles are in sediments in the southern end of the canal, including the wetland in the southwest portion of the site, and in the drainage east of the GE plant. The canal sediments, especially at the southern end, contain visible coal tar product. Also, there appears to be elevated concentrations of contaminants in the wetland drainage area south of Lakeside Avenue, which provides access to the GE plant. The sediments in this area contained higher levels of organics and semi-volatiles than most other portions of the site. The level of contaminants in canal sediments generally declines northward up the canal.

2.3.2.4 Soils

Surface soil investigations conducted by PEER in 1989 indicate that soils between two and six inches throughout the site are contaminants with low levels (0-10 ppb) of volatiles (PEER, 1990b). Most of the substances detected in surface soils are degreasers and industrial solvents. One sample just north of the former coal gasification plant had a relatively high (50 ppb) level of volatiles. Acetone, which has the highest observed concentration of the volatile compounds in the surface soils, may be the result of recent decontamination procedures in conjunction with past site investigations.

In comparison to the rest of the site, three specific areas had high concentrations of semi-volatiles in the surface soil: the site of the former coal gasification plant, about 300 feet north of the former plant, and the area northeast of the turning basin (PEER, 1990b).

The extent of subsurface soil contamination appears to generally resemble the extent of groundwater contamination; the highest contaminant levels are in the area of the former gasification plant, the wetlands immediately west of the plant, and in the canal. Volatiles and semi-volatiles were also detected on the northern part of the site, near the Ultramar gas storage tanks. Volatiles and semi-volatiles detected at this site probably resulted from a fuel oil spill in 1986 (PEER, 1989). Soil contaminants have been estimated to reach a depth of approximately

20 feet throughout the site, and pockets of contaminants have been identified as deep as 36 feet, although few samples have been taken below 30 feet. Prior to the excavation of contaminated material at Maltex Pond, the Vermont AEC and AOT estimated the amount of contaminated fill to be between 10,000 and 20,000 cubic yards (E & E, 1982). During the emergency removal in 1985, approximately 500 cubic yards of material were excavated and removed from the site (PEER, 1989). Perkins Jordan (1984) estimated between 120,000 and 240,000 cubic yards of contaminated soil on site.

The lithology of the site apparently influences the pattern of contaminant dispersion. Soil contaminant levels appear to be highest in the peat rather than in the clay/silt layers above or below, and on most of the site the peat appears to define the lower extent of contaminant dispersion. E & E (1982) determined an area of peat contamination from south to north from the vicinity of the Burlington Gas Light Company and the GE plant to at least the southern boundary of the turning basin. The east-west limits are most likely the western bank of the Pine Street canal and a line approximately 300 feet west of Pine Street. The affected area covers approximately eleven acres.

Pesticides were detected in soils only in the southern part of the site and may be associated with sewer outfalls (PEER, 1990b).

In conclusion, semi-volatiles and inorganics in surface soils appear to be present in higher concentrations than volatiles. Significant concentrations of semi-volatiles were found beneath the former coal gasification plant, in the wetlands west of the site, in the canal, and in the area of the northern barge slip and petroleum storage area. Volatile organics (benzene, toluene, and xylene), pesticides, dioxins, and PCBs do not appear to be present in significant levels in site surface soils.

2.3.2.5 Summary of Contamination Investigations

Results from PEER (1989) investigations indicate that the highest concentrations of contaminants are in the bottom of the canal and in adjacent wetlands, where inorganics and semi-volatiles adhere to and are retained in sediments. The highest concentrations were observed in the sediments of the canal near the wetland area.

2.4 Existing Ecological Information

An examination of the existing ecological conditions at the Pine Street site provides an insight into the possible effects of contaminants on ecological pathways. Similarly, a comparison of ecological parameters at the site to characteristics at a similar, unaltered area can aid in the identification of ecological processes and patterns that are affected by the contaminants at the Pine Street site. A brief analysis of regional wetlands and waters provides additional background on natural conditions in the area. This section briefly summarizes the pertinent ecological information on the Pine Street Canal, on a potential reference site (Mallet's Creek and adjacent wetlands), and on Lake Champlain regional wetlands and waters.

2.4.1 Pine Street Canal Ecological Information

A considerable amount of effort has been directed toward characterizing the ecological conditions of the Pine Street canal and adjoining wetlands, particularly since the listing of the site on the National Priority List in 1981. This section will briefly summarize the existing ecological information on the soils, hydrology, vegetation, wetlands, wildlife, and fisheries of the Pine Street Canal site.

2.4.1.1 Background

The Pine Street Canal and associated wetlands form an isolated ecological community less than a half mile from the center of Burlington. While the site has been dramatically altered by human activity, the cessation of industrial operations on portions of the site within the last two decades has allowed those portions to revert back to a quasi-natural state characterized by early successional vegetation and wildlife adapted to human activity.

2.4.1.2 Soils

The generalized lithology of the site consists of an upper layer of fill, an upper clay/silt layer, a layer of peat, a lower clay/silt layer, a thin cover of gravel or till, and bedrock consisting of fractured sandstones and dolomites (PEER, 1989). Fill varies in depth and composition and is as great as fourteen feet thick. Most of the fill is pebble-rich sand to silty clay, but some gravel, stones, sawdust, pipes, lumber, tires, and other refuse is also included in the fill layer. Much of the fill layer is contaminated with coal tar (PEER, 1989).

The peat layer underlies both the uplands and the canal, but is generally thickest near the center and southern portions of the site. The peat is nearly 100 percent organic and burns when dried. The peat is approximately seven feet thick on average and as great as fourteen feet in several places. Distribution of the peat layer is important because the organic nature of the peat retains many organic contaminants. The ability of the peat to retain contaminants may be beneficial because the peat might tend to restrict further movement of the contaminants through the site and into the environment (PEER, 1989). On the northern portion of the site a five to six foot-thick layer of sand is present directly below the peat (PEER, 1990). Throughout the site bedrock is approximately 140 to 160 feet below the surface (PEER, 1989).

2.4.1.3 Hydrology

The hydrology of the canal and adjacent wetlands is directly influenced by the level of Lake Champlain. During the spring thaw, rising lake levels and snowmelt runoff combine to submerge much of the wetlands adjacent to the canal. The site slopes from an elevation of 108 feet above mean sea level (MSL) at Pine Street to approximately 98 feet above MSL at the canal. The level of Lake Champlain averages 96.6 feet above MSL, but the level of Burlington Bay is periodically and seasonally influenced by runoff from the city (PEER, 1989). Past site inspections have revealed dark high water marks on trees along the canal's edge and on the borders of Maltex Pond (PEER, 1989). Some wetland trees, such as green ash (<u>Fraxinus pennsylvanica</u>) and red maple (<u>Acer rubra</u>), may lose foliage earlier in the fall than others because of fluctuations in water levels (PEER, 1989).

The water in the canal is generally shallow, with depths of less than one foot at the southern end, to two feet in the canal, to as much as ten feet in the turning basin. Most of the canal is approximately 80 to 100 feet wide.

Drainage on the site is poorly developed because of the hummocky topography that resulted from dispersed filling. At least three drainage swales traverse the site and receive runoff from adjacent parking lots and roads. The stream that feeds the southern portion of the site receives runoff from the GE facility and sanitary discharge from the St. Johnsbury Trucking Company.

PEER (1989) concluded that groundwater on the site both discharges to and recharges from Lake Champlain on a seasonal basis; groundwater may recharge the lake during dry periods and be recharged by the lake during wet periods.

The direction of groundwater flow on the site is generally westerly, from Pine Street toward Lake Champlain. The elevation of the water table on the site fluctuates from four to six feet per year (PEER, 1989). The hydraulic conductivity of the lacustrine deposits that underlie the site is generally low. Groundwater movement is therefore probably more lateral than vertical (PEER, 1989). The assumed low conductivity of the lacustrine clays would serve to confine or prevent the percolation of groundwater to bedrock. Estimates on annual groundwater flow through the site range from 255,000 gallons to 5.1 million gallons (PEER, 1989). The linear rate of groundwater flow has been estimated to be between 0.1 and 1.0 feet per year (PEER, 1989). Values of 50 gpd/ft and 0.12 were calculated for the transmissivity and storage coefficient, respectively (PEER, 1989).

Parsons et al (1988) used the U.S. Army Corps of Engineers' Wetland Evaluation Technique (WET 2.0) to perform a functional analysis of the Pine Street wetlands. Several hydrological parameters were evaluated. The results of the WET 2.0 analysis suggest that the wetland is highly effective at providing storm and floodwater conveyance, flood storage capacity, and nutrient retention. The canal is moderately effective at trapping sediments and anchoring the shoreline. WET 2.0 indicates that the wetland is ineffective at both groundwater discharge and groundwater recharge (Parsons, 1988).

2.4.1.4 Vegetation

The vegetation of the Pine Street site is representative of Lake Champlain wetlands and early successional uplands. The site contains an interspersed mix of vegetation types (Figure 2). The dominant wetland types are palustrine emergent and lacustrine unconsolidated bottom (USFWS, no date). Small areas of palustrine forested wetland and palustrine shrub-scrub wetlands are also present. Recent site investigations by Metcalf & Eddy, Inc. indicate vegetation types including those dominated by cattail (Typha) and Phragmites, red maple, and deciduous shrubs and saplings such as red-osier dogwood (Cornus stolonifera), speckled alder (Alnus rugosa), European buckthorn (Rhamnus frangula), and willows (Salix spp.). A large cattail-dominated emergent wetland is at the southwestern portion of the site, and a red maple-dominated forested wetland is primarily on the western edge of the canal. Two palustrine shrub-scrub wetland areas exist on the site; one between the canal and the railroad tracks and the other just

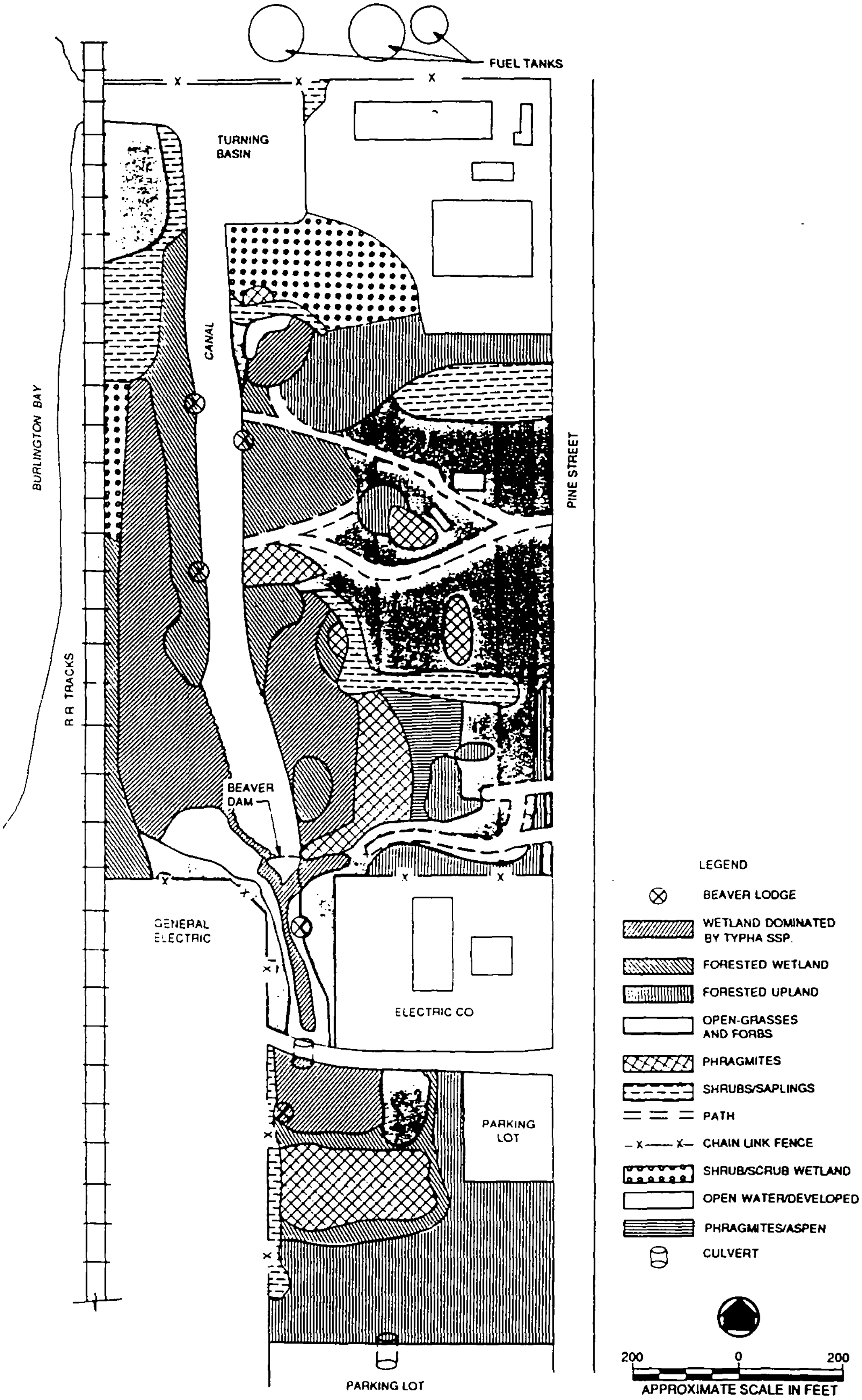

Figure 2. Pine Street Canal Vegetation Zones

north of the former Maltex Pond. A 1988 site visit by EPA revealed that the open portion of the channel has minimal aquatic vegetation (PEER, 1989).

Upland vegetation consists of open areas dominated by grasses and forbs, sparsely forested areas with aspen (Populus tremuloides), black locust (Robinia pseudoacacia), boxelder (Acer negundo), and buckthorn saplings, and large cottonwood (Populus deltoides) and American elm (Ulmus americana) trees.

In 1989 PEER, Inc. conducted a search for buffalo-berry (Shepherdia canadensis) and border meadow rue (Thalictrum venulosum). Both species were classified as rare the Nature Conservancy's Vermont Natural Heritage Program, and the species' ranges were described as encompassing the Pine Street Canal site. Neither species was identified on the site (PEER, 1989). Previous surveys conducted in conjunction with the I-89 Environmental Impact Statement also found no indications of unique or rare flora on the site (FHA, 1977).

