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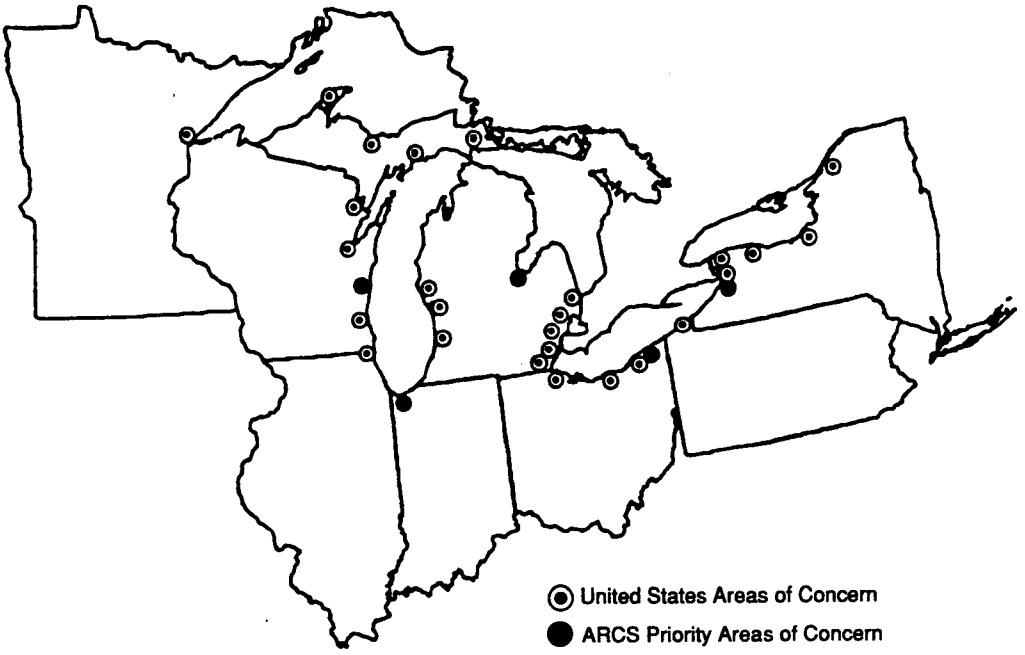
# Assessment and Remediation Of Contaminated Sediments (ARCS) Program

# POLLUTANT LOADINGS TO THE BUFFALO RIVER AREA OF CONCERN FROM INACTIVE HAZARDOUS WASTE SITES



# Pollutant Loadings to the Buffalo River Area of Concern from Inactive Hazardous Waste Sites

*Final Report - December, 1991*

prepared for

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## ABSTRACT

An analysis is presented which identifies inactive hazardous wastes sites contributing one or more targeted pollutants (PCBs, pesticides, PAHs, metals) to the Buffalo River Area of Concern via groundwater flows and estimates the associated pollutant loadings. Based on a review of existing data, six sites are identified which likely contribute pollution to the Buffalo River: Allied Chemical, Buffalo Color, Lehigh Valley Railroad, MacNaughton-Brooks, Madison Wire, and West Seneca Transfer Station. Other sites are identified (Tifft Farm Nature Preserve and Houghton Park) which might potentially be contributing pollutants to the Buffalo River, but data are not sufficient to allow estimation of loadings from these sites.

The principal targeted pollutants present at the identified sites include copper, iron, lead, and PAHs. While PCBs are present at low levels in the soils at three sites and the pesticide chlordane present at a low level at one site, these chemicals were not detected in the groundwater. Available data suggests that PCB and pesticide pollution of the Buffalo River via the groundwater pathway does not appear to be significant; therefore, loadings for these chemicals are not evaluated. It is also noted that several of the identified sites likely contributing significant quantities of non-targeted volatile and semi-volatile organic and metal pollutants to the Buffalo River in addition to those targeted in the present study.

Pollutant loadings to the Buffalo River are estimated using mathematical models for contaminant transport by groundwater. An analytical model is applied at the Allied Chemical, Lehigh Valley Railroad, MacNaughton-Brooks, Madison Wire and West Seneca Transfer Station sites, while a numerical model is applied at the Buffalo Color site. These models are parameterized using published data and literature values. Computed metal loadings for individual sites range as follows: copper, 0 to 78.6 kg/yr; iron, 0 to 1,620 kg/yr; and lead, 0 to 2.09 kg/yr. Computed PAHs loadings are as follows: benzo(a)anthracene, 0.223 kg/yr; benzo(b)fluoranthene, 0.0709 kg/yr; benzo(k)fluoranthene, 0.0081 kg/yr; benzo(a)pyrene, 0.0192 kg/yr; and chrysene, 0.0304 kg/yr. Decreasing the uncertainty associated with these loading estimates will require site specific field investigations.

## TABLE OF CONTENTS

1. Introduction ..... 1
    1.1 Background ..... 1
    1.2 Objectives and Scope ..... 1
    1.3 Approach ..... 2
2. Regional Geology and Hydrogeology ..... 2
3. Site Identification ..... 3
    3.1 Inactive Hazardous Waste Sites in Buffalo River AOC ..... 4
    3.2 Inactive Hazardous Waste Sites With Targeted Contaminants ..... 8
    3.3 Inactive Hazardous Waste Sites Discharging to the Buffalo River ..... 14
    3.4 Inactive Hazardous Waste Sites and Non-Targeted Pollutants ..... 18
4. Loading Estimate Methodology ..... 19
    4.1 Plane Dispersion Model ..... 19
        4.1.1 Governing Equation and Solution ..... 19
        4.1.2 Parameterization ..... 20
    4.2 Method of Characteristics Model ..... 24
        4.2.1 Governing Equation and Solution ..... 24
        4.2.2 Parameterization ..... 24
5. Results ..... 49
    5.1 Allied Chemical, Lehigh Valley, MacNaughton-Brooks, Madison Wire, West Seneca ..... 49
    5.2 Buffalo Color ..... 49
6. Discussion ..... 57
    6.1 Pollutant Loadings via Groundwater ..... 57
    6.2 Uncertainty Associated with Loading Estimates ..... 58
    6.3 Pollutant Loadings via Other Pathways ..... 59
7. Summary and Recommendations ..... 59
8. References ..... 62

# 1. INTRODUCTION

## 1.1 Background

On May 1, 1990, the Great Lakes Program of the State University of New York at Buffalo and the Center for Environmental Research and Education at the State University College at Buffalo entered into a cooperative agreement with the Great Lakes National Program Office of the U. S. Environmental Protection Agency (USEPA) to provide field, laboratory and engineering support for the Buffalo River Mass Balance Project. The work scope of this project includes estimates of pollutant loadings to the Buffalo River Area of Concern (AOC) from industrial and municipal wastewater discharges, inactive hazardous waste sites, combined sewer outfalls, and upstream tributaries. This report summarizes the pollutant loadings to the Buffalo River AOC from inactive hazardous waste sites.

## 1.2 Objectives and Scope

Primary study objectives include: (1) identification of inactive hazardous waste sites which may be contributing one or more targeted pollutants to the Buffalo River AOC through groundwater flows; and (2) estimation of the groundwater pollutant loadings (dissolved phase) from the identified inactive hazardous waste sites to the Buffalo River AOC.

The scope of this study is limited to a list of pollutants targeted by the USEPA. The list includes a number of hydrophobic organic chemicals, including polychlorinated biphenlys (PCBs), 3 pesticides, and 5 polycyclic aromatic hydrocarbons (PAHs), and 3 metals. Specific chemicals and some of their properties are summarized in Table 1.1. Iron, a conventional parameter in this study, has been included in the list due to evidence of high groundwater concentrations. While many other organic and inorganic pollutants are present at some waste sites, and are contributing significantly to the pollution of the Buffalo River, loading estimates for these non-targeted pollutants are not within the present work scope.