2.4.1.5 Wetlands

The exact extent of wetlands on the site has not been determined. At the time the I-89 EIS was completed (1977), the Landscape Engineer for the state Highway Department indicated that the original wetland area comprised approximately 21 acres, but wetlands have since been substantially filled and altered (FHA, 1977). The FHA EIS indicates the current wetland area to be approximately 11.5 acres (FHA, 1977). The USFWS National Wetlands Inventory map of the site depicts the canal and surrounding wetlands as two types: palustrine open water that is intermittently exposed/permanent, and palustrine forested wetland with saturated soils and deciduous trees (Figure 3) (USFWS, no date).

2.4.1.6 Wildlife

The first of two wildlife surveys of the site by Metcalf & Eddy, Inc., was conducted on February 21 and 22, 1990. Species observed during this survey are listed in Attachment 2. Gulls (Larus spp.) were numerous and were constantly observed flying over the site. Mallards (Anas platyrhynchos) and black ducks (Anas rubripes) were observed resting on the southern portion of the canal. Beavers (Castor canadensis) are very active on the site, as evidenced by at least two active lodges and one active dam. One red fox (Vulpes) was observed on the site. Of thirty-five small mammal traps set, only one trap captured a specimen (a deer mouse, Peromyscus manuculatus).

According to PEER (1989), the Pine Street Canal site is a nesting area for black ducks and wood ducks (Aix sponsa), and it is frequented by a number of other birds and small mammals. Birds observed on the site by PEER (1989) include mallards, great blue

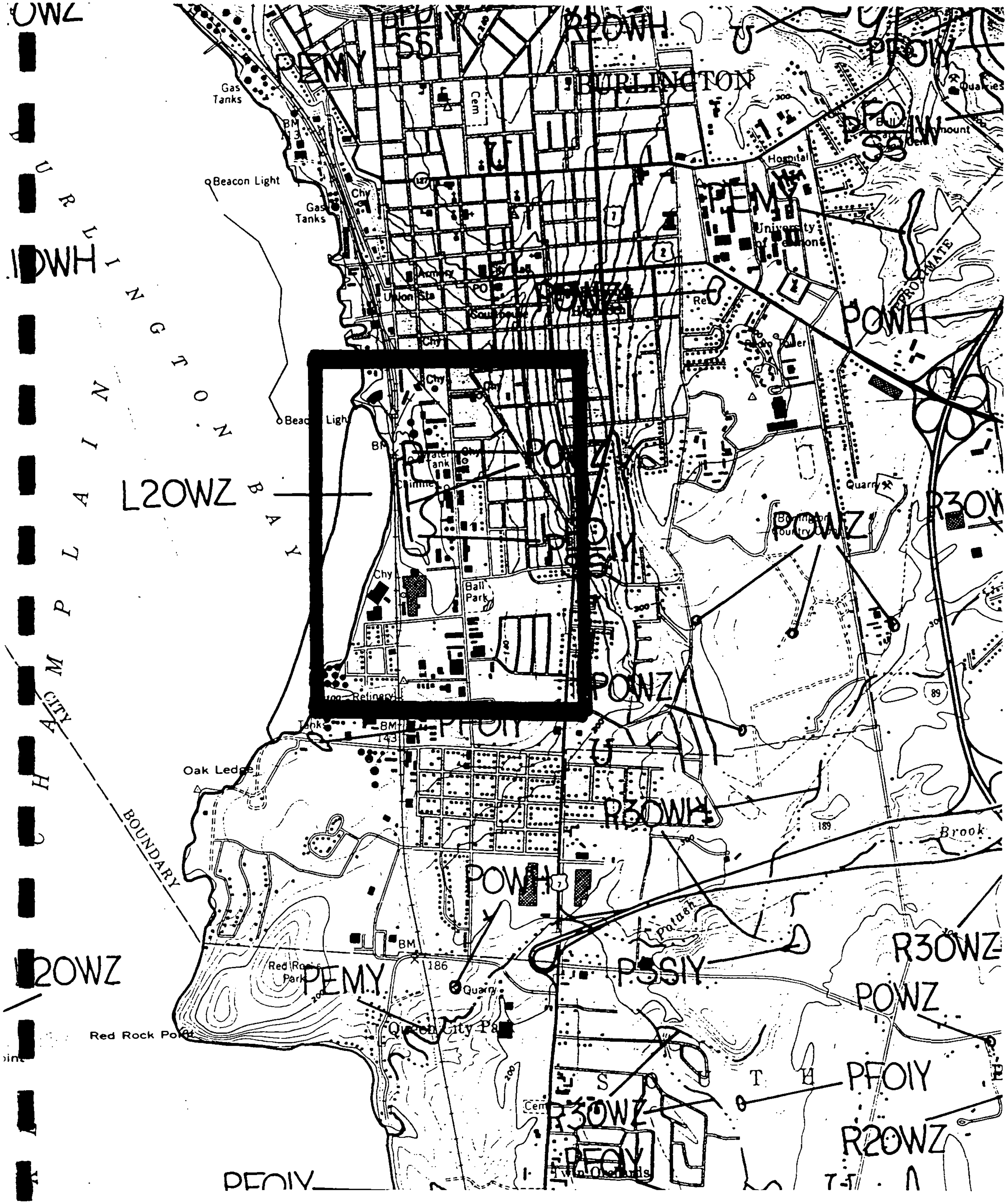

Figure 3. National Wetlands Inventory map of the Pine Street Canal.

herons (Ardea herodias), belted kingfishers (Ceryle alcyon), red-winged blackbird (Agelaius phoeniceus), American kestrel (Falco sparverius), and common grackle (Quiscalus quiscula). Beavers, woodchucks (Marmota monax), raccoons (Procyon lotor), and a dead red fox were also observed on the site. A 1988 site inspection by the EPA indicated that the canal bank had evidence of active runways for burrowing animals. Parsons (1988) indicated that the canal and adjoining wetlands are used by beaver, muskrat (Ondatra zibethicus), waterfowl, Goshawks (Accipiter gentilis), shorebirds, herons, and other water dependent species.

Parsons (1988) performed a wildlife functional analysis of the Pine Street Canal and associated wetlands using the USFWS Habitat Evaluation Procedures (HEP). As part of the analysis, the value of the wetland for providing habitat for several wildlife species was assessed. Potential habitat was calculated by multiplying habitat values by the number of acres in each habitat type. Predicted habitat values were then calculated by evaluating the present habitat conditions. Muskrat received a rating of 30 (potential 110), ground-nesting waterfowl 45 (potential 110), and cavity nesters 52 (potential 110), general wildlife habitat 87 (potential 105).

2.4.1.7 Fisheries

In coordination with the Federal Highway Administration I-89 EIS, the Vermont AEC indicated that the Pine Street Canal is important as a spawning area to fish. PEER (1989) conducted fish sampling by gillnetting in the Pine Street Canal. Five species were caught in the canal: rock bass (Ambolitis rupestris), northern pike (Esox lucious), yellow perch (Perca flavescens), chain pickerel (Esox niger), and golden shiner (Notemigonus crysoleucas). Golden shiners were the most abundant fish in the sample. All rock bass netted in the canal had a circular reddish growth, probably a bacteria, near the caudal peduncle (PEER, 1989).

2.4.1.8 Unique Areas

In support of the I-89 Connector EIS, the Fragile Area Map of Chittenden County, in the Land Capability map series published by the Vermont State Planning Office, identified no area of special or unusual ecological interest in the project area (FHA, 1977). No rare, threatened or endangered species were identified on the site by Parsons (1988), and the site was not considered to contain any unique communities. The State Archaeologist conducted a field reconnaissance of the project area and found no significant archeological artifacts (PEER, 1989).

2.4.2 Mallet's Creek

A number of studies have been conducted on the waters and wetlands of Mallets Creek. This area was selected as a reference site for comparison to the Pine Street site because of the similarities in physiographic and ecological parameters (Figure 4). The following is a brief synopsis of some of the available ecological information on Mallet's Creek and the adjacent Mallet's Bay.

2.4.2.1 Benthic Invertebrates

Invertebrate populations in Mallet's Bay are typical of deep water lakes of the glaciated regions of North America. The populations provide an indication of a typical invertebrate species composition in an unaffected area of Lake Champlain. The inner bay, adjacent to Mallet's Creek, is dominated by Chironomidae, with Oligochaeta and Sphaeriidae also important taxa. The oligochaete fauna of the inner bay is dominated almost exclusively by immature capilliform species (Myer and Gruendling, 1979). The density of invertebrate organisms is significantly higher in the shallow areas of Mallets Bay than in deeper areas, except where the substrate is bedrock. Other information in Myer and Gruendling (1979) includes species composition data for outer Mallets Bay and seasonal species distributions in relation to dissolved oxygen concentrations.

2.4.2.2 Wetlands

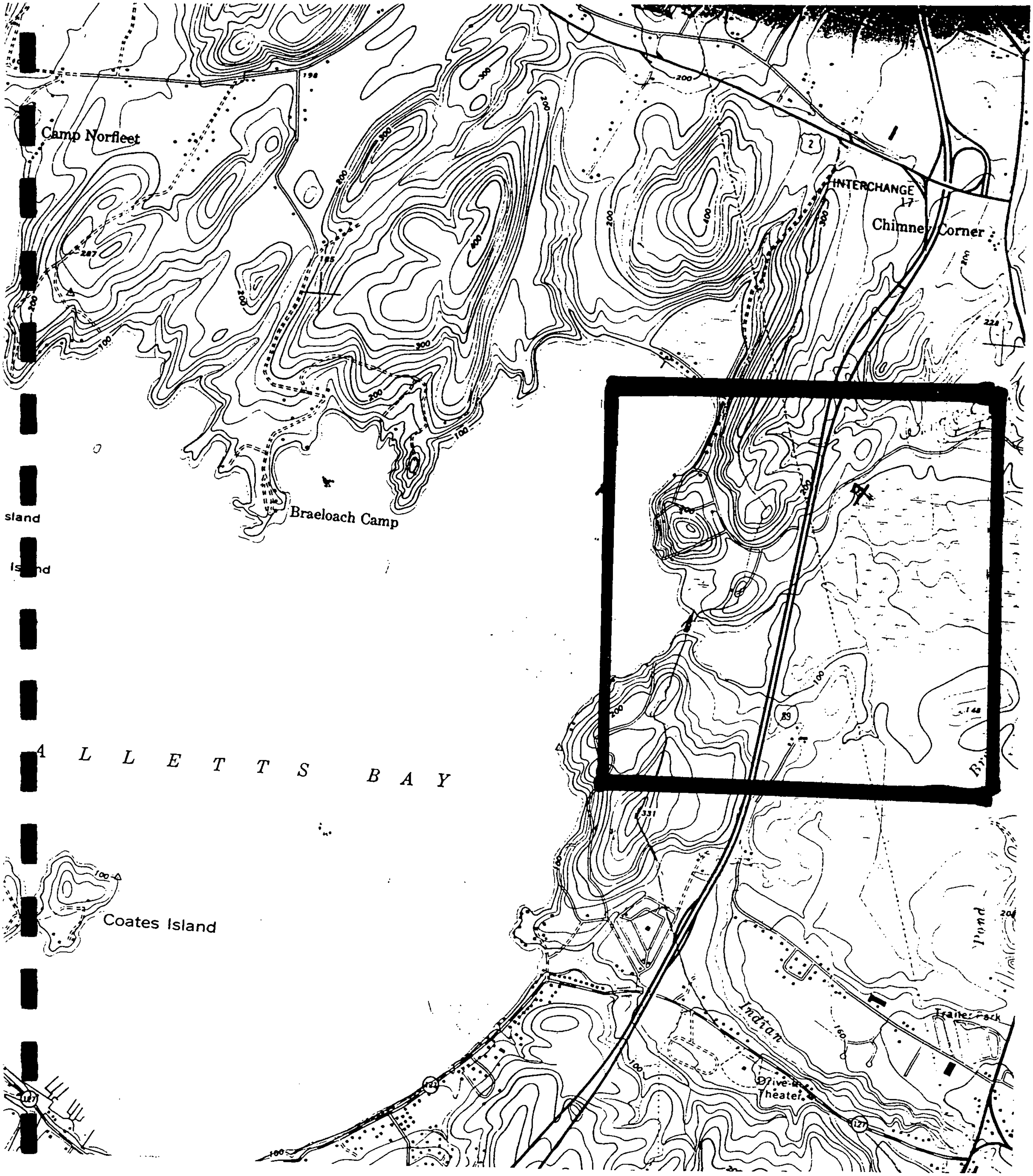

Figure 4. Location of Mallet's Creek and Mallet's Bay, Vermont.

Wetlands in Mallet's Creek are characterized by spatial interspersion of emergent vegetation, forested areas, and open waters. Four streams, totaling about 5.5 miles in length, traverse the wetland. The eastern portion of the Creek is generally dominated by deciduous trees, and the western portion is dominated by emergent vegetation. Forested areas comprise about 30 percent of the acreage and are located on the levees of the tributaries and adjacent to the upland habitats (Gruendling and Bogucki, 1979). Approximately 25 percent of the area consists of dispersed fields and pastures located along the edge of the wetland, creating excellent "edge" habitat that provides interspersion between habitat types. Emergent vegetation comprises 35 percent of the total wetland acreage (Gruendling and Bogucki, 1979). Typical emergent plants include reed canary grass (Phalaris arundinacea), burreed (Sparganium eurycarpum), cattail (Typha angustifolia), and horsetail (Equisetum spp.). During growing seasons with high water levels, wild rice (Zizania aquatica) is included in the emergent zone. This species significantly enhances the value of the area to wildlife (Gruendling and Bogucki, 1978).

2.4.2.3 Fisheries and Wildlife

Wildlife use of Mallet's Creek is typical of wildlife use in the region. Waterfowl use of the wetland is quite high during all seasons. Muskrat and beaver evidence is abundant in the area. Chain pickerel is the dominant fish in the wetland (Gruendling and

Bogucki, 1978). Gruendling and Bogucki (1978) also provide information on phytoplankton and zooplankton in Mallet's Bay.