Loading estimates are provided for dissolved phase pollutants only. Data at the Buffalo Color Corporation site suggest the presence of nonaqueous phase liquid (NAPL) contamination of the subsurface. Estimating the potential loadings to the Buffalo River from NAPL migration is beyond the scope of this investigation.

Note that the identification of inactive hazardous waste sites and pollutant loading estimates are based on data that were available in the form of Phase I, Phase II, Remedial Investigation and other studies prepared for the New York State Department of Environmental Conservation (NYSDEC). The preliminary nature of this study precluded site-specific field work which might better characterize the hydrogeology and extent of off-site migration of the targeted pollutants for the various waste sites.

Table 1.1. Pollutants of concern and their chemical properties (chemical properties from USEPA Risk Reduction Engineering Laboratory Treatability Data Base, and Lyman et al., 1990).

| Chemical Name | Water Solubility ($\mu$g/L) | Henry's Constant (atm-m$^3$/mole) | Log $K_{ow}$ |
|---|---|---|---|
| **PCBs** | | | |
| Total | 0.46 to 7,000 | 9e-6 to 2.5e-4 | 4.33 to 7.13 |
| **Pesticides** | | | |
| Chlordane | 56 | 4.79e-5 | 2.78 |
| Dieldrin | 186 | 5.84e-5 | 4.09 |
| p,p'-DDT | 3.1 | 3.89e-5 | 6.19 |
| **PAHs** | | | |
| Benzo(a)anthracene | 44 | ? | 5.61 |
| Benzo(a)pyrene | 3.8 | 4.90e-7 | 5.98 |
| Benzo(b)fluoranthene | 14 | 1.19e-5 | 6.57 |
| Benzo(k)fluoranthene | 1.6 | ? | 6.84 |
| Chrysene | 6 | 1.05e-6 | 5.61 |
| **Metals** | | | |
| Copper | - | - | - |
| Iron | - | - | - |
| Lead | - | - | - |

### 1.3 Approach

The approach taken in this study was to (1) identify inactive hazardous waste sites which likely contribute one or more of the targeted pollutants to the Buffalo River via the groundwater pathway, and (2) quantify the associated pollutant loadings (mass per unit time). Candidate sites were identified using existing soils and groundwater data. Pollutant loadings were estimated using groundwater pollutant transport models. The complexity of the groundwater modeling effort was commensurate with available data, i.e., numerical model studies were performed at sites where the hydrogeology is well-characterized, while simple engineering analyses were performed at sites where data are sparse.

## 2. REGIONAL GEOLOGY AND HYDROGEOLOGY

The surficial geology of this region is described by Muller (1977) and the bedrock geology by Buehler and Tesmer (1963). The regional hydrogeology is described by La Sala (1968). Additional descriptions are given in the various Phase I, Phase II and Remedial Investigation Reports for sites within the AOC.

The Buffalo River AOC lies within the Erie-Niagara basin and the Erie-Ontario lowland physiographic province. Approximately 10,000 years ago, the Lake Erie plain was covered by glacial lakes ancestral to the present Lake Erie. This area consists of smooth to gently rolling hills which rise in elevation toward the south to 1,000 ft MSL.

Overburden in the region is comprised of unconsolidated, poorly sorted glacial till and moraine deposits and clay-rich lacustrine deposits, which lie unconformably over sedimentary bedrock. These units form a thin mantel over bedrock. As the ancestral glacial lakes retreated, beach sands were deposited. Recent alluvium is present also at sites immediately adjacent to the Buffalo River, derived by the re-working of the flood plain by the river.

Bedrock in this region is exclusively sedimentary, consisting of shale, limestone, and dolomite of the Silurian and Devonian Periods. Bedrock units dip southward at approximately 40 ft/mi. Formations underlying the unconsolidated glacial sediments within the Buffalo River AOC include Onondaga Limestone, Marcellus Shale, and Skaneateles Shale. The Onondaga Limestone, which is approximately 108 ft thick and consists of a gray, cherty limestone, is Devonian in age and unconformably overlies the upper Silurian formations. The Marcellus Shale is 30 to 50 ft thick and consists of a black, dense fissile shale. The Skaneateles Shale is 60 to 90 ft thick and consists of olive gray, gray and black, fissile shale with some calcareous beds and pyrite.

Significant amounts of groundwater occur in the overburden and the some of the lower bedrock units. The glacial sediments and glaciolacustrine sediments have very low hydraulic conductivities, due to their high silt and clay contents. Beach sand deposits have relatively high hydraulic conductivities, but they are generally too discontinuous to transmit sufficient water for industrial or domestic use. The recent alluvium also exhibits relatively high hydraulic conductivities. These glacial and alluvial deposits are the water-bearing zones of interest in the present study.

Of the bedrock formations underlying the AOC, only the Onondaga Limestone formation is an aquifer. Groundwater in the Onondaga Aquifer moves through solutions channels formed along fractures, vertical joints, and bedding planes and yields of up to 100 gal/min have been reported (Staubitz and Miller, 1987). Only minor amounts of groundwater are found in the overlying Marcellus Shale and Skaneateles Shale, and only minor groundwater transmission occurs along small fractures. In the southern portion of Erie County, these shale formations behave as aquitards and aquicludes.

## 3. SITE IDENTIFICATION

Inactive hazardous waste sites which may be contributing one or more of the targeted pollutants to the Buffalo River through groundwater flows were identified by a tiered screening process:

(1) Sites within or adjacent to the Buffalo River AOC and having some potential for contaminant migration were identified.

(2) Sites identified in (1) were further screened for the presence of the targeted pollutants in subsurface soils and groundwater. Sites were identified for which the targeted pollutant levels were present in the groundwater and in excess of the background levels and/or water quality standards.

(3) Groundwater levels for the sites identified in (2) were examined to determine regional flow patterns. Sites for which groundwater flows discharge to the Buffalo River were identified.

Loading estimates were then performed for sites identified by the screening procedure. Details of the site identification process are given below.

### 3.1 Inactive Hazardous Waste Sites in Buffalo River AOC

The Buffalo River Remedial Action Plan (RAP) developed by NYSDEC (1989) lists 32 inactive hazardous waste sites in the Buffalo River watershed, 18 of which may be potential contributors of pollution to the Buffalo River AOC. Locations of all sites are given in Figures 3.1 and 3.2, and some characteristics for the 18 sites local to the AOC are summarized in Table 3.1.

Included in Table 3.1 is an assessment for contaminant migration potential as determined by the RAP, based on data available at the time of its publication. Contaminant migration was "confirmed" at one site, "indicated" at four sites, "not indicated" at five sites, and "indeterminable" at eight sites. Sites for which contaminant migration was "not indicated" were eliminated and included: Ameron, Bengart & Memel, Inc., Houdaille Industries Manzell Division, Mobile Oil Corporation, and Mollenburg-Betz Machine. Also, sites where contaminant migration was deemed "indeterminable" were eliminated in the absence of soil or water quality data, i.e., no studies beyond the Phase I level exist. Environmental sampling is usually not within the work scope of these preliminary studies. Therefore, the following sites were eliminated from further consideration in this study: Clinton-Bailey, Tifft-Hopkins, and U. S. Steel Eastern Division. Finally, the Erie-Lackawana Railroad site was removed from consideration since it has been de-listed from the "Registry of Inactive Hazardous Waste Disposal Sites in New York State" subsequent to the preparation of the RAP (personal communication, Martin Doster, NYSDEC, August 15, 1991).