According to a creel survey conducted by the Vermont Fish and Wildlife Department, the most abundant fish species in Mallet's Bay are, in order of decreasing abundance, yellow perch, smallmouth bass (Micropterus dolomieui), northern pike, largemouth bass, chain pickerel, brown bullhead (Ictalurus nebulosus), black crappie (Pomoxis nigromaculatus), rock bass, pumpkinseed (Lepomus gibbosus), and landlocked salmon (Salmo salar) (Vt. Fish and Wildlife, 1978).

2.4.3 Regional Characteristics

Certain characteristics of regional wetlands can provide further indications of the conditions occurring in an unaffected environment. This section describes some of the characteristics typical of Lake Champlain wetlands.

2.4.3.1 Wetlands

Gruendling and Bogucki (1978) provide a general description of vegetation and wildlife typically found in Lake Champlain wetlands. Wetland forests usually consist of silver maple (Acer negundo), green ash, and occasionally swamp white oak (Quercus bicolor) and red maple. Understory often contains sensitive fern (Onochlea sensibilis), wood nettle (Laportea canadensis), and various shrubs. The emergent zone typically contains bulrushes (Scirpus spp.), burreed (Sparganium spp.) cattail (Typha spp.), and duck potato (Sagittaria spp.).

2.4.3.2 Fisheries

Lake Champlain in general, and Burlington Bay in particular, support several species of fish that depend on wetlands as spawning grounds. Yellow perch is the dominant fish in shallow lake waters. Other species common in Burlington Bay include walleye (Stizostedion vitreum), brown bullhead, pumpkinseed, bowfin (Amia calva), northern pike, chain pickerel, largemouth bass (Micropterus salmoides), black crappie, carp (Cyprinus carpio), longnose gar (Lepisosteus osseus), and eastern mudminnow (Umbra pygmaea) (Gruendling and Bogucki, 1978; Vermont Department of Fish and Wildlife, 1978). The lake sturgeon (Acipenser fulvescens), listed as endangered by the state of Vermont, also inhabits the lake.

PEER (1989) sampled fish by gillnetting at the mouth of the LaPlatte River, approximately four miles south of the Canal site. Seven fish species were caught: brown bullhead, pumpkinseed, golden shiner, rock bass, northern pike, yellow perch, and chain pickerel.

2.4.3.3 Wildlife

Wetlands of Lake Champlain support a variety of waterfowl and terrestrial wildlife, particularly during migration. Representative waterfowl species in Lake Champlain wetlands include black duck, common goldeneye (Bucephala clangula), scaup (Aythya marila and Aythya affinis), mallard, green-winged teal (Anas crecca), blue-winged teal (Anas discors), ring-necked duck (Aythya collaris), canvasback (Aythya valiniseri), merganser (Mergus merganser), wood duck, and Canada goose (Branta canadensis). Furbears include wetland dependent species such as muskrat (Ondatra zibethicus), beaver, mink (Mustela vison), racoon (Procyon lotor), and otter (Lutra canadensis), in addition to upland species such as red fox, gray fox (Urocyon cinereoargenteus), coyote (Canis latrans), bobcat (Felix rufus), weasel (Mustela frenata), and fisher (Martes pennanti).

2.5 Summary of Site Information

The Pine Street Canal and adjacent wetlands apparently contain elevated concentrations of contaminants primarily as a result of waste stream discharge from the coal gasification plant on the site. Other industries currently or formerly operating on the site have also contributed to the contamination. Contamination appears to be concentrated in the sediments and soils near the canal, wetlands, and former gasification complex. The highest concentrations of contaminants appear to be of semi-volatiles and inorganics; volatiles are apparently not present in high concentrations. The Pine Street Canal currently supports vegetation and wildlife fairly typical of a Lake Champlain palustrine emergent wetland. An active beaver community inhabits the southern and central portion of the canal, and other wildlife commonly use the site.

2.6 Review of Applicable or Relevant and Appropriate Requirements

Section 121(d)(2)(A) of the Comprehensive Emergency Response, Compensation, and Liability Act of 1980 (CERCLA, also known as the Superfund Act), requires that all Superfund remedial actions meet federal and more stringent state standards, requirements, criteria, or limitations that are "applicable or relevant and appropriate requirements" (ARARs) (EPA, 1989). This section briefly describes some of the ARARs that may be pertinent to the actions at the Pine Street Canal. A list of possible ARARs is provided in Attachment 3. A more comprehensive identification and description of ARARs will occur once the site specific remedial actions are determined.

2.6.1 Federal Regulations

The broadest federal requirements are the Resource Conservation and Recovery Act (RCRA), Clean Air Act, Clean Water Act, and Toxic Substances Control Act (PEER, 1989). There are also non-promulgated federal guidelines and criteria to be considered in designing a remedial action that is sufficiently protective. Examples of such guidelines include RCRA guidance on designing caps for site closure and groundwater classification guidelines.

RCRA contains extensive regulations related to treatment, storage, and disposal of solid and hazardous wastes. Several facets of RCRA may be applicable, appropriate, or relevant to remedial action at the Pine Street Canal. RCRA Maximum Concentration Limits are standards for 14 toxic compounds, primarily metals and pesticides. RCRA also contains explicit limitations on where on-site storage, treatment, or disposal of hazardous waste may occur. The Hazardous and Solid Waste Amendments of 1984 mandate the development of location requirements concerning vulnerable hydrogeology. Substantive RCRA provisions that are applicable to hazardous waste management include, but are not limited to: 40 CFR Part 262 (Subpart C, Pre-Transportation Requirements), 40 CFR Part 263 (Transportation Standards), 40 CFR 264 (Subpart I, Container Storage and Subpart L, Waste Piles).

Both RCRA and the Department of Transportation (DOT) regulate transportation of hazardous wastes. RCRA requirements include tracking of waste shipments, and DOT requirements include proper packaging and labeling.

The Clean Water Act establishes effluent discharge limitations, pretreatment standards, and regulations pertaining to dredging and filling of navigable waters. Section 404 of the Act prohibits the discharge of fill material into navigable waters without a permit. CERCLA on-site actions do not require a Section 404 permit, but the substantive requirements of Section 404 regarding such an action are usually relevant and serve as guidance. Therefore, all procedures necessary to obtain a Section 404 permit should be pursued. Such procedures include delineation of the site wetlands according to the three-criteria approach outlined in the Corps of Engineers Wetlands Delineation Manual (1989), complete descriptions of the proposed project and potential impacts, and a discussion of alternatives to the proposed action.

Section 10 of the Rivers and Harbors Act of 1899 requires a permit for any permanent or temporary obstruction or alteration to navigable waters, including dredging or filling. Approval of Section 10 permits is subject to the authority of the ACOE and is usually coordinated with Section 404 permits.

Wetlands and floodplains are also regulated by 40 CFR Part 6, Appendix A. This rule sets forth EPA policy for carrying out the provisions of Executive Orders 11988 (Floodplain Management) and 11990 (Wetlands Protection). These executive orders ensure that the values of wetlands and floodplains are retained whenever possible. Review of compliance with these Executive Orders is conducted by the U.S. Fish and Wildlife Department in coordination with ACOE review of Section 404 permit applications.

The National Historic Preservation Act of 1966 requires an action to take into account effects on properties included in or eligible for the National Register of Historic Places and to minimize harm to National Historic Landmarks. The Pine Street Canal may be eligible for listing on the National Register; Art Cohen of the Basin Harbor Maritime Museum has commented that historic canal boats and other ships may be present in the sediments at the bottom of the canal and turning basin (PEER, 1989).

The Endangered Species Act of 1973 requires an action to avoid jeopardizing the continued existence of listed threatened or endangered species or modification of their habitat. Initial consultation with the U.S. Fish and Wildlife Service suggest that no federally-listed species are known to exist in the area (PEER, 1989). However, a database search by the Vermont Agency of Natural Resources has resulted in two rare (but unprotected) plant species (Theliotrum venulosum and Sheperdia canadensias) being identified on or adjacent to the site (PEER, 1989).

The Fish and Wildlife Coordination Act requires an action to protect fish and wildlife from actions modifying streams or areas affecting streams. The Act requires the proponent of an action to consult with the U.S. Fish and Wildlife Service with regard to potential impacts to fish and wildlife and wildlife habitat.

The Clean Air Act and resulting state implementation plans contain requirements for control of ambient emissions, including hazardous air pollutants. The Clean Air Act also establishes National Ambient Air Quality Standards for six common air contaminants.

The Occupational Safety and Health Act establishes monitoring, personal protection, and other worker protection requirements. Section 126 of the Superfund Reauthorization Act (SARA) of 1986 also pertains to worker protection for remedial investigations on hazardous waste sites.

The EPA Ambient Water Quality Criteria for the Protection of Aquatic Life are non-enforceable recommendations which provide information on minimum concentrations of contaminants that have been shown to have adverse health effects on aquatic life.

2.6.2 Vermont State Regulations

Several Vermont state regulations may pertain to remedial activities at the Pine Street Canal site: the Vermont Wetland Rules, the Land Use Development Law, the Vermont Water Pollution Control Law (and corresponding Water Quality Standards), the Vermont Solid Waste Management Law (and corresponding Regulations and Guidelines), and the Vermont Hazardous Waste Management Law (and corresponding regulations and guidelines).

The Vermont Wetland Rules became effective February 23, 1990. The rules outline a classification system for identifying all wetlands in the state. Three classes of wetlands are defined. Class one wetlands are wetlands which the Water Resources Board determines are exceptional or irreplaceable in their contribution to Vermont's natural heritage. These wetlands merit the highest level of protection under the rules. Currently no class one wetlands have been identified in the state. Class two wetlands are identified primarily by USFWS NWI maps. The wetlands at the Pine Street site most likely qualify as class two wetlands. Class one and two wetlands are considered significant and are regulated by the rules, while class three wetlands are considered not functionally significant and are therefore not protected by the State rules although they may be regulated by other federal or local regulations or ordinances.

A wetland permit, or "conditional use application," can be granted to conduct work in class one or class two wetlands. Applications must include a description of the location and action, a descriptive narrative of why the applicant believes the action can comply with the rules, copies of supporting documents, and the names of property owners. Permits are granted by the State Water Resources Board.

Mitigation of wetland impacts is allowable; however, avoidance and minimization of impacts is strongly preferred rather than wetland replication. Replication is not allowed at all in class one wetlands except in rare cases of public need.

The Land Use Development Law (Act 250) requires a permit for any activity that may cause a significant impact in one or more of the following areas: water pollution, air pollution, water supply, soil erosion, traffic impacts, educational services, municipal services, aesthetic resources, conformance with land use planning, and municipal planning. Applications must include a complete description of the project, a description of the potential violations of the ten criteria, and a description of methods used to minimize impacts. Applications are reviewed by one of nine District Environmental Commissions. Major actions require a public hearing.

The Vermont Water Quality Standards were established under the authority of the Vermont Water Pollution Control Act. The Act establishes water quality standards for three classes of water. Permits are required for actions which may adversely affect the water quality in one of these three classes of water. Permits are reviewed by the Secretary of Environmental Conservation.

The State of Vermont Hazardous Waste Management Law and corresponding Regulations and the Vermont Solid Waste Management Law and corresponding Regulations contain provisions similar to RCRA regulations, including standards for clean-up, transport, and storage of contaminated soil, water, and sediment.

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ATTACHMENTS

ATTACHMENT 1

PINE STREET BARGE CANAL SITE POTENTIALLY RESPONSIBLE PARTIES

April 1, 1988

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Source: PEER, 1989

ATTACHMENT 1 (continued)

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ATTACHMENT 2 - SPECIES OBSERVED

BIRDS - Visual/Auditory

Mallard	*Anas platyrhynchos*
American black duck	*Anas rubripes*
Ring-billed gull	*Larus delawarensis*
Herring gull	*Larus argentatus*
Great black-backed gull	*Larus marinus*
Belted kingfisher	*Ceryle alcyon*
Rock dove (Domestic pigeon)	*Columba livia*
Black-capped chickadee	*Parus atricapillus*
American crow	*Corvus brachyrhynchos*
European starling	*Sturnus vulgaris*
Northern mockingbird	*Mimus polyglottos*
American goldfinch	*Carduelis tristis*
House finch	*Carpodacus mexicanus*
Northern cardinal	*Cardinalis cardinalis*

ADDITIONAL BIRDS - Sign

Downy/hairy woodpecker	*Picoides pubescens/villosus*
Pileated woodpecker	*Dryocopus pileatus*
Gray catbird	*Dumetella carolinensis*
Yellow warbler	*Dendroica petechia*

MAMMALS - Visual observations

Beaver	*Castor canadensis*
Red fox	*Vulpes vulpes*
Deer mouse	*Peromyscus maniculatus*

ADDITIONAL MAMMALS - Sign

Domestic dog	*Canis familiaris*
Domestic cat	*Felis domesticus*
Eastern cottontail	*Sylvilagus floridanus*
Raccoon	*Procyon lotor*
Muskrat	*Ondatra zibethicus*

ATTACHMENT 3

Selected Action-Specific ARARs
Pine Street Canal Site

Action	Selected Requirements	Citation
	Analysis of feed materials	40 CFR 264.341
	Standards for POHC, dioxins, HCl,	40 CFR 264.343
	Operating requirements	40 CFR 264.345
	Monitoring and inspection	40 CFR 264.347
	Disposal of produced wastes	40 CFR 264.351
	Special regulations for PCBs	40 CFR 761.70
Land Treatment	General RCRA requirements	40 CFR Part 264, Subpart M
	Treatability, pre-land treatment standards, treatment zone restrictions, run-on/run-off controls	40 CFR 264.271-273
	Unsaturated zone monitoring	40 CFR 264.278
	Requirements if food chain crops are involved	40 CFR 264.276
	Ignitable, reactive, incompatible, or dioxin-containing wastes	40 CFR 264.281-283
	Closure and post closure	40 CFR 264.280
Slurry Walls	Excavation may trigger closure and/or landfilling requirements	40 CFR 264.111 and 40 CFR Part 264, Subpart N
Surface Water Control	Run-on and run-off controls	40 CFR 264.251(c) and (d)
Dredging	Removal of contaminated soil (see Clean Closure requirements)	40 CFR 264.111
	Compliance with Rivers and Harbors Act, Section 10	33 USC 403
	U.S. Army COE requirements	33 CFR 320 - 330
Excavation	May trigger closure requirements	40 CFR 264.11
	May trigger landfilling requirements	40 CFR 264, Subpart N
Incineration	General requirements	Clean Air Act; 40 CFR Part Subpart E; 40 CFR Part 264, Subpart O; Vermont Environmental Protection Regs - Chapter 5