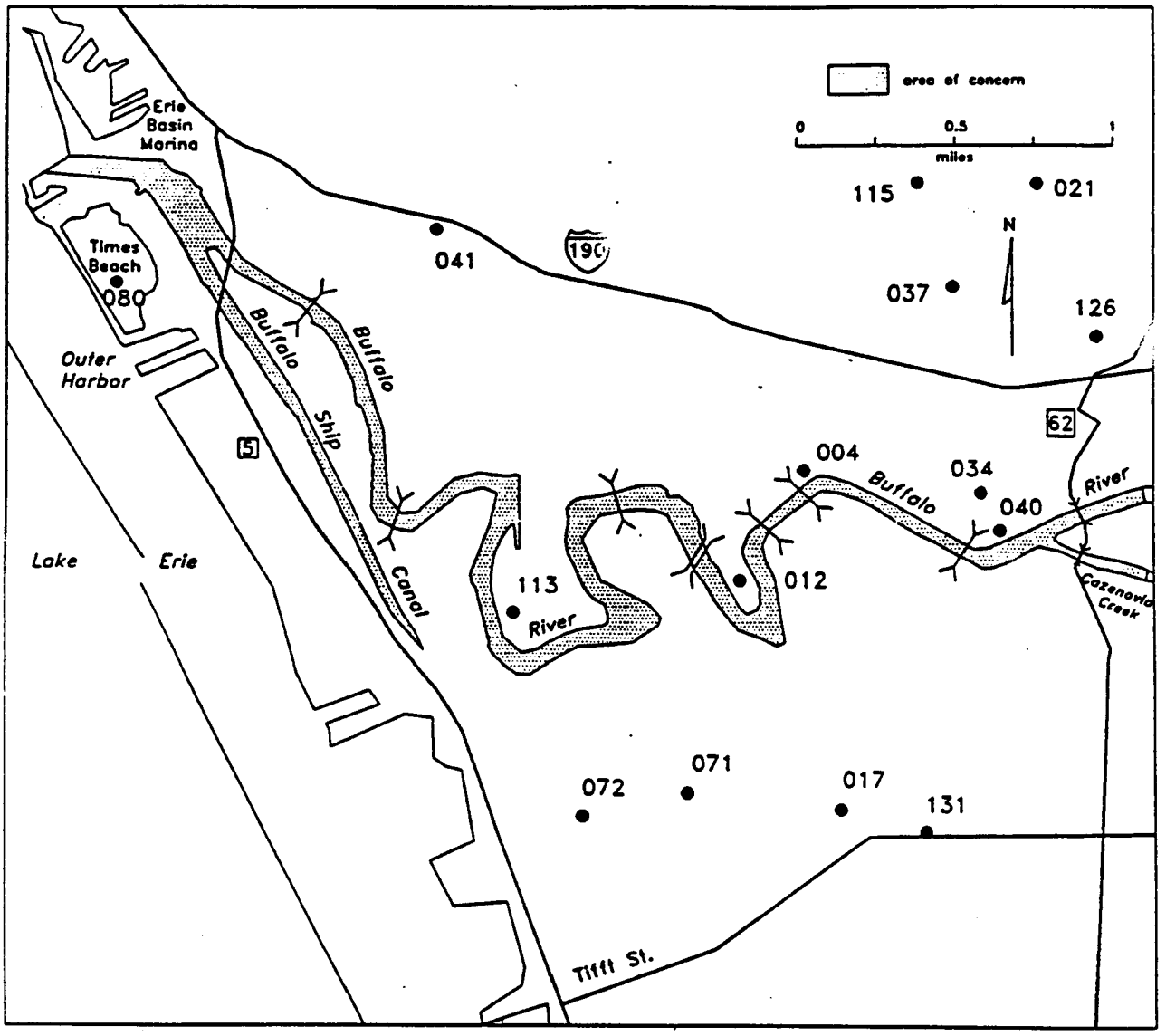



Fig. 3.1. Location of inactive hazardous waste sites within the Buffalo River AOC (after NYSDEC, 1989).

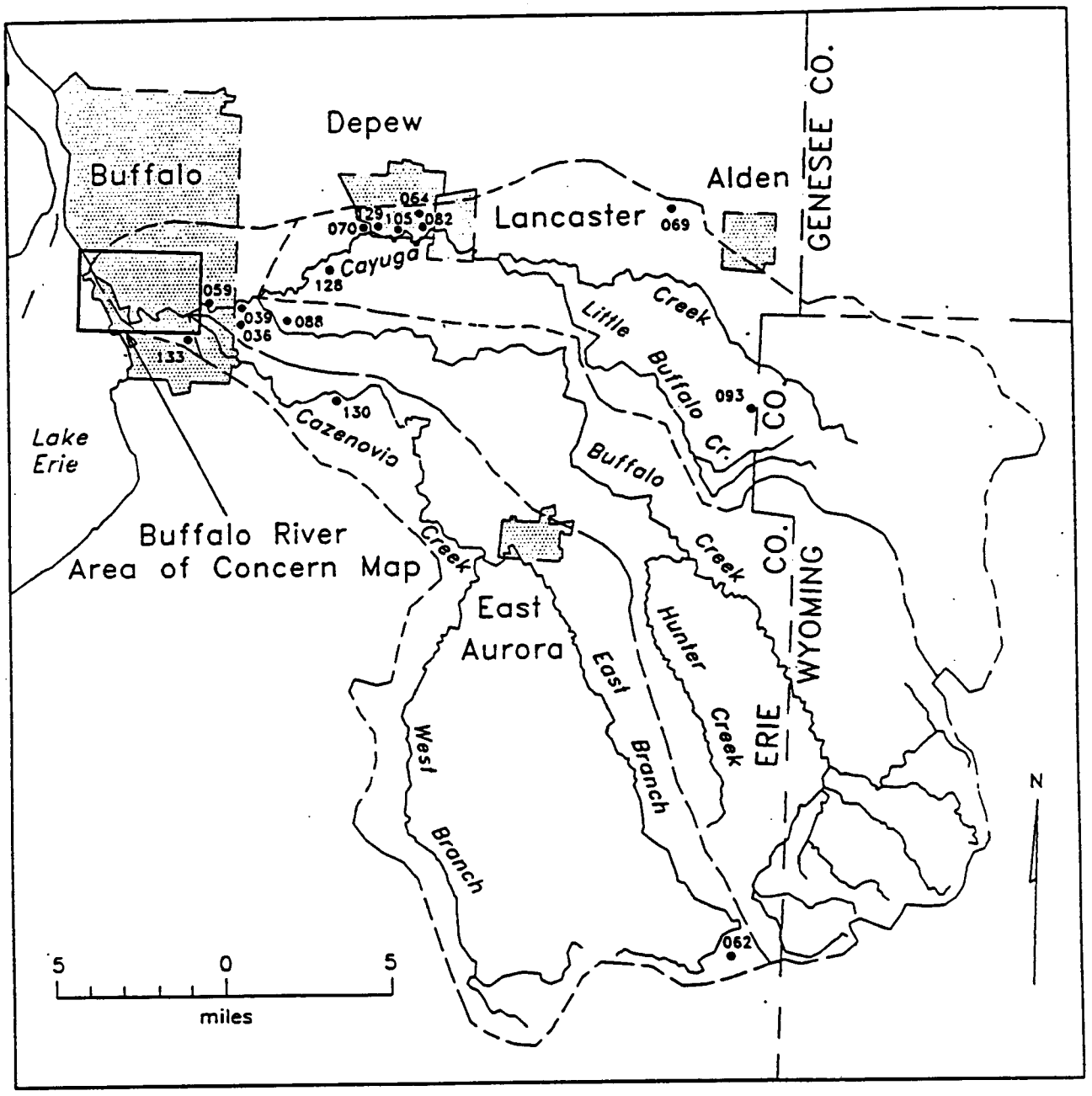



Fig. 3.2. Location of inactive hazardous waste sites within the Buffalo River watershed (after NYSDEC, 1989).

Table 3.1. Characteristics of inactive hazardous wastes sites local to the Buffalo River AOC.

| Site Name | Site Number | Years in Operation | Size | Distance to Buffalo River | Remediation Status | Contaminant Migration Potential |
|---|---|---|---|---|---|---|
| Allied Chemical Ind. Chem. Div. | 915004 | 1930-1977 | 1 ac | 50 ft | Phase II | Indicated |
| Ameron | 915133 | 1960-1983 | 1 ac | 6,600 ft | Remediation underway | Not Indicated |
| Bengart & Memel, Inc. | 915115 | 1950-1978 | 1 ac | 5,000 ft | Remediated | Not Indicated |
| Buffalo Color Corp. | 915012 | 1960-1976 | 2 ac | adjacent | Remedial Investigation | Confirmed |
| Clinton-Bailey | 915126 | unknown | 12 ac | 3,500 ft | Phase I | Indeterminable |
| Donner Hanna Coke | 915017 | 1951-1975 | 20 ac | 2,000 ft | Phase II | Indeterminable |
| Erie-Lackwana Railroad | 915021 | unknown | NA | 5,700 ft | Phase I | Indeterminable |
| Houdaille Ind. Manzell Div. | 915037 | ?-1978 | 1 ac | 4,000 ft | ? | Not Indicated |
| Houghton Park | 915059 | ?-1973 | 15 ac | 100 ft | Phase I | Indicated |
| Lehigh Valley Railroad | 915071 | unknown | 20 ac | 500 ft | Phase II | Indeterminable |
| MacNaughton-Brooks | 915034 | 1960-1966 | 1 ac | 800 ft | Phase II | Indicated |
| Madison Wire | 915036 | ?-1982 | 1 ac | 3,800 ft | Remedial Investigation | Indicated |
| Mobil Oil Corp. | 915040 | 1951-1976 | 3 ac | adjacent | Phase II | Not Indicated |
| Mollenberg-Betz Machine | 915041 | ?-1978 | 1 ac | 2,000 ft | Phase I | Not Indicated |
| Tifft Farm Nature Preserve | 915072 | 1940s-1973 | 260 ac | 500 ft | Phase II | Indeterminable |
| Tifft-Hopkins St. | 915131 | unknown | 2.3 ac | 4,000 ft | Phase I underway | Indeterminable |
| U.S. Steel Eastern Div. | 915113 | 1917-1979 | 1 ac | 100 ft | Phase I | Indeterminable |
| West Seneca Transfer Station | 915039 | 1930s-1970 | 10 ac | 200 ft | Phase II | Indeterminable |

## 3.2 Inactive Hazardous Waste Sites With Targeted Contaminants

Sites identified in the previous section as having some potential for contaminant migration were further screened for presence of the targeted pollutants in both soils and groundwater at elevated concentrations using the data in Phase II, Remedial Investigation and other studies prepared for the NYSDEC. The data sources used for each site assessment are given in Table 3.1. Soil concentrations for metals were considered elevated if observed values exceeded the typical background range for soils of this region as reported by Shacklette and Boerngen (1984). Groundwater concentrations for metals and organics were considered elevated if observed values exceeded the NYSDEC Class GA water quality standard (NYSDEC, Water Quality Regulations Title 6, Chapter 10, Part 703.5).

Results are summarized in Table 3.2 which reports the observed pollutant concentrations range and frequency of detection in both soils and groundwater. For example, measured chrysene concentrations in the soils at the Buffalo Color site ranged from 0.35 to 180 mg/kg and the chemical was detected in 6 out of the 43 soil samples analyzed. Elevated concentrations, i.e., those exceeding the NYSDEC Class GA water quality standards are highlighted. A review of Table 3.2 shows the primary soil and groundwater contaminants to be metals and PAHs with isolated occurrences of PCBs and the pesticide chlordane.

Copper, iron, and lead are present at elevated levels in both soils and groundwater at virtually all sites. Concentrations are often well in excess of expected background levels in soils and the Class GA standards. Iron concentrations appear to be universally high. It is not clear from the data available if these levels are attributable to waste disposal practices, or if the iron concentrations in the soil and groundwater are naturally high for this region.

PAHs are present in the soils of 6 sites, including Buffalo Color, Donner Hanna Coke, Houghton Park, Lehigh Valley Railroad, Madison Wire, and Tifft Farm Nature Preserve. In the groundwater, however, PAHs were detected at only the Buffalo Color site. The lack PAHs in the groundwater at sites where the chemicals are prevalent in the soils is attributed to the high affinity of the PAHs for soil-associated organic carbon. A simple order-of-magnitude analysis can be made using the partitioning theory for hydrophobic organic chemicals (Karickhoff, 1984). At equilibrium, the solid phase concentration, S, is related to the water phase concentration, C, as

(3.1) $S = K_p C$

where $K_p$ = partition coefficient. The magnitude of $K_p$ can be estimated as

(3.2) $K_p = 0.63 K_{ow} f_{oc}$

where $K_{ow}$ = octanol-water partition coefficient; and $f_{oc}$ = soil fraction organic carbon. Assuming a Log $K_{ow}$ = 6 to be representative of PAHs and a typical value of $f_{oc}$ = 0.01, an expected groundwater concentration can be computed from (3.1) and (3.2) given a soil concentration. A perusal of Table 3.2 shows a typical PAH subsurface soil concentration to be on the order of 1 mg/kg. The corresponding groundwater concentration is computed to be 0.16 $\mu$g/L. Values of this magnitude (parts per trillion) are usually below the contract detection limit for most inactive hazardous waste site investigations and small enough to be negligible in terms

of groundwater transport. Therefore, PAH loading estimates were made only for the Buffalo Color site where there is evidence of groundwater migration.

PCBs were detected at low levels in the soils of the Lehigh Valley Railroad, Tifft Farm Nature Preserve, and West Seneca Transfer Station Sites. Soil concentrations are on the order of 1 mg/kg which is well below the level constituting hazardous waste. No PCBs were detected in the groundwater, probably due to the hydrophobic nature of these chemicals. Of the pesticides, only chlordane was detected in one soil sample of the MacNaughton-Brooks site. No chlordane was found in the groundwater. Otherwise, there is no evidence of pesticide contamination at the waste sites examined. In view of the presently available data, there appears to be only very limited PCB and pesticide contamination of the inactive hazardous waste sites of concern and no evidence of groundwater migration. Therefore, these pollutants were not considered in groundwater loadings to the Buffalo River.