Source: PEER, 1989

ATTACHMENT 3
(Continued)

Selected Action-Specific ARARs
Pine Street Canal Site

Ground Water Treatment - Direct Discharge	General CWA requirements	40 CFR Part 122
	Vermont water pollution rules	10 V.S. Chapters 47 & 49
	Best available treatment technology	40 CFR 122.44(a)
	Federal and State Water Quality Standards	40 CFR 122.44; Vermont Wat Quality Standards
	Prevent release of toxic constituents to surface waters	40 CFR 125.104 and 40 CFR 122.41(i)
	Monitoring	40 CFR 122.44(i)
	Mitigation of adverse effects of releases	40 CFR 122.41(d)
	Operation and maintenance of treatment system	40 CFR 122.41(e)
Closure with Waste in Place	General closure requirements for hazardous waste facilities.	40 CFR Part 264, Subpart G
	Specific landfill closure requirements: capping, liners, leachate collection, leak detection, ground water monitoring.	40 CFR 264.310

TASK 3

REVIEW OF CONTAMINANT INFORMATION

TASK 3 - REVIEW OF CONTAMINANT INFORMATION

LIST OF APPENDICES

TASK 3 - REVIEW OF CONTAMINANT INFORMATION

3.0 Introduction

This memorandum summarizes the pertinent information concerning fate and transport, toxicity, and sublethal effects of the primary contaminants found on the Pine Street Canal site in Burlington, Vermont. The contaminants of concern are polycyclic aromatic hydrocarbons (PAHs), benzene, toluene, and xylene. The discussion of toxic and sublethal effects is limited to effects on wildlife, aquatic organisms, and vegetation, where this information is available. In several cases the effects of contaminants on wildlife must be inferred from the effects on laboratory animals (e.g. mice, rats, etc.).

PAHs are evaluated the most thoroughly, primarily because of the recent available information in Eisler (1987). For the other compounds, Clement (1985) served as a primary reference, although EPA (1978), EPA (1979), EPA (1980), EPA (1984), EPA (1985), PHS (1987), and PHS (1989) were also reviewed and incorporated.

The fate and transport of contaminants in the environment depends on the properties of both the contaminant and the environmental medium in which it occurs. The information provided in this memorandum is comparatively generic rather than site specific. This generic information can be used, however, in conjunction with information from Task 2 (Review of Site Information) and information from ongoing site investigations to create at least a qualitative model of specific fate and transport processes at the Pine Street site.

An examination of the toxic and sublethal effects of specific contaminants on individual species of fish and wildlife is necessary to determine the overall impact of contamination on the ecosystem. Toxicants can adversely effect a species by direct exposure or by secondary exposure via a contaminated food source. The latter type of exposure is of particular concern because of the ability of persistent chemicals to be biomagnified to toxic levels. Predators and scavengers near the top of the food chain are fewer in number than prey species and may therefore be less able to adapt to a declining population by increasing reproductive output (Clement, 1985). Information on toxicity, sublethal effects, and biomagnification potential can be combined with knowledge of fate and transport mechanisms to produce a model of the effects of contaminant movement through the food chain.

3.1 Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) consist of hydrogen and carbon in the form of two or more fused benzene rings. PAHs are virtually ubiquitous in nature, primarily as a result of natural processes such as forest fires, microbial synthesis, and volcanic activities. They have been detected in animal and plant tissues, sediments, soils, air, surface water, river water, drinking water, and groundwater (Eisler, 1987). Anthropogenic causes of PAHs in the environment include high temperature pyrolysis of organic materials typical of processes used in the steel industry, heating and power generation, and petroleum refining. The majority of PAHs at the Pine Street site are most likely a result of coal tar contamination.

Environmental concern has focused on PAHs that range in molecular size from two-ring structures to 7-ring structures. The number of rings on the molecule strongly affects its biochemical interactions in the environment. Consequently, the fate, transport, and toxicity of PAHs correlate strongly to the specific size of the PAH molecule.

3.1.1 Fate and Transport

3.1.1.1 Physical Pathways

Relatively little information is known on the fate and transport of specific PAHs. Information on PAHs as a group is largely inferred from information on benzo(a)pyrene and mixtures of PAHs (Clement, 1985).

In water, PAHs may evaporate, disperse into the water column, become incorporated into bottom sediments, concentrate in aquatic biota, or experience chemical oxidation and biodegradation (Eisler, 1987). The chemical properties of PAHs suggest that the most likely fate is adsorption onto suspended particulate matter, especially particulates high in organic content. Approximately two-thirds of PAHs in the water are typically associated with particulates, and one-third are dissolved (Eisler, 1987). The ultimate fate of PAHs on aqueous particulates is sedimentation followed by photo-oxidation, chemical oxidation, biotransformation, or biodegradation by bacteria and benthic organisms (Eisler, 1987). In such a case the specific fate and transport of PAHs would depend largely on the hydrogeologic condition of the environment (EPA, 1979). PAHs in aquatic sediments generally degrade slower than PAHs in the atmosphere. Furthermore, in the absence of penetrating radiation or oxygen, PAHs in aquatic sediments degrade extremely slowly and may persist indefinitely (Eisler, 1987). Under appropriate hydrogeologic conditions (e.g. turbulent water), volatilization could be as important an aquatic transport process as adsorption (EPA, 1979).

The remaining third of PAHs existing in dissolved solution may be degraded by rapid photolysis and, to a lesser extent, by oxidation (EPA, 1979). Oxidation by chlorine and ozone may be the most important fate process for aqueous PAHs when these oxidants are available in sufficient quantities (Clement, 1985).

The fate of PAHs in the atmosphere depends on the size of the specific compound. Adsorption onto airborne particles is the likely fate of many larger molecular weight PAHs. These adsorbed PAHs photodecompose readily in the atmosphere by reaction with ozone and various oxidants. Degradation times range from less than one day to several weeks, depending on the size of the PAH and the size of the particle. Many low-molecular weight PAHs are volatile. Airborne PAHs that do not photodecompose are eventually returned to aquatic and terrestrial systems by precipitation (Clement, 1985).

PAHs in surface soils will likely be volatilized into the atmosphere. PAHs in subsurface soils may be assimilated by plants, degraded by soil microorganisms, or accumulated to relatively high levels in the soil. High PAH concentrations in the soil can lead to high microorganism populations capable of degrading the compounds (Eisler, 1987).

3.1.1.2 Biological Pathways

Biodegradation and biotransformation by benthic organisms, including microbes and invertebrates, are probably the ultimate biological fate processes for PAHs in sediments (EPA, 1979). Most animals and microorganisms (shellfish and algae are notable exceptions) can metabolize and transform PAHs to breakdown products that may ultimately experience complete degradation (Eisler, 1987). PAHs with high molecular weights are degraded slowly (half-lives of up to a few years) by microbes and readily by multicellular organisms (EPA, 1979). Microbes more effective than mammals at degrading PAHs (EPA, 1979). Biodegradation probably occurs more slowly in aquatic systems than in soil, and it may be much more important in systems with high PAH concentrations (Clement, 1985).

Some PAHs rapidly bioaccumulate in most animals because of the high lipid solubility of the PAHs (Eisler, 1987). The rate of PAH bioaccumulation is inversely related to the rate of PAH metabolism. Both rates are dependent on the size of the specific PAH; PAHs with less than four rings are readily metabolized and not bioaccumulated, while PAHs with more than four rings are more slowly metabolized and tend to bioaccumulate on a short-term basis (USFWS, 1989; Clement, 1985; EPA, 1979). Bioconcentration factors for selected species are given in Appendix A-1. PAHs of all sizes are probably not bioaccumulated and retained in biota in the long term (EPA, 1979; Clement, 1985; Eisler, 1987). Bioaccumulation is thus not considered an important fate in most multicellular organisms because it is usually a temporary process (USFWS, 1989).

Terrestrial vegetation can accumulate significant concentrations of PAHs, possibly due to the inefficient or missing mixed-function oxidase systems in plants (USFWS, 1989). Plants can absorb PAHs from soils through root uptake and translocate them to other plant parts such as developing shoots. Above-ground parts generally contain higher concentrations, probably because of airborne deposition (USFWS, 1989). Little data is available on bioaccumulation in vegetation of terrestrial and aquatic food chains (Eisler, 1987).

Fungal degradation of PAHs may also be important in the detoxification and elimination of PAHs in the environment. Very little research has been conducted on this possible fate process (Eisler, 1987).

3.1.2 Toxicity and Sublethal Effects

3.1.2.1 General Toxicity Characteristics

Polycyclic aromatic hydrocarbons (PAHs) are moderately persistent in the environment and therefore may cause significant effects to vegetation, fish, and wildlife. A variety of adverse biological effects have been reported in numerous species of organisms under lab conditions, including carcinogenic effects as well as effects on survival, growth, and metabolism (Appendix A-2) (Eisler, 1987).

The carcinogenicity of PAH differs by group (Appendix A-3). Unsubstituted lower molecular weight compounds containing two or three rings exhibit acute toxicity and other adverse effects to some organisms, but are non-carcinogenic. In contrast, the higher molecular weight compounds (four to seven rings) are significantly less toxic, but many are demonstrably carcinogenic, mutagenic, or teratogenic (causing fetal malformations or disturbance to fetal growth) to a wide variety of organisms, including fish and other aquatic life, amphibians, birds, and mammals (Eisler, 1987). Past studies indicate that inter and intraspecies responses to carcinogenic PAHs were quite variable, and were significantly modified by many chemicals, including other PAHs that are weakly carcinogenic or noncarcinogenic. Differences in responses may be attributable to differences in ability to adsorb and assimilate food. For example, crustaceans and fish readily assimilated PAHs from contaminated food, whereas assimilation by mollusks and polycheate annelids was limited. In all cases, following ingestion metabolism and excretion was quite rapid (Eisler, 1987).

3.1.2.2 Effects on Aquatic Biota

The potential effects of PAHs on aquatic biota include reduced survival, decreased food uptake, carcinogenesis, inhibited reproduction, decreased heart rate and respiration, increased weight of body organs in fish, photosynthetic inhibition in algae and macrophytes, and abnormal blood chemistry in oysters (Eisler, 1987).

All but the most heavily contaminated fresh waters contain total

PAH concentrations in the parts per trillion or low parts per billion range. Fish in unpolluted waters do not appear to contain grossly elevated levels of PAHs. This fact may be related to the ability of fish to efficiently metabolize and degrade PAHs (Eisler, 1987). In particular, higher molecular weight PAHs, which include the largest class of chemical carcinogens, do not seem to accumulate in fish in unpolluted waters. PAHs identified as carcinogenic to laboratory animals have not been unequivocally linked to increased cancer incidence in any laboratory populations of aquatic organisms.

Some circumstantial evidence links PAHs to cancer in feral fish, however, especially bottom dwelling fish from areas heavily contaminated with PAHs. For example, sediments heavily contaminated with industrial PAH wastes have directly caused elevated PAH body burdens and increased frequency of liver neoplasia (tumorous growth) in fishes (Eisler, 1987). In one study, sediments and sediment extracts from the Buffalo River, New York, contained elevated levels of carcinogenic PAHs (1,000 to 16,000 ug/kg). Brown bullheads (Ictalarus nebulosa), in response to repeated applications of Buffalo River sediment extracts, showed epidermal hyperplasia and neoplasia when compared to controls (Eisler, 1987). In a separate study, a positive relationship was established between sediment PAH levels and liver tumors in fish from the Black River, Ohio. Sediment PAH concentrations ranged from 50 to 100 mg/kg. Brown bullheads exposed to the sediment contained from 1.1 mg/kg PAHs to 5.7 mg/kg PAHs and exhibited a 33 percent higher frequency of liver tumors than controls (Eisler, 1987).

Non-carcinogenic PAHs vary substantially in their toxicity to aquatic organisms. A sample of toxicities of various PAH compounds is in Appendix A-4. Toxicity is most pronounced in crustaceans and least among teleosts (bony fishes). In all but a few cases, PAH concentrations that are acutely toxic to aquatic organisms are several orders of magnitude higher than concentrations in the most heavily polluted waters (Eisler, 1987). Data were not considered adequate to establish acute or chronic Ambient Water Quality Criteria (EPA, 1986).

Only limited data is available on the potential effects of PAHs on amphibians and reptiles. Potential effects include production of lymphosarcomas (lymphoid tumors) and hepatic (liver) tumors in adult South African clawed toads (<u>Xenopus laevis</u>) after implantation of 1.5 mg of benzo(a)pyrene crystals into the abdominal cavity. In amphibians and reptiles, as in mammals, the mixed-function oxidase system acts to detoxify PAHs (Eisler, 1987).

3.1.2.3 Effects on Terrestrial Wildlife

PAHs can be taken into the mammalian body by inhalation, ingestion, or skin contact. PAHs have been shown to have carcinogenic, toxic, and sublethal effects on laboratory mammals. The effects of PAHs on mammals can be divided onto two groups: carcinogenic PAHs and non-carcinogenic PAHs.

Several PAHs are among the most potent carcinogens known to exist, producing tumors in some laboratory animals through single exposures to microgram quantities (Eisler, 1987). PAHs that are known carcinogens (mostly four, five, and six-ring structures) have been shown to cause mammalian tumors both at the point of application and systemically; their effects have been demonstrated in nearly every tissue tested, regardless of the route of administration (Clement, 1985; USFWS, 1989).