In summary, one or more of the targeted metals were detected in the groundwater at the following sites: Allied Chemical, Buffalo Color, Donner Hanna Coke, Houghton Park, Lehigh Valley Railroad, MacNaughton Brooks, Madison Wire, Tifft Farm Nature Preserve, and West Seneca Transfer Station. PAHs were detected in the groundwater only at the Buffalo Color site.

| | Allied Chemical Ind. Chem. Div. | | Buffalo Color Corporation | | |
|---|---|---|---|---|---|
| Pollutant<br>NA = not analyzed<br>ND = not detected | Soil Concentrations (mg/kg) | Groundwater Concentrations (ug/L) | Surface Soil Concentrations (mg/kg) | Subsurface Soil Concentrations (mg/kg) | Groundwater Concentrations (ug/L) |
| Chlorinated Aromatic Hydrocarbons | | | | | |
| Total PCBs | NA | ND (6/6) | NA | NA | ND (35/35) |
| Chlordane | NA | ND (6/6) | NA | NA | ND (35/35) |
| Dieldrin | NA | ND (6/6) | NA | NA | ND (35/35) |
| p,p'-DDT | NA | ND (6/6) | NA | NA | ND (35/35) |
| Polycyclic Aromatic Hydrocarbons | | | | | |
| Benzo(a)anthracene | NA | ND (6/6) | 180 (1/9) | 1.1-6.7 (4/34) | 1.0-12 (4/35) |
| Benzo(a)pyrene | NA | ND (6/6) | 140 (1/9) | 0.17-5.5 (7/34) | 0.6-7 (2/35) |
| Benzo(b)fluoranthene | NA | ND (6/6) | 140 (1/9) | 1.6-9.7 (4/34) | 0.3 (1/35) |
| Benzo(k)fluoranthene | NA | ND (6/6) | 140 (1/9) | ND (34/34) | 0.6 (1/35) |
| Chrysene | NA | ND (6/6) | 180 (1/9) | 0.35-8.2 (5/34) | 0.9-11 (4/35) |
| Metals | | | | | |
| Copper | NA | 30-290 (4/6) | 36.2-3,580 (9/9) | 6-4,630 (34/34) | 15-78,700 (33/35) |
| Iron | NA | 15,500-333,900 (5/6) | 15,200-537,000 (9/9) | 1.75-360,000 (34/34) | 3,940-405,000 (35/35) |
| Lead | NA | 32.2-200 (3/6) | 8.9-27,300 (9/9) | 8.4-83,200 (34/34) | 5-2,670 (28/35) |

Table 3.2. Summary of pollution at inactive hazardous waste sites.

| | Donner Hanna Coke | | Houghton Park | | Lehigh Valley Railroad | |
|---|---|---|---|---|---|---|
| Pollutant<br>NA = not analyzed<br>ND = not detected | Subsurface Soil Concentrations (mg/kg) | Groundwater Concentrations (ug/L) | Subsurface Soil Concentrations (mg/kg) | Groundwater Concentrations (ug/L) | Subsurface Soil Concentrations (mg/kg) | Groundwater Concentrations (ug/L) |
| Chlorinated Aromatic Hydrocarbons | | | | | | |
| Total PCBs | ND (1/1) | ND (6/6) | ND (20/20) | ND (7/7) | 1.1-4.1 (3/6) | ND (7/7) |
| Chlordane | ND (1/1) | ND (6/6) | NA | NA | ND (6/6) | ND (7/7) |
| Dieldrin | ND (1/1) | ND (6/6) | NA | NA | ND (6/6) | ND (7/7) |
| p,p'-DDT | ND (1/1) | ND (6/6) | NA | NA | ND (6/6) | ND (7/7) |
| Polycyclic Aromatic Hydrocarbons | | | | | | |
| Benzo(a)anthracene | 0.12 (1/5) | ND (6/6) | 8.7 (1/1) | NA | 0.23-1.4 (5/6) | ND (7/7) |
| Benzo(a)pyrene | 0.079 (1/5) | ND (6/6) | 17 (1/1) | NA | 0.15-0.69 (2/6) | ND (7/7) |
| Benzo(b)fluoranthene | 0.12 (1/5) | ND (6/6) | 22 (1/1) | NA | 0.26-0.77 (3/6) | ND (7/7) |
| Benzo(k)fluoranthene | 0.12 (1/5) | ND (6/6) | 6.3 (1/1) | NA | 0.28-0.52 (3/6) | ND (7/7) |
| Chrysene | 0.24 (1/5) | ND (6/6) | 14 (1/1) | NA | 0.24-0.72 (4/6) | ND (7/7) |
| Metals | | | | | | |
| Copper | 47.3 (1/1) | 11-85 (5/6) | 11.3-1,090 (20/20) | 50-205 (7/7) | 13.4-10,980 (6/6) | ND (7/7) |
| Iron | 53.5-8,100 (5/5) | 630-9,300,000 (6/6) | NA | NA | 4,098-179,000 (6/6) | 580-211,000 (7/7) |
| Lead | 150 (1/1) | 96.4 (1/6) | 1.05-2,740 (20/20) | 23.2-959 (7/7) | 35.3-280 (6/6) | 8.6 (1/7) |

| | MacNaughton-Brooks | | Madison Wire | | |
|---|---|---|---|---|---|
| Pollutant<br>NA = not analyzed<br>ND = not detected | Subsurface Soil Concentrations (mg/kg) | Groundwater Concentrations (ug/L) | Surface Soil Concentrations (mg/kg) | Subsurface Soil Concentrations (mg/kg) | Groundwater Concentrations (ug/L) |
| Chlorinated Aromatic Hydrocarbons | | | | | |
| Total PCBs | ND (2/2) | ND (3/3) | NA | ND (40/40) | ND (14/14) |
| Chlordane | 92 (1/2) | ND (3/3) | NA | ND (40/40) | ND (14/14) |
| Dieldrin | ND (2/2) | ND (3/3) | NA | ND (40/40) | ND (14/14) |
| p,p'-DDT | ND (2/2) | ND (3/3) | NA | ND (40/40) | ND (14/14) |
| Polycyclic Aromatic Hydrocarbons | | | | | |
| Benzo(a)anthracene | ND (2/2) | ND (3/3) | 0.099-17 (13/18) | 0.12-17 (12/36) | ND (14/14) |
| Benzo(a)pyrene | ND (2/2) | ND (3/3) | 0.058-12 (15/18) | 0.25-14 (13/36) | ND (14/14) |
| Benzo(b)fluoranthene | ND (2/2) | ND (3/3) | 0.079-23 (17/18) | 0.29-15 (14/36) | ND (14/14) |
| Benzo(k)fluoranthene | ND (2/2) | ND (3/3) | ND (18/18) | ND (36/36) | ND (14/14) |
| Chrysene | ND (2/2) | ND (3/3) | ? | 0.26-17 (14/36) | ND (14/14) |
| Metals | | | | | |
| Copper | 0.18-0.44 (2/2) | 40-400 (3/3) | 28.2-1,120 (19/19) | 15.2-7,320 (59/59) | 10.3-9,550 (6/14) |
| Iron | 31.4-65.5 (2/2) | 32,600-341,200 (3/3) | 10,300-264,000 (19/19) | 5,570-429,000 (59/59) | 384-104,000 (14/14) |
| Lead | 1.27-1.28 (2/2) | ND (3/3) | 53.9-3,220 (19/19) | 9-11,500 (59/59) | 7.6-384 (6/14) |

Table 3.2. Summary of pollution at inactive hazardous waste sites.