In mammals, numerous carcinogenic PAH compounds are distinct in their ability to produce tumors in skin and most epithelial tissues. Topically applied PAHs can also pass through mammalian skin and cause carcinogenesis in many internal organs. Acute and chronic exposure to carcinogenic PAHs have been shown to cause tumors in the stomach, lung, and skin, respectively, of laboratory animals (mice, rats, and hamsters) (Clement, 1985). PAHs have also been proved to cause destruction of hematopoietic and lymphoid tissues, ovatoxicity, antispermatogenesis, adrenal necrosis, changes in the intestinal and respiratory epithelia, mutagenesis, and immunosuppression (Eisler, 1987). In most cases, there are often no overt effects until the dose is high enough to produce a high tumor incidence (Eisler, 1987).

PAH carcinogens transform cells through genetic injury involving metabolism of the parent compound into a reactive diol epoxide, which alters nucleic DNA and RNA (Eisler, 1987). Many chemicals are known to modify the action of carcinogenic PAHs by altering the metabolism of the carcinogen, preventing carcinogens from reaching their critical target sites, and causing competitive antagonism with carcinogens (Eisler, 1987).

The environmental effects of most non-carcinogenic PAHs are poorly understood. Available information suggests that PAHs are not very potent teratogens or reproductive toxins. Documented non-carcinogenic internal effects include damage to the liver and kidney, and non-carcinogenic external effects include destruction of sebaceous glands, hyperkeratosis (hardening of the skin), and ulceration (Clement, 1985, Eisler, 1987).

Little research has been conducted on the effects of PAHs on species other than laboratory mammals. Two studies have been conducted on the toxicity of PAHs to mallards (Anas platyrhynchos), however. When fed 4000 mg/kg PAHs for seven months, no mortality or visible signs of toxicity resulted. Other effects were noted, however; the average liver size increased 25 percent, and the blood flow to the liver increased 30 percent. Embryotoxicity was noted upon application of PAHs to mallard embryos (Eisler, 1987)

3.1.2.4 Effects on Vegetation

Documented phytotoxic effects of PAH are rare. Most plants can catabolize benzo(a)pyrene, and possibly other PAHs, but pathways are not clearly defined (Eisler, 1987). Some plants contain chemicals known to protect against PAH effects. In other plants, PAHs may act as growth hormones (Eisler, 1987).

3.1.3 Summary

The fate, transport, toxicity, and sublethal effects of PAHs vary widely with the specific size and structure of the molecule. Some generalizations can be made, however. The dominant fate of PAHs in the environment is adsorption onto particulates, especially in media high in organic content. Most PAHs can be metabolized by higher organisms and are therefore not bioaccumulated in the long term. PAHs exhibit both carcinogenic and non-carcinogenic properties: smaller PAHs are acutely toxicity to several organisms, and larger PAHs have been shown to be notably carcinogenic, mutagenic, or teratogenic in a variety of fish and wildlife specimens. PAHs in sediments have been linked to tumors in bottom-dwelling fish. Higher molecular weight PAHs are relatively immobile because of their large molecular volumes and their extremely low volatility and solubility. The effects of PAHs on vegetation are poorly understood.

3.2 Benzene

Benzene is a single-ring hydrocarbon that in a pure state exists as a clear, colorless liquid. It is a naturally occurring substance produced by volcanoes and forest fires and present in many plants and animals. Anthropogenic benzene sources such as automobile emissions and emissions from coal-fired power plants, however, are probably the primary contributors of benzene to the environment (PHS, 1987). At the Pine Street site, benzene occurs as a component of wastes produced by the former coal gasification plant.

3.2.1 Fate and Transport

The predominant process of transport and removal of benzene in the environment is volatilization to the atmosphere, followed by photo-oxidation involving the reaction with hydroxyl radicals (EPA, 1979; Clement, 1985; PHS, 1987). The atmospheric residence time of benzene ranges from a few hours to a few days, depending on the concentration of available hydroxyl radicals (PHS, 1987). Undoubtedly some atmospheric benzene is returned to soil and water in the form of precipitation (PHS, 1987).

Most benzene in surface waters volatilizes readily and is easily transported through the air. The half-life of benzene in surface waters has been estimated to be between four and five hours (PHS, 1987). Sorption processes are potential removal mechanisms in both surface water and groundwater (Clement, 1985). Both the vapor pressure and solubility of benzene in water are fairly high, however, and persistence of benzene in the water column would be expected in most cases. While oxidation is the primary mode of benzene degradation in the atmosphere, oxidation in water is unlikely (EPA, 1979; PHS, 1987). A more probable fate of aqueous benzene is aerobic biodegradation; there is evidence of gradual biodegradation of benzene at low concentrations by aquatic microorganisms such as <u>Nocardia</u> spp. and <u>Psuedomonas</u> spp. (PHS, 1987; Clement, 1985). Anaerobic decomposition may also occur, but the rate is likely much slower than that for aerobic decomposition (PHS, 1987). Apparently the rate of benzene degradation is enhanced when other hydrocarbons are present (EPA, 1979; Clement, 1985). Nonetheless, in most cases benzene degradation in water and soil is slower than degradation in air.

Benzene released to the soil can be biodegraded by microorganisms or can be transported to the air through volatilization, to surface water through runoff, and to groundwater as a result of leaching. In soils and sediments, the physical characteristics of benzene indicate that adsorption onto organic material would be significant only under conditions of constant exposure (Clement, 1985). Biodegradation is probably the ultimate fate process in soils (PHS, 1987). Volatilization and runoff would only occur if benzene were near the surface; benzene deeper in soils would likely be biodegraded or leached to groundwater (PHS, 1987). Factors which might affect the rate of leaching include soil type (e.g. sand or clay), amount of rainfall, and depth to groundwater (PHS, 1987).

The bioaccumulation potential of benzene by aquatic organisms at pollutant concentrations anticipated in environmental waters would probably be low (EPA, 1979; Clement, 1985).

3.2.2 Toxicity and Sublethal Effects

Benzene appears to be of low acute toxicity when administered by various routes to laboratory animals (Clement, 1985). Several adverse health effects of benzene have been demonstrated on small mammals (rats and mice), however. Adverse effects include chromosomal damage (although benzene is not mutagenic in microorganisms), fetotoxicity, and embryotoxicity. The most significant adverse health effects of benzene are hematotoxicity (damage to the blood-forming mechanisms in bone marrow), immunotoxicity, and neurotoxicity (PHS, 1987).

Hematotoxic effects (effects on blood and blood-forming mechanisms) have been observed after short-term exposures of 10 ppm and include leukopenia (decreased amount of white blood cells), thrombocytopenia (decreased amount of platelettes in the blood), and pancytopenia (decreased amount of both white and red blood cells) (Clement, 1985; PHS, 1987). Despite these short-term consequences, hematotoxic effects have been correlated more strongly with chronic, long-term exposure than with acute, short-term exposure (PHS, 1987). Immunotoxic effects include damage to the lymphatic cells responsible for antibody production (B-cells) and self-mediated immunity (T-cells). These effects were also observed at doses of 10 ppm (PHS, 1987). Neurotoxic effects of inhalation exposure include disturbed neuronal transport characteristics, narcosis (relaxation), loss of reflex actions, and general behavioral alterations (PHS, 1987).

A considerable amount of data is available on specific dose limits and effects of benzene on laboratory animals (Appendix B) (PHS, 1987). In the rat, the LC50 value (concentration at which half the population dies) of benzene for a four hour inhalation exposure was estimated to be 13,700 ppm. For oral exposure, the LD50 was 128 mg/kg. Some specific information is also available for aquatic organisms. The EC50 (concentration at which half the experimental animals show an effect) values for benzene in a variety of invertebrate and vertebrate freshwater aquatic species range from 5,300 ug/liter to 386,000 ug/liter (Clement, 1985). The concentration of 5,300 ug/liter is listed in the EPA Quality Criteria for Water as the lowest observable effect level (L.O.E.L) for acute toxicity of benzene. Because of the lack of sufficient data, no formal criteria have been established for acute or chronic benzene toxicity to aquatic life in freshwater (EPA, 1986).

3.2.3 Summary

Benzene is a highly volatile compound that quickly evaporates from surface waters and surface soils. In subsurface soils and sediments, some benzene is adsorbed onto particulates and eventually biodegraded or biotransformed by microorganisms. The most significant health effects of benzene are hematotoxicity, immunotoxicity, and neurotoxicity.

3.3 Toluene

Toluene is a clear, colorless liquid with a sweet odor. It exists naturally in crude oil but is more abundant as a by-product of petroleum refining, styrene production and coke oven operations (PHS, 1989). It is used industrially in the refining of gasoline, in chemical manufacturing, in the manufacturing of paints, adhesives, and rubber, and as a general solvent (PHS, 1989). Toluene exists on the Pine Street site as part of the discharge from the coal gasification plant.

3.3.1 Fate and Transport

There is apparently little tendency for toluene to persist in the environment because it readily decomposes in soil and evaporates rapidly (PHS, 1989). As is the case with benzene, the primary means of removal of toluene from the environment is volatilization, and once volatilization occurs, atmospheric photo-oxidation of toluene generally subordinates all other fates (EPA, 1979). Although it is a liquid at room temperature, toluene is sufficiently volatile that the majority of toluene in the environment exists in the air (PHS, 1989).

It is likely that atmospheric toluene and its breakdown products are precipitated in rain since they are soluble in water (PHS, 1989). Once in the water or in surface soils, toluene tends to evaporate quickly (PHS, 1989). The rate of evaporation depends on whether the water is turbulent or static. The t1/2, or half-life of a substance, is the estimated time it takes for half the substance to degrade. In turbulent water the t1/2 for toluene evaporation is five to six hours, and in static water the t1/2 for evaporation is up to sixteen days (PHS, 1989). Under average conditions, over 90 percent of the toluene in the upper soil layer volatilizes in the first 24 hours (PHS, 1989). Toluene has a relatively high affinity for organic soils; it is moderately adsorbed onto soils and sediments rich in organic matter, but readily leached from soils low in organic matter.

Toluene which is not volatilized from shallow groundwater, surface water, or surface soils is typically degraded by microbial activity (PHS, 1989). The rate of biodegradation depends on several factors (temperature, duration of microbial acclimation, etc.) with biodegradation half-lives under one day in favorable conditions.

Regardless of the conditions, volatilization remains the dominant fate process in these media (Clement, 1985; PHS, 1989).

Toluene is moderately lipophilic and therefore has a moderate tendency to bioaccumulate in fatty tissues of aquatic species. The bioaccumulation factor has been estimated to be 10.7 in fish and 4.2 in mussels (PHS, 1989). Toluene can apparently be detoxified and excreted by mammals (Clement, 1985).

3.3.2 Toxicity and Sublethal Effects

3.3.2.1 Effects on Mammals

The effects of inhalation exposure to laboratory animals are summarized in Appendix C. There is no conclusive evidence that toluene is carcinogenic or mutagenic in animals or humans (EPA, 1984). Several non-carcinogenic effects of toluene have been demonstrated on laboratory animals, however. Effects include fetotoxicity, hearing impairment, decreased body and brain weight, lung and kidney damage, and growth inhibition (PHS, 1989).

The embryotoxic and fetotoxic effects are perhaps the most significant. Oral administration of toluene at doses as low as 260 mg/kg produced a significant increase in embryonic lethality in mice (Clement, 1985). Other sublethal fetotoxic effects on mice include decreased fetal weight at doses of 434 mg/kg and increased incidence of cleft palate at 867 mg/kg (Clement, 1985). The oral LD50 value and inhalation LC50 values for rats are estimated to be 5,000 mg/kg and 15,000 mg/m3, respectively (Clement, 1985).

Synergistic effects have been documented for toluene and other toxic compounds. For example, coadministration of toluene along with benzene or styrene has been shown to suppress the metabolism of benzene or styrene in rats (Clement, 1985).

3.3.2.2. Aquatic Organisms

Aquatic organisms are relatively insensitive to toluene. The EC50 and LC50 values for five freshwater species tested with toluene range from 12,700 to 313,000 ug/liter, respectively (Clement, 1985). Two freshwater algal species tested with toluene were relatively insensitive, with EC50 values of at least 245,000 ug/liter reported (Clement, 1985). The Quality Criteria for Water lists 17,500 ug/l as the LOEL for toluene. No formal freshwater acute or chronic criteria have been established, however, because of the lack of sufficient data (EPA, 1986).

3.3.3 Summary

Toluene is not very persistent in the environment because it readily decomposes in soil and evaporates rapidly from surface waters and surface soils. Although toluene has not been shown to be carcinogenic or mutagenic, several toxic and sublethal effects have been demonstrated at relatively high doses in laboratory animals. The most significant effects are embryotoxic and fetotoxic (Clement, 1985).

3.4 Xylene

Xylene is a monocyclic aromatic hydrocarbon which exists in the form of a colorless, aromatic liquid. Commercial xylene is a mixture of three isomers: o-xylene, m-xylene, and p-xylene. Xylene has been associated with the location of the former coal gasification plant at the Pine Street site.

3.4.1 Fate and Transport

Xylene binds to sediments in water and to organics in soils and undergoes microbial degradation in both media; biodegradation is probably the most important fate process in sediments and in subsurface soils (PHS, 1989; Clement, 1985). Nonetheless, biodegradation can be a slow process, and xylenes have been shown to persist for up to six months in some soil types (Clement, 1985). Some xylene in subsurface soils may eventually infiltrate into groundwater if soils are low in organic carbon (PHS, 1989). Because of their low solubility in water and rapid biodegradation, however, xylenes are unlikely to leach into groundwater in high concentrations (Clement, 1985).

In surface water and shallow groundwater, volatilization and subsequent photo-oxidation by reaction with hydroxyl radicals in the atmosphere are probably the most important fate processes (EPA, 1979). The estimated half-life of the three xylene isomers in water ranges from 2.6 to 11 days (EPA, 1979). The half-life of xylene in air ranges from eight hours for m-xylene to fifteen hours for p-xylene (EPA, 1979). Products of the atmospheric photo-oxidation reaction include carbon dioxide, peroxyacetylnitrate (PAN), and cresol.

The bioconcentration factors for o-xylene, m-xylene, and p-xylene have been estimated to be 45, 105, and 95, respectively (EPA, 1979). Little research has been conducted on the effects of xylene bioconcentration in food chains.