| | Tifft Farm Nature Preserve | | West Seneca Transfer Station | |
|---|---|---|---|---|
| Pollutant<br>NA = not analyzed<br>ND = not detected | Surface Soil Concentrations (mg/kg) | Groundwater Concentrations (ug/L) | Subsurface Soil Concentrations (mg/kg) | Groundwater Concentrations (ug/L) |
| Chlorinated Aromatic Hydrocarbons | | | | |
| Total PCBs | ND-3.1 | ND (7/7) | 3.8 (1/1) | ND (3/3) |
| Chlordane | ? | ND (7/7) | ND (1/1) | ND (3/3) |
| Dieldrin | ? | ND (7/7) | ND (1/1) | ND (3/3) |
| p,p'-DDT | ? | ND (7/7) | ND (1/1) | ND (3/3) |
| Polycyclic Aromatic Hydrocarbons | | | | |
| Benzo(a)anthracene | 0.14-32.7 | ND (7/7) | ND (1/1) | ND (3/3) |
| Benzo(a)pyrene | 0.01-6.0 | ND (7/7) | ND (1/1) | ND (3/3) |
| Benzo(b)fluoranthene | 0.10-68 | ND (7/7) | ND (1/1) | ND (3/3) |
| Benzo(k)fluoranthene | ? | ND (7/7) | ND (1/1) | ND (3/3) |
| Chrysene | 1.4 | ND (7/7) | ND (1/1) | ND (3/3) |
| Metals | | | | |
| Copper | 3-14,270 | ND (7/7) | 58.5 (1/1) | 85.9-122 (2/3) |
| Iron | 1,400-190,500 | 600-40,000 (7/7) | 31,500 (1/1) | 4,250-88,800 (3/3) |
| Lead | 10-3,590 | 5-50 (5/7) | 168 (1/1) | 5.1-134 (3/3) |

### 3.3 Inactive Hazardous Waste Sites Discharging to the Buffalo River

To evaluate the potential for pollutant migration to the Buffalo River via groundwater flows for the sites identified above, regional groundwater flow patterns were examined using groundwater levels reported in NYSDEC investigations. Sites were then identified for which the groundwater flows discharged to the Buffalo River. The hydrogeology, and groundwater levels and flow directions for each site are described below.

#### Allied Chemical Industrial Chemical Division

Based on the Phase II Investigation, the subsurface geology of the Allied Chemical site can be characterized as 3 to 13 ft of fill overlying up to 50 ft of alluvial and glacial sediments deposited over limestone bedrock.

Water levels were monitored in 6 wells: 3 shallow wells screened in the shallow, unconfined aquifer consisting of coarse-grained alluvium, and 3 deep wells screened in the upper portion of the limestone bedrock aquifer and partially into the overlying, confining glacial till. Levels in bedrock aquifer wells exceeded those in the shallow, unconfined aquifer. Therefore, the vertical component of flow is upward and only the flow direction in the shallow, unconfined aquifer need be considered in this study. Water levels in the shallow, unconfined aquifer indicates a south-southeasterly flow direction with apparent discharge to the Buffalo River.

#### Buffalo Color Corporation

The hydrogeology of the Buffalo Color site is much like that of the adjacent Allied Chemical site. Based on the Remedial Investigation, three major hydrogeologic units exist: (1) an unconfined, shallow aquifer consisting of fill with an underlying layer of alluvial silt, sand, and gravel having a saturated thickness of 10 to 18 ft; (2) an underlying aquitard comprised of very low permeability glaciolacustrine deposits and glacial till having a thickness of 35 to 45 ft; and (3) a confined, deep bedrock aquifer comprised of limestone.

Water levels were monitored in 24 wells, 22 screened in the unconfined, shallow aquifer and 2 screened in the glacial till of the underlying aquitard. Levels in the aquitard exceeded those in the unconfined aquifer above, indicating an upward component of flow. Groundwater levels in the unconfined, shallow aquifer on July 7 and August 16, 1988 show groundwater discharging to the Buffalo River.

#### Donner Hanna Coke

Results of the Phase II Investigation for the Donner Hanna Coke site, along with the adjacent Allifft Realty site, shows the stratigraphy to be slightly different to that of the Allied Chemical and Buffalo Color sites. The geology is characterized as 4 to 7 ft of coarse-grained coke fill overlying 40 ft of lacustrine sediments overlying glacial till deposited over limestone bedrock. The recent alluvium, present at sites closer to the Buffalo River, is absent at the Donner Hanna Coke site.

Four wells were monitored, all screened in the unconfined, shallow aquifer which exists in the fill material and upper portions of the lacustrine sediments. Measured water levels show groundwater flows to the southwest and southeast with general flow to the south. Regionally,

the groundwater flows westerly towards Lake Erie. Without additional data, there does not appear a groundwater flow component to the Buffalo River.

**Houghton Park**

Groundwater levels were not monitored at this site as part of the Phase I Investigation. Because the site is however located adjacent to the Buffalo River, it is likely that groundwater discharges to the river. However, without measured head gradients and hydraulic conductivities, groundwater flow velocities and, therefore, pollutant loading rates cannot be estimated.

**Lehigh Valley Railroad**

The Phase II Investigation for the Lehigh Valley Railroad site shows the presence of fill overlying lacustrine sediments comprised of inter-bedded silts, clays and sands. Presumably, the lacustrine sediments are the same as those detected at the adjacent Donner Hanna Coke site and at more distal sites. Borings were not advanced sufficiently to define the extent of any underlying till or bedrock, although fine to medium sands were encountered at the base of two borings.

An unconfined, shallow aquifer exists in the lower portions of the fill and upper portions of the lacustrine sediments. Water levels were measured at 5 wells on-site and 2 wells at the Tifft Farm site to the west. Since the monitoring wells were completed and screened in different stratigraphic units, the Phase II Investigation did not attempt to construct a potentiometric map, but did state that "the groundwater flow direction would appear to be towards the west" or Lake Erie. In the present analysis, there appears to be groundwater flow to the Buffalo River from the northern portion of the Lehigh Valley Railroad, while the middle and southern portions likely flow to the west and Lake Erie. Therefore, contaminants present in the northern part of the site (iron) will likely migrate towards the Buffalo River.

**MacNaughton-Brooks**

Based on the results of the Phase II Investigation for the MacNaughton-Brooks site, the subsurface geology can be characterized as 11 ft of fill consisting of sand, gravel, clay, and brick deposited over lacustrine clay. While no borings were advanced through the lacustrine deposit, this strata is probably underlain by glacial till deposited over limestone bedrock, as was determined at the nearby Allied Chemical site.

An unconfined, shallow aquifer is present in the fill and lacustrine clay. Water levels were measured in 3 monitoring wells screened in the fill and lacustrine clay on November 24, 1987 and February 18, 1988. Data on both dates show groundwater discharging to the southeast towards the Buffalo River.

**Madison Wire**

The Remedial Investigation for the Madison Wire site identified the following sedimentary strata: (1) fill material which consists of silts, clays, bricks, limestone chips, and metallic debris; (2) an upper heterogeneous unit of recent alluvium composed of gravels sands, and silty clays; (3) a middle unit of lacustrine clays and silty clays; (4) a lower unit of glacial

outwash composed of sand and gravel with moderate silts and minor clays; and (5) Skaleanteles shale which unconformably underlies the previously described overburden deposits.

Based on water measurements in 11 monitoring wells, the Remedial Investigation determined that the upper recent alluvium forms a shallow, unconfined aquifer and the lower glacial outwash forms a deep, confined aquifer. The middle lacustrine clay separates behaves as an aquiclude and separates the two aquifers. This middle aquiclude is prevalent over the entire site and effectively prevents hydraulic communication between the unconfined and confined aquifers. Also, analytical results for groundwater samples obtained from monitoring wells screened in the deep, confined aquifer show no evidence of significant contamination. Therefore, groundwater flows in the deep, confined aquifer were removed from further consideration.

Groundwater levels in the shallow, unconfined aquifer were measured on August 29, 1988, November 7, 1988 and March 24, 1989. There is seasonal variation associated with groundwater flow directions. For the most part however, groundwater flows southeasterly and discharges to a Class D stream which parallels the east property line of the site, and northerly and discharges to a marsh located just north of the site. The Class D stream flows north along the eastern site boundary and eventually enters the Calais Street sewer about 0.5 miles west of the site. Discharge from Calais Street sewer enters the Buffalo River at South Ogden Street, providing a pathway for groundwater contaminants to enter the Buffalo River via surface water. The marsh to the north of the site is poorly drained; groundwater discharging to the north may contaminant sediments and surface water in the marsh, but there is no surface water connection between the marsh and the Buffalo River.