3.4.2 Toxicity and Sublethal Effects

The effects of xylene on laboratory animals are summarized in Appendix D. Although no carcinogenic, mutagenic, or teratogenic effects of xylene have been identified in rats and mice, xylene has been shown to be fetotoxic in both species. Acute exposure to high levels of xylene cause sublethal effects including central nervous system damage and irritation of mucous membranes in adult rats and mice (Clement, 1985). The oral LD50 value of xylene in rats is 5,000 mg/kg (Clement, 1985).

Some studies suggest that xylene adversely affects growth and survival of aquatic species. Xylene adversely affected adult trout at concentrations as low as 3.6 mg/liter in a continuous flow system, and trout fry avoided xylene at concentrations greater than 0.1 mg/liter (Clement, 1985). The LD50 value in adult trout was determined to be 13.5 mg/l (Clement, 1985). No Ambient Water Quality Criteria have been established for acute or chronic freshwater exposure to xylene.

Information on the toxicity of xylenes to terrestrial wildlife or domestic animals is not available. However, because of the low acute toxicity it is unlikely that xylene would be toxic to birds and mammals (Clement, 1985).

3.4.3 Summary

Xylene is a volatile compound which can be moderately persistent in the environment. The most important fate process is likely biodegradation, although it can be slow in sediments and subsurface soils. While no carcinogenic or mutagenic effects have been demonstrated in laboratory animals, xylene has been shown to be acutely fetotoxic in rats and mice following exposure to high inhalation doses (Clement, 1985). Evidence also suggests that xylene may adversely affect aquatic species (Clement, 1985).

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APPENDICES

Appendix A-1. PAH bioconcentration factors (BCF) for selected species of aquatic organisms.

PAH compound, organism, and other variables	Exposure period[a]	BCF	Reference[b]
ANTHRACENE			
Cladoceran, <u>Daphnia magna</u>	60 m	200	EPA 1980
Fathead minnow, <u>Pimephales promelas</u>	2 to 3 d	485	Southworth 1979
Cladoceran, <u>Daphnia pulex</u>	24 h	760 to 1200	Southworth et al. 1978; Southworth 1979; EPA 1980; Neff 1985
Mayfly, <u>Hexagenia</u> sp.	28 h	3,500	EPA 1980
Rainbow trout, <u>Salmo gairdneri</u>	72 h	4,400 to 9,200	Linder et al. 1985
9-METHYLANTHRACENE			
Cladoceran, <u>Daphnia pulex</u>	24 h	4,583	Neff 1985
BENZ(a)ANTHRACENE			
Cladoceran, <u>Daphnia pulex</u>	24 h	10,109	Southworth et al. 1978
BENZO(a)PYRENE			
Teleosts, 3 spp., Muscle	1 h to 96 h	0.02 to 0.1	EPA 1980
Clam, <u>Rangia cuneata</u>	24 h	9 to 236	Neff 1979; EPA 1980
Bluegill, <u>Lepomis macrochirus</u>	4 h	12	Leversee et al. 1981
Atlantic salmon, <u>Salmo salar</u> Egg	168 h	71	Kuhnhold and Busch 1978
Midge, <u>Chironomus riparius</u>, larvae	8 h	166	Leversee et al. 1981
Rainbow trout, liver	10 d	182 to 920	Gerhart and Carlson 1978

Source: Eisler, 1987

Appendix A-1 **(Continued)**

PAH compound, organism, and other variables	Exposure period[a]	BCF	Reference[b]
Oyster, *Crassostrea virginica*	14 d	242	EPA 1980
Northern pike *Esox lucius*			
Bile and gallbladder	3.3 h	3,974	Balk et al. 1984
"	19.2 h	36,656	
"	8.5 d	82,916	
"	23 d	53,014	
Liver	3.3 h	259	
"	19.2 h	578	
"	8.5 d	1,376	
"	23 d	619	
Gills	3.3 h	283	
"	19.2 h	382	
"	8.5 d	372	
"	23 d	213	
Kidney	3.3 h	192	
"	19.2 h	872	
"	8.5 d	1,603	
Other tissues	3.3 h to 23 d	<55	
Mosquitofish, *Gambusia affinis*	3 d	930	Lu et al. 1977
Bluegill			
No dissolved humic material (DHM)	48 h	2,657	McCarthy and Jimenez 1985
20 mg/l DHM	48 h	225	
Cladoceran, *Daphnia magna*	6 h	2,837	Leversee et al. 1981
Alga, *Oedogonium cardiacum*	3 d	5,258	Lu et al. 1977
Periphyton, mostly diatoms	24 h	9,600	Leversee et al. 1981
Mosquito, *Culex pipiens quinquefasciatus*	3 d	11,536	Lu et al. 1977
Sand sole, *Psettichthys melanostictus*			
Egg	6 d	21,000	Hose et al. 1982
Snail, *Physa* sp.	3 d	82,231	Lu et al. 1977
Cladoceran, *Daphnia pulex*	3 d	134,248	

Appendix A-1. (Continued)

PAH compound, organism, and other variables	Exposure period[a]	BCF	Reference[b]
CHRYSENE			
Clam, *Rangia cuneata*	24 h	8	Neff 1979
Mangrove snapper, *Lutjanus griseus*			
Liver	4 d	83 to 104	Miller et al. 1982
Liver	20 d	258 to 367	
Pink shrimp, *Penaeus duorarum*			
Cephalothorax	28 d	248 to 361	
Cephalothorax	28 d + 28 d postexposure	21 to 48	
Abdomen	28 d	84 to 199	
Abdomen	28 d + 28 d postexposure	22 to 91	
FLUORANTHENE			
Rainbow trout, liver	21 d	379	Gerhart and Carlson 1978
FLUORENE			
Bluegill	30 d	200 to 1,800	Finger et al. 1985
NAPHTHALENE			
Clam, *Rangia cuneata*	24 h	6	Neff 1979
Sandworm, *Neanthes arenaceodenta*	3 to 24 h	40	Neff 1982a
Sandworm	24 h + 300 h post-treatment	not detectable	
Atlantic salmon, egg	168 h	44 to 83	Kuhnhold and Busch 1978
Cladoceran, *Daphnia pulex*	24 h	131	Neff 1985
Crustaceans, 3 spp.	72 h	195 to 404	Neff 1979
Bluegill, whole	24 h	310	McCarthy and Jimenez 1985

Appendix A-1. (Concluded)

PAH compound, organism, and other variables	Exposure period[a]	BCF	Reference[b]
DIMETHYLNAPHTHALENES			
Crustaceans, 3 spp.	72 h	967 to 1,625	Neff 1979
PERYLENE			
Cladoceran, *Daphnia pulex*	24 h	7,191	Neff 1985
PHENANTHRENE			
Clam, *Rangia cuneata*	24 h	32	Neff 1979
Cladoceran, *Daphnia pulex*	24 h	325	Neff 1985
PYRENE			
Cladoceran *Daphnia pulex*	24 h	2,702	
Rainbow trout, liver	21 d	69	Gerhart and Carlson 1978

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[a] m = minutes, h = hours, d = days.

[b] Each reference applies to the values in the same row and in the rows that follow for which no other reference is indicated.

Appendix A-2. Some effects of PAHs on selected laboratory animals.

Effect (units), organism, PAH compound	Concentration	Reference[a]
LD-50, ACUTE ORAL (mg/kg body weight)		
Rodents (*Rattus* spp., *Mus* spp.)		
Benzo(a)pyrene	50	Sims and Overcash 1978
Phenanthrene	700	
Naphthalene	1,780	
Fluoranthene	2,000	
CARCINOGENICITY, CHRONIC ORAL (mg/kg body weight)		
Rodents		
7,12-dimethylbenz(a)anthracene	0.00004-0.00025	Lo and Sandi 1978
Benzo(a)pyrene	0.002	Sims and Overcash 1983
Dibenz(a,h)anthracene	0.006	
Benz(a)anthracene	2.0	
Benzo(b)fluoranthene	40.0	
Benzo(k)fluoranthene	72.0	
Indeno(1,2,3-cd)pyrene	72.0	
Chrysene	99.0	
Anthracene	3,300.0	
CARCINOGENICITY, APPLIED EXTERNALLY AS TOPICAL (mg)		
Mice, *Mus* spp.		
Benzo(a)pyrene	0.001	Lo and Sandi 1978
Dibenz(a,c)anthracene	0.001	
7,12-dimethylbenz(a)anthracene	0.02	
Dibenz(a,j)anthracene	0.039	
Anthracene	0.08	
Benzo(g,h,i)perylene	0.8	
Benz(a)anthracene	1.0	
CARCINOGENICITY, SUBCUTANEOUS (mg)		
Mice		
Dibenz(a,h)anthracene		
Adults	>0.0002	

Source: Eisler, 1987.

Appendix A-2 (Continued)

Effect (units), organism, PAH compound	Concentration	Reference[a]
Newborn	>0.00008	
Dibenzo(a,i)pyrene		
In sesame oil	0.05	
In peanut oil	0.6	
Benzo(a)pyrene	0.06	
Dibenzo(a,e)pyrene	>0.6	
Benzo(b)fluoranthene	1.8	
Benz(a)anthracene	5.0	
Dibenzo(a,h)pyrene	6.0	
TESTICULAR DAMAGE (mg)		
Rat, *Rattus* spp.		
Benzo(a)pyrene, oral	100.0 (no effect)	EPA 1980
7,12-dimethylbenz(a)anthracene		
Intravenous		
Young rats	0.5 - 2.0	
Older rats	5.0	
Oral	20.0	
OOCYTE AND FOLLICLE DESTRUCTION, SINGLE INTRAPERITONEAL INJECTION (mg/kg body weight)		
Mice		
Benzo(a)pyrene	80.0	Mattison 1980
3-methylcholanthrene	80.0	
7,12-dimethylbenz(a)anthracene	80.0	
ALTERED BLOOD SERUM CHEMISTRY AND NEPHROTOXICITY, SINGLE INTRAPERITONEAL INJECTION (mg/kg body weight)		
Rat		
Phenanthrene	150.0	Yoshikawa et al. 1985
Pyrene	150.0	

Appendix A-2 (Concluded)

Effect (units), organism, PAH compound	Concentration	Reference[a]
FOOD CONSUMPTION, DAILY FOR 5 DAYS (mg/kg body weight)		
Deer mice, *Peromyscus maniculatus*		
2-methoxynaphthalene		
30% reduction	825	Schafer and Bowles 1985
2-ethoxynaphthalene		
3% reduction	1,213	
House mice, *Mus musculus*		
2-methoxynaphthalene		
50% reduction	825	
2-ethyoxynaphthalene		
50% reduction	1,213	

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[a] Each reference applies to the values in the same row, and in the rows that follow for which no other reference is indicated.

Appendix A-3
CARCINOGENICITY OF PAHs

Chemicals for which there is sufficient evidence that they are carcinogenic in animals:

Benzo(a)anthracene
Benzo(b)fluoranthene
Benzo(j)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Dibenzo(a,h)acridine
Dibenzo(a,j)acridine
Dibenzo(a,h)anthracene
7H-Dibenzo(c,g)carbazole
Dibenzo(a,e)pyrene
Dibenzo(a,h)pyrene
Dibenzo(a,i)pyrene
Dibenzo(a,l)pyrene
Indeno(1,2,3-c,d)pyrene
5-Methylchrysene

Chemicals for which there is limited evidence that they are carcinogenic in animals:

Anthranthrene
Benzo(c)acridine
Carbazole
Chrysene
Cyclopenta(c,d)pyrene
Dibenzo(a,c)anthracene
Dibenzo(a,j)anthracene
Dibenzo(a,e)fluoranthene
2-, 3-, 4-, and 6-Methylchrysene
2- and 3-Methylfluoranthene

Chemicals for which the evidence is inadequate to assess their carcinogenicity:

Benzo(a)acridine
Benzo(g,h,i)fluoranthene
Benzo(a)fluorene
Benzo(b)fluorene
Benzo(c)fluorene
Benzo(g,h,i)perylene
Benzo(c)phenanthrene
Benzo(e)pyrene
Coronene
1,4-Dimethylphenanthrene
Fluorene
1-Methylchrysene
1-Methylphenanthrene
Perylene
Phenanthrene
Triphenylene

Chemicals for which the available data provide no evidence that they are carcinogenic:

Anthracene
Fluoranthene
Pyrene

SOURCE: Clement Assoc., 1985.

Appendix A-4. Toxicities of selected PAHs to aquatic organisms.

PAH compound, organism, and other variables	Concentration in medium (ug/l)	Effect[a]	Reference[b]
BENZ(a)ANTHRACENE			
Bluegill, *Lepomis macrochirus*	1,000	LC-87 (6 m)	EPA 1980
BENZO(a)PYRENE			
Sandworm, *Neanthes arenceodentata*	>1,000	LC-50 (96 h)	Neff 1979
CHRYSENE			
Sandworm	>1,000	LC-50 (96 h)	
7,12-DIMETHYLBENZ(a)ANTHRACENE			
Minnows, *Poeiciliopsis* spp.			
Juveniles	250	LC-0 (20 h)	Schultz and Schultz 1982
Juveniles	500	LC-100 (20 h)	
DIBENZ(a,h)ANTHRACENE			
Sandworm	>1,000	LC-50 (96 h)	Neff 1979
FLUORANTHENE			
Sandworm	500	LC-50 (96 h)	
FLUORENE			
Grass shrimp, *Palaemonetes pugio*	320	LC-50 (96 h)	
Bluegill	500	LC-12 (30 d)	Finger et al. 1985
Amphipod, *Gammarus pseudoliminaeus*	600	LC-50 (96 h)	
Rainbow trout, *Salmo gairdneri*	820	LC-50 (96 h)	
Bluegill	910	LC-50 (96 h)	
Sandworm	1,000	LC-50 (96 h)	Neff 1979

Source: Eisler, 1987.