**Tifft Farm Nature Preserve**

The Phase II Investigation for the Tifft Farm Nature Preserve shows the presence of 5 to 16 ft of fill overlying glaciolacustrine deposits consisting of inter-bedded clay, silt, and fine sand. While borings were not advanced to bedrock, the glaciolacustrine deposits were thought to be underlain by shale of the Marcellus Formation at a depth of about 50 ft.

Monitoring wells were installed at 7 locations and screened in the fill and upper portions of the glaciolacustrine deposit. Water levels were measured on November 9, 1985 and March 10-11, 1987. Since the wells were screened in different materials, the Phase II Investigation did not attempt to develop a potentiometric map to establish groundwater flow directions, but noted that "it appears that the flow is tending towards the west" and therefore towards Lake Erie.

Historical evidence shows that a rather extensive canal system once served this area and was hydraulically connected to the Buffalo River, the canals having been filled subsequently with porous and hazardous materials (personal communication, Robert Sweeney, Ecology & Environment). In fact, the linear features associated with these filled canals are evident today in the various surface water features of Tifft Farm. These filled canals might serve as a source of contamination and provide a conduit to the Buffalo River and Lake Erie. Since there has been no effort to assess these high permeability conduits in terms of contaminant transport potential, groundwater flow magnitudes and directions at this site are unknown. Without additional data, groundwater flow direction is considered "indeterminable" and further hydrogeological studies are recommended.

**West Seneca Transfer Station**

Based on the Phase II Investigation for the West Seneca Transfer Station, the geology can be characterized as fill overlying a sand/silt layer overlying a clay layer deposited over bedrock. The fill is 0 to 14 ft thick and consists of organic soils and construction and demolition debris. The underlying sand and silt layer also contains variable amounts of gravel and clay. Beneath the sand and silt layer is a homogeneous layer of lacustrine gray clay that extends in depth to bedrock at approximately 30 ft. The underlying bedrock, comprised of limestone and chert and bedrock, is part of the Skaneateles Formation.

Three monitoring wells were installed: two installed and screened in the unconsolidated sediments, and one installed and screened through the lower portion of the lacustrine clay and upper portion of the bedrock. Water levels measured on October 30, 1990 show northerly flow to the Buffalo River.

**Summary of Groundwater Discharges**

In summary, the available hydrogeological data indicates that groundwater discharges to the Buffalo River at the following hazardous waste sites: Allied Chemical, Buffalo Color, Houghton Park, Lehigh Valley Railroad (northern portion of site), MacNaughton-Brooks, and West Seneca Transfer Station. At the Madison Wire site, groundwater discharges to a Class D stream which eventually flows to the Buffalo River. For the Houghton Park site, insufficient hydrogeological data exists to allow estimation of pollutant loadings. The sites for which pollutant loadings were estimated and the targeted pollutants identified at each site are summarized in Table 3.3.

The sites identified in this study as being contributors of pollution to the Buffalo River are largely consistent with those identified by a previous USEPA study (Koszalka et al., 1985). Of the inactive hazardous waste sites within the AOC, Koszalka et al. (1985) identified Allied Chemical, Buffalo Color, McNaughton-Brooks, and Mobile Oil as having a major potential for contaminant migration. Mobile Oil was not included in the present study because the Phase II Investigation completed subsequently to the USEPA study indicated no significant contaminant migration.

Table 3.3. Summary of targeted pollutants at inactive hazardous waste sites of concern.

| Site | Organic Pollutants | Inorganic Pollutants |
|---|---|---|
| Allied Chemical | | Iron, lead |
| Buffalo Color | PAHs | Copper, iron, lead |
| Lehigh Valley Railroad | | Iron |
| MacNaughton-Brooks | | Iron |
| Madison Wire | | Copper, iron, lead |
| West Seneca Transfer | | Iron, lead |

### 3.4 Inactive Hazardous Waste Sites and Non-Targeted Pollutants

In addition to the targeted pollutants, a variety of volatile and semi-volatile organics and metals are present in the groundwater at several of the waste sites which discharge to the Buffalo River. In fact, the organic pollutants targeted for the present study often represent a small fraction of the overall site contamination. Loadings of these pollutants are not considered in the present study; however, these other pollutants may have significant consequences for the long-term management of the Buffalo River. The principal groundwater pollutants at each site, aside from those targeted in this study, are summarized in Table 3.4. Inorganic pollutants were listed if Class GA standards/guidance values were exceeded.

A review of Table 3.4 shows the Buffalo Color site to be one of the more heavily contaminated sites. Most of the organic contamination appears to consist of simple aromatics, chlorinated benzenes, and amines. Of the PAHs, only naphthalene is present is significant quantities. None of the targeted organic pollutants are present in significant quantities in the groundwater. Most of the metal contamination is attributed to iron, copper, aluminum, zinc, lead, chromium, and arsenic. Hence, a good case can be made for targeting iron, copper, and lead in Buffalo River mass balance modeling.

Table 3.4. Summary of principal non-targeted groundwater pollutants at inactive hazardous waste sites of concern.

| Site | Organic pollutants | Inorganic pollutants |
|---|---|---|
| Allied Chemical | benzene, toluene | cadmium, mercury, silver |
| Buffalo Color | aniline, chlorobenzene, ethylbenzene, 1-naphthylamine, benzene, 1,2-dichlorobenzene, 4-chloroaniline, naphthalene, 1,4-dichlorobenzene, toluene, 2-chlorophenol, xylene, 1,2,4-trichlorobenzene, benzidine, phenol | arsenic, cadmium, chromium, mercury, zinc |
| Houghton Park | phenols | barium, cadmium, chromium |
| Lehigh Valley Railroad | xylenes,1,2-dichloroethene | manganese |
| MacNaughton-Brooks | benzene | arsenic, barium, magnesium, manganese |
| Madsion Wire | 1,1-dichloroethane, 1,2-dichloroethene, 1,1,1-trichloroethane, toluene, benzene, ethyl benzene, xylene, pyrene (trace levels of all) | arsenic, chromium, manganese |
| Tifft Farm Nature Preserve | | magnesium, manganese |
| West Seneca Transfer | | chromium, magnesium, manganese, zinc |

## 4. LOADING ESTIMATE METHODOLOGY

Loadings of the targeted pollutants to the Buffalo River were estimated for the six inactive hazardous waste sites identified in Section 3.3. The methodology for making these estimates was chosen to be commensurate with the level of contamination and availability of data. Hence, at sites where only Phase II studies have been completed (Allied Chemical, Lehigh Valley Railroad, MacNaughton-Brooks, West Seneca Transfer Station), loading estimates were made using a simple, analytically-based model for subsurface contaminant transport. Sites for which more intensive Remedial Investigations have been completed (Buffalo Color, Madison Wire) have sufficient data to construct a numerical model for estimating contaminant loadings, and loadings were generated by numerical modeling for the Buffalo Color site. While sufficient data exists for modeling the Madison Wire site, there is no evidence of PAHs in the groundwater, which appear to be the principal contaminants found in the sediments of the Buffalo River. Loadings for the Madison Wire site were therefore computed with the simple, analytically-based transport model. A description of both models, as well as the data needed to parameterized these models, follows.