Appendix A-4. **(Continued)**

PAH compound, organism, and other variables	Concentration in medium (ug/l)	Effect[a]	Reference[b]
Sheepshead minnow, *Cyprinodon variegatus*	1,680	LC-50 (96 h)	
Snail, *Mudalia potosensis*	5,600	LC-50 (96 h)	Finger et al. 1985
Mayfly, *Hexagenia bilineata*	5,800	LC-50 (120 h)	
Fathead minnow, *Pimephales promelas*	>100,000	LC-0 (96 h)	
NAPHTHALENE			
Copepod, *Eurytemora affinis*	50	LC-30 (10 d)	Neff 1979
Pink salmon, *Oncorhynchus gorbuscha*, fry	920	LC-50 (24 h)	
Dungeness crab, *Cancer magister*	2,000	LC-50 (96 h)	Neff 1985
Grass shrimp	2,400	LC-50 (96 h)	Neff 1979
Sheepshead minnow	2,400	LC-50 (24 h)	
Brown shrimp, *Penaeus aztecus*	2,500	LC-50 (24 h)	
Amphipod, *Elasmopus pectenicrus*	2,680	LC-50 (96 h)	
Coho salmon, *Oncorhyncus kisutch*, fry	3,200	LC-50 (96 h)	Neff 1985
Sandworm	3,800	LC-50 (96 h)	Neff 1979
Mosquitofish, *Gambusia affinis*	150,000	LC-50 (96 h)	
1-METHYLNAPHTHALENE			
Dungeness crab, *Cancer magister*	1,900	LC-50 (96 h)	
Sheepshead minnow	3,400	LC-50 (24 h)	
2-METHYLNAPHTHALENE			
Grass shrimp	1,100	LC-50 (96 h)	Neff 1985
Dungeness crab	1,300	LC-50 (96 h)	
Sheepshead minnow	2,000	LC-50 (24 h)	Neff 1979

Appendix A-4 (Concluded)

PAH compound, organism, and other variables	Concentration in medium (ug/l)	Effect[a]	Reference[b]
TRIMETHYLNAPHTHALENES			
Copepod, *Eurytemora affinis*	320	LC-50 (24 h)	
Sandworm	2,000	LC-50 (96 h)	
PHENANTHRENE			
Grass shrimp	370	LC-50 (24 h)	
Sandworm	600	LC-50 (96 h)	EPA 1980
1-METHYLPHENANTHRENE			
Sandworm	300	LC-50 (96 h)	

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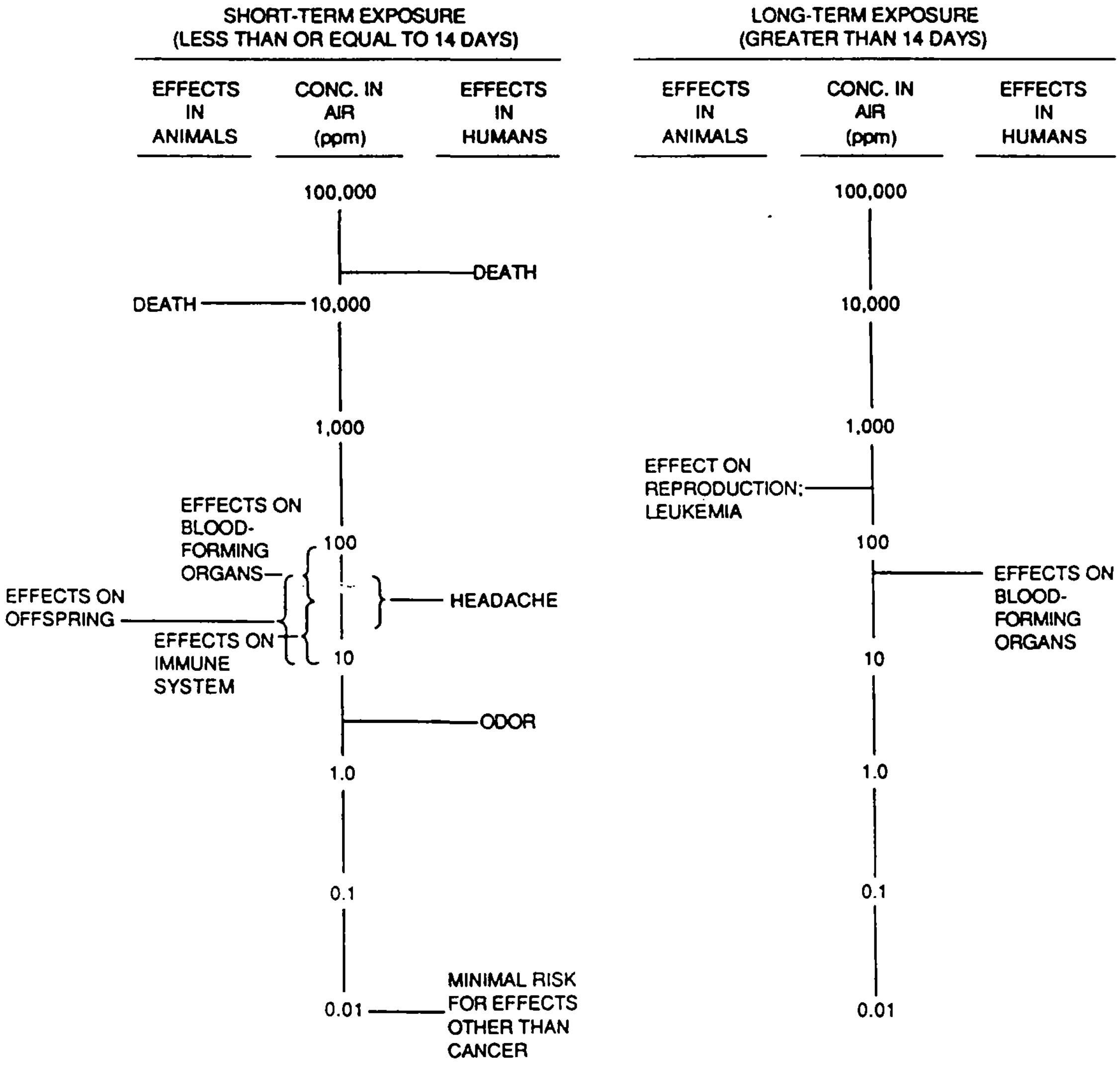
[a] m = months, d = days, h = hours.

[b] Each reference applies to data in the same row and in the rows that immediately follow for which no reference is indicated.

Appendix B-1

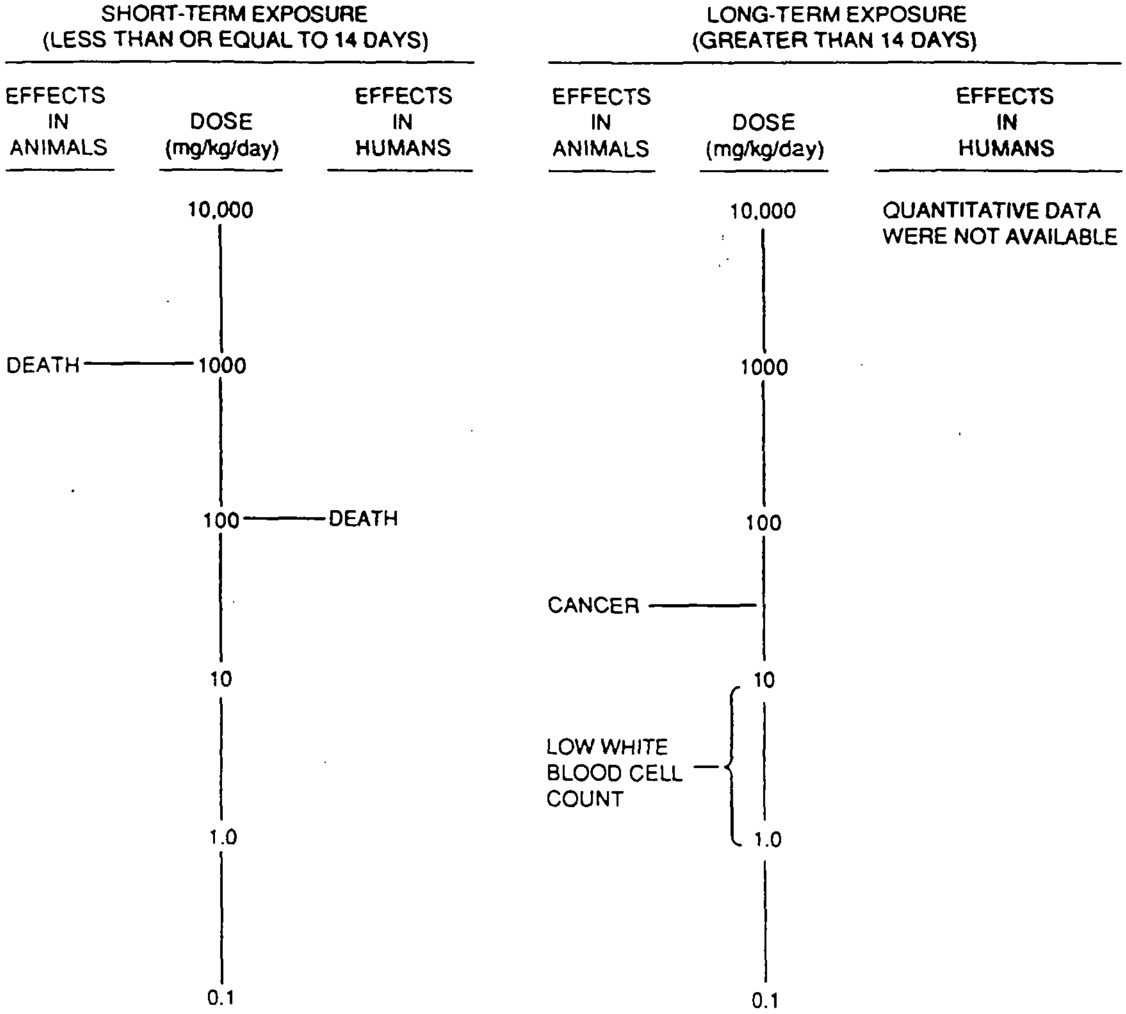


Health effects from breathing benzene.

Source: PHS, 1987.

[redacted]

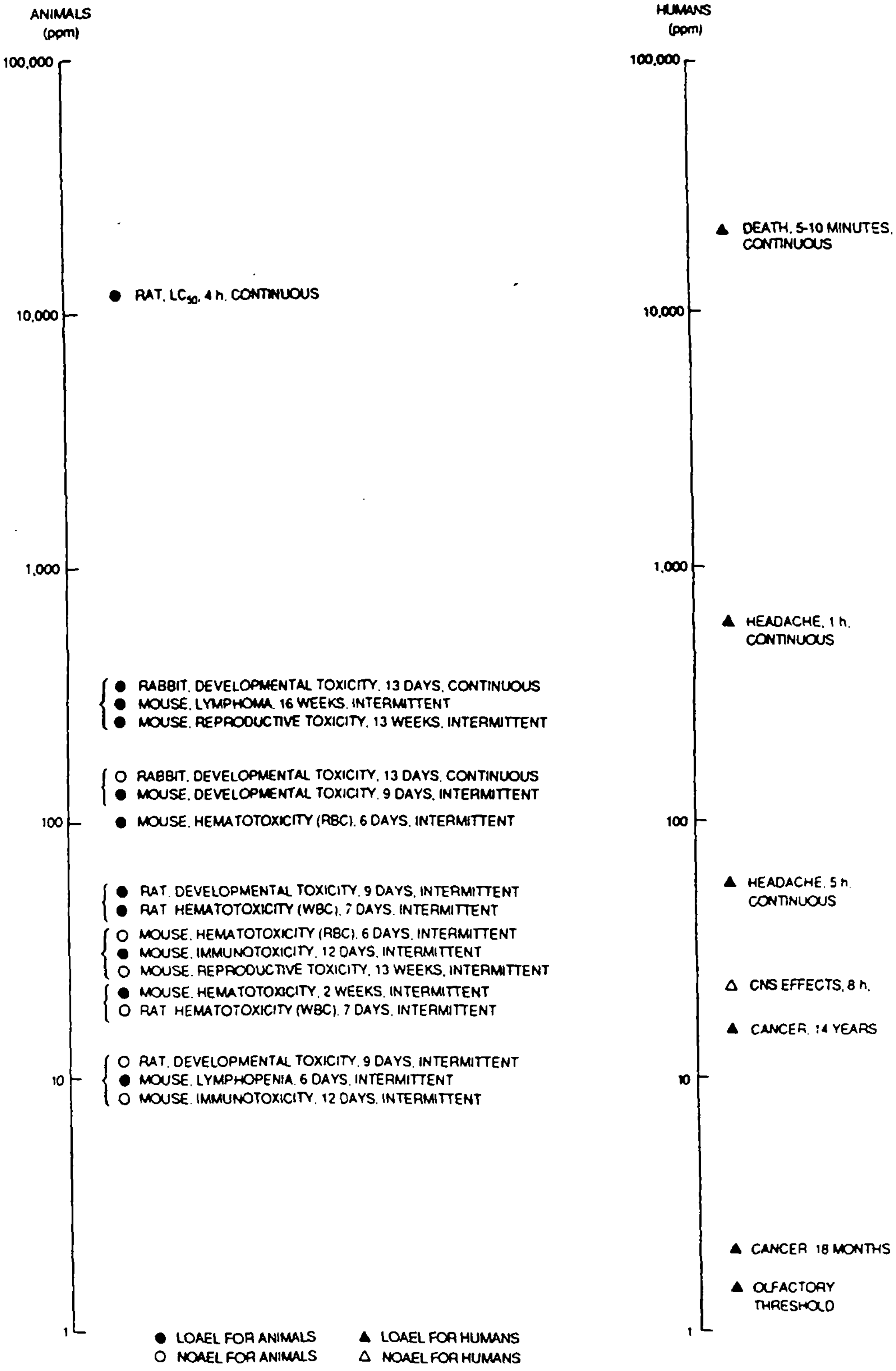
Appendix B-2



Health effects from ingesting benzene.

Source: PHS, 1987.

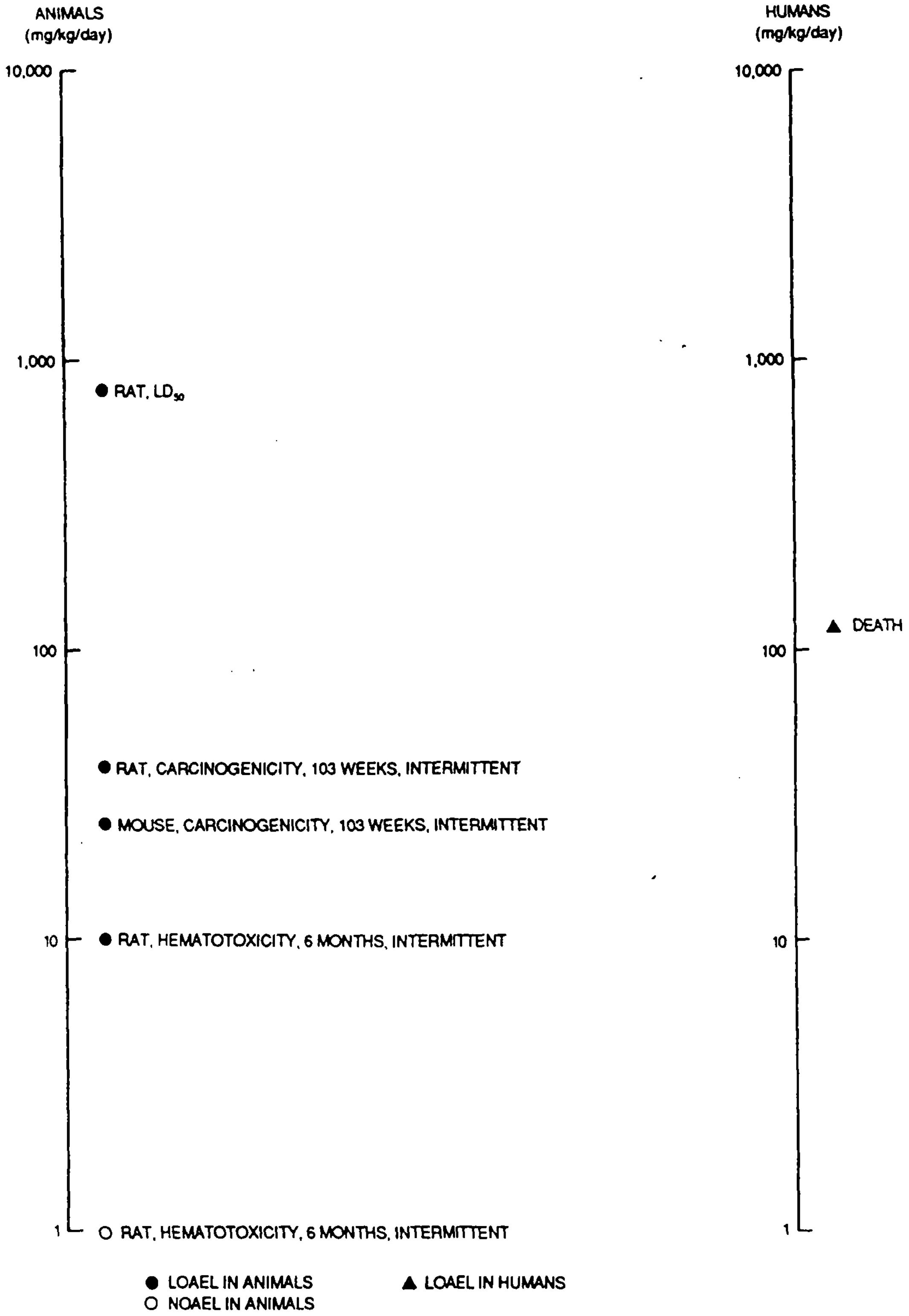
Appendix B-3



Effects of benzene—inhalation exposure.

Source: PHS, 1987.

Appendix B-4

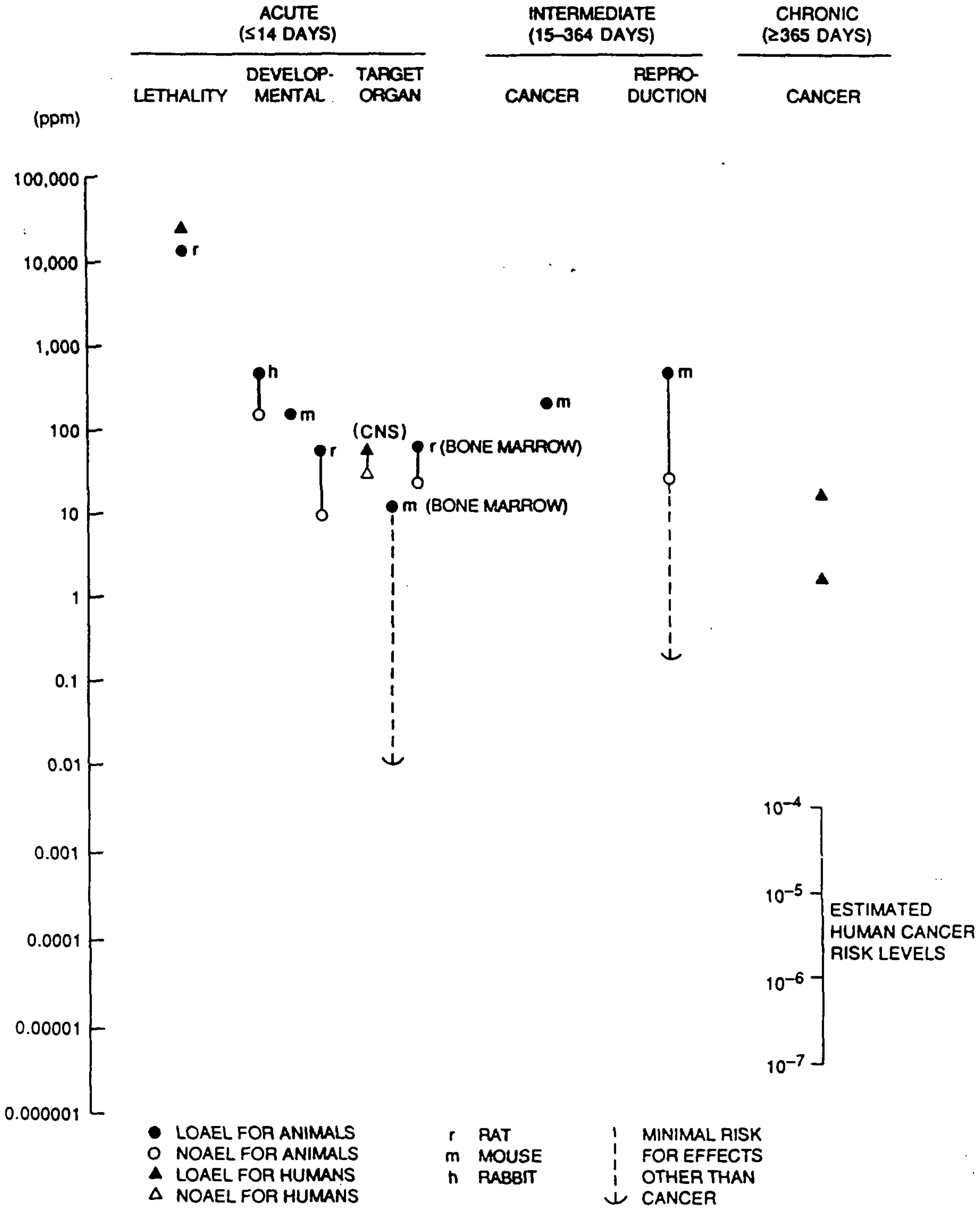


Effects of benzene—oral exposure.

Source: PHS, 1987

[redacted]

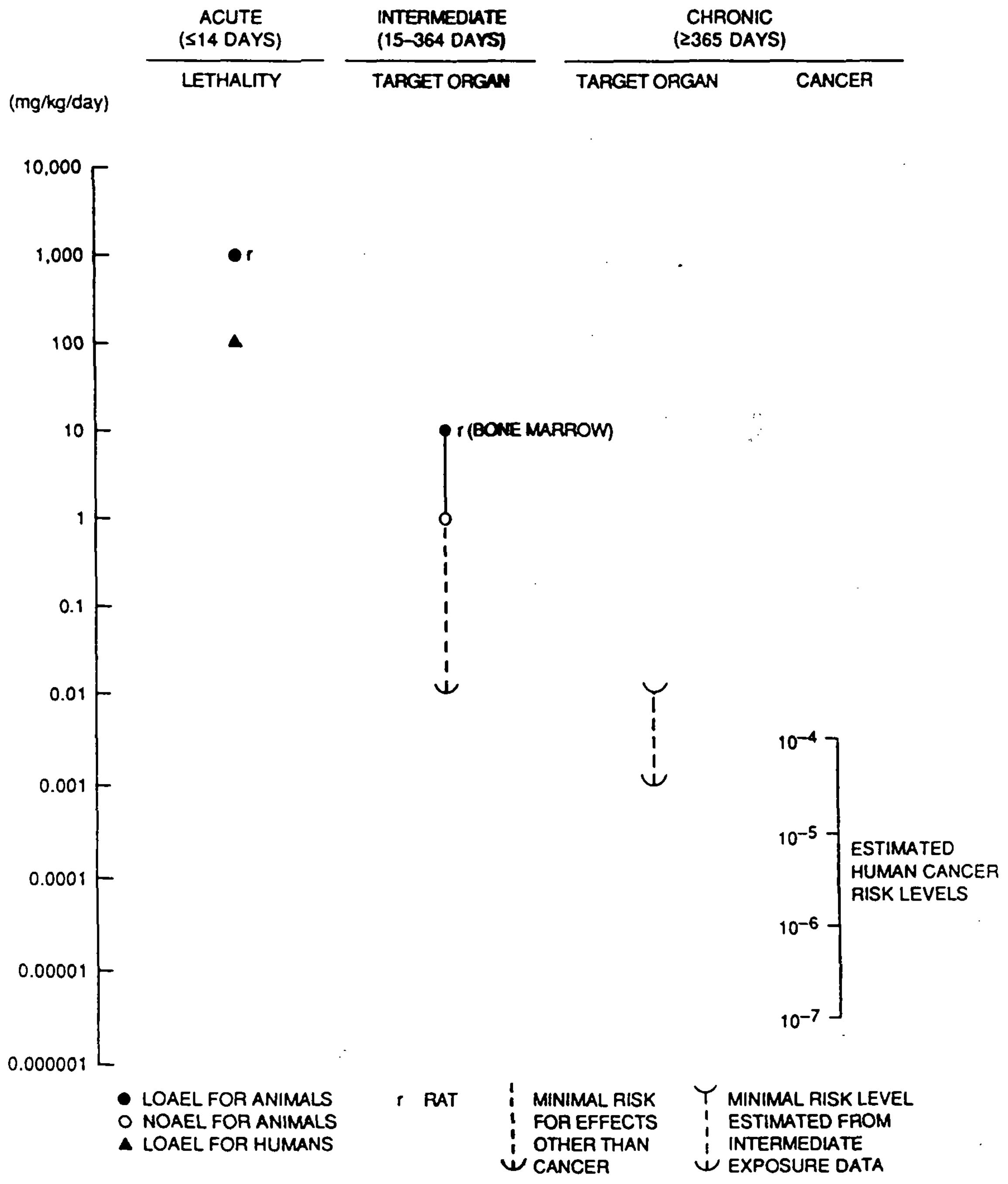
Appendix B-5



Levels of significant exposure for benzene—inhalation.

Source: PHS, 1987

Appendix B-6



. **Levels of significant exposure for benzene—oral.**

Source: PHS, 1987

Appendix C. Animal Health Effects from Breathing Toluene

Short-term Exposure
(less than or equal to 14 days)

Levels in Air (ppm)	Duration of Exposure	Description of Effects**
200	1 wk	Abnormal fetal development in mice
1000	2 wks	Loss of hearing in rats
2600	3 hrs	Intoxicated state in mice
3000	1 wk	Slight effect on liver weight in rats

Long-term Exposure
(greater than 14 days)

Levels in Air (ppm)	Duration of Exposure	Description of Effects**
320	1 mo	Decreased body and brain weight in rats
600	5 wks	Lung irritation and moderate kidney damage
2000	95 days	Inhibition of growth in rats

** These effects are listed at the lowest level at which they were first observed. They may also be seen at higher levels.

Source: PHS, 1989

APPENDIX D

Summary Table for Xylene

	Species	Experimental Dose/Exposure	Effect	Acceptable Intake (AIS or AIC)	Reference
Inhalation					
AIS					
o-xylene	rat	150 mg/m³	fetotoxicity NOEL	67.2 mg/day	Ungvary et al., 1980
m-xylene	rat	4750 mg/m³ 8 hours/day	hepatomegaly weight loss	70.7 mg/day	Tatrai et al., 1981
mixed xylenes	rat	433 mg/m³ 6 hours/day	fetotoxicity NOEL	48.3 mg/day	Litton Bionetics, 1978
p-xylene	NA	NA	NA	ND	NA
AIC					
o-xylene	rat	4750 mg/m³ 8 hours/day	hepatomegaly weight loss	14.1 mg/day	Tatrai et al., 1981
m-xylene	rat	4750 mg/m³ 8 hours/day	hepatomegaly weight loss	14.1 mg/day	Tatrai et al., 1981
mixed xylenes	rat	3500 mg/m³ 6 hours/day	transient blood alterations	27.9 mg/day	Carpenter et al., 1975
p-xylenes	NA	NA	NA	ND	NA

Source: EPA, 1984.

Appendix D (cont'd)

	Species	Experimental Dose/Exposure	Effect	Acceptable Intake (AIS or AIC)	Reference
Oral					
AIS					
o-, m- and mixed xylenes	rat	200 ppm food	ultrastructural liver changes	7 mg/day	Bower et al., 1982
p-xylene	NA	NA	NA	ND	NA
AIC					
o-, m- and mixed xylenes	rat	200 ppm food	ultrastructural liver changes	0.7 mg/day	Bowers et al., 1982
p-xylene	NA	NA	NA	ND	NA

NA = Not applicable; ND = not derived