### 4.1 Plane Dispersion Model

#### 4.1.1 Governing Equation and Solution

The analytically-based transport model used to compute pollutant loadings to the Buffalo River is based on the two-dimensional plane dispersion model described by Javandel et al., (1984). This model assumes that the aquifer is homogeneous and isotropic and that the x axis is aligned with the groundwater flow direction, and a strip-type contaminant source of length 2a is assumed to exist along the y axis (Figure 4.1). The aquifer is also assumed to be initially free of contamination. For this study, the pollutant is assumed to be a conservative substance, and the pollutant source concentration is assumed to be constant. The governing advection-dispersion equation and associated auxiliary conditions can then be stated as

(4.1) $$R\frac{\partial C}{\partial t} = D_L\frac{\partial^2 C}{\partial x^2} + D_T\frac{\partial^2 C}{\partial y^2} - V\frac{\partial C}{\partial x}$$

(4.2) $C(x,y,0) = 0$

(4.3) $C(0,y,t) = C_0 \quad -a \le x \le a \quad \text{and} \quad C(0,y,t) = 0 \quad \text{otherwise}$

(4.4) $$\frac{\partial C}{\partial x}(\infty,y,t) = \frac{\partial C}{\partial y}(x,\pm\infty,t) = 0$$

where:

$C$ = concentration;
$R$ = retardation factor;
$D_L$ = longitudinal dispersion coefficient;
$D_T$ = transverse dispersion coefficient;
$V$ = average linear velocity;
$C_0$ = contaminant source concentration; and
$2a$ = source width.

The analytical solution to this system is given as (Javandel et al., 1984):

$$(4.5)\quad C(x,y,t) = \frac{C_0 x}{4\sqrt{\pi D_L}} \exp\left[\frac{Vx}{2D_L}\right] \int_0^{t/R} \exp(-V^2\tau/4D_L - x^2/4D_L\tau)\, \tau^{-3/2}$$
$$\times \left[\operatorname{erf}\left(\frac{a-y}{2\sqrt{D_T\tau}}\right) + \operatorname{erf}\left(\frac{a+y}{2\sqrt{D_T\tau}}\right)\right] d\tau$$

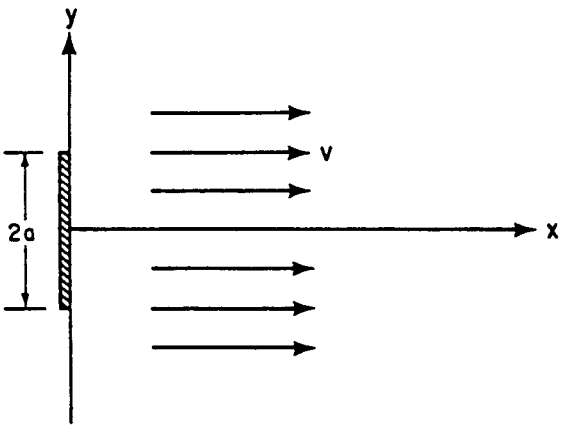



Fig. 4.1. Schematic diagram showing the two-dimensional Plane Dispersion Model (after Javandel et al., 1984).

For a source located a distance L from the river, the pollutant flux, J, to the river (mass per unit area per unit time) is obtained from

$$(4.6)\quad J(y,t) = \phi\, V\, C(L,y,t)$$

where $\phi$ = porosity. Total pollutant loading, F, to river (mass per unit time) entails the integration of J over the vertical aquifer cross-sectional area, A, intersecting the river. Hence,

$$(4.7)\quad F(t) = \int_A J dA = b\, \phi\, V \int_{-\infty}^{+\infty} C(L,y,t) dy$$

where b = aquifer thickness.

### 4.1.2 Parameterization

To predict pollutant loadings with the Plane Dispersion Model, a number of physical and chemical parameters must be known or estimated. These parameters were obtained from the NYSDEC investigations whenever possible and estimated data from literature sources in the absence of field data. A summary of the parameters appears in Table 4.1, and a discussion of how these parameters were estimated is given below.

**Aquifer thickness (b).** Aquifer thicknesses were estimated from well log data provided in the NYSDEC investigations. At all sites, the aquifer of concern was taken to be the shallow, unconfined aquifer existing in the upper portion of the overburden.

**Average linear velocity (V).** Average linear velocities for each site were estimated from Darcy's law

$$(4.8) \quad V = -\frac{K}{\phi}\frac{dh}{dl}$$

where:

$\phi$ = porosity
K = hydraulic conductivity; and
dh/dl = head gradient.

A porosity of $\phi = 0.35$ was assumed for all sites which is representative of sandy soils (Morris and Johnson, 1967). The hydraulic conductivity at each site was computed as the geometric mean of the measured hydraulic conductivities for the aquifer of concern. Head gradients were computed from monitoring well water levels by triangulation.

**Longitudinal and transverse dispersion coefficients ($D_L$ and $D_T$).** Dispersion coefficients were computed as

$$(4.9) \quad D_L = \alpha_L V$$
$$(4.10) \quad D_T = \alpha_T V$$

where $\alpha_L$ and $\alpha_T$ = longitudinal and transverse dispersivity, respectively. No field data were available to estimate the magnitudes of the dispersivities, and a value of $\alpha_L = 10$ m and a ratio of $\alpha_T/\alpha_L = 0.1$ were assumed from the literature (de Marsily, 1986). Computed transient pollutant loadings are relatively insensitive to the assumed dispersivity values, and the steady-state loadings are independent of the dispersivities.

**Retardation factor (R).** Retardation factors were estimated assuming that adsorption is reversible and instantaneous. The partitioning of metals between the water and solid phases was assumed to be governed by the Freundlich isotherm

$$(4.11) \quad S = k\,C^{1/n}$$

where k and n are Freundlich isotherm constants. The retardation factor was evaluated as

$$(4.12) \quad R = 1 + \frac{(1-\phi)\rho_S k}{\phi n} C^{1/n-1}$$

where $\rho_S$ = soil mass density which was assumed to be 2.65 g/cm$^3$. Use of Equation (4.12) to

parameterize the linear Plane Dispersion Model requires that the retardation factor be evaluated at some constant concentration. The source concentration, $C_0$, was chosen for this purpose.

No data were available to determine site-specific Freundlich constants for the sites under consideration. Freundlich constants estimated for the Buffalo Color site (Table 4.2) were therefore adopted in the absence of site-specific data.

**Source width (2a) and distance to river (L).** These parameters were estimated from the information provided in NYSDEC investigations. Source widths were taken to be widths of unlined impoundments, debris piles, etc. which were suspected by the investigators to be pollutant sources. The down-gradient distances from the suspected pollutant source to the Buffalo River were estimated from maps provided in the NYSDEC reports.

It should be noted that characterizing the size and location of pollutant sources is a subjective process, given the limited amount of information available for most of the sites under study (Remedial Investigation has been performed only for the Madison Wire site). Both transient and steady-state pollutant loadings are sensitive to the size of the source area. Any improvement in loading estimates will require better characterization of the pollutant sources.

**Source concentration ($C_0$).** Source concentrations were estimated as

$$(4.13)\quad C_0 = \max[C_{max}, (S_{max}/k)^n]$$

where: $C_{max}$ = maximum observed groundwater concentration; and $S_{max}$ = maximum observed subsurface soil concentration. The quantity $(S_{max}/k)^n$ represents the groundwater concentration which would be in equilibrium with the maximum soil concentration. Since soil borings and monitoring wells are installed in different physical locations, and because soil boring often outnumber monitoring wells, estimation of the source concentration in the this fashion increases the probability that the maximum source concentration has been adequately characterized.

As with source size and location, pollutant loading estimates are sensitive to the source concentration; any desired improvement in pollutant loadings will require more intensive environmental sampling.

Table 4.1. Summary of Plane Dispersion Model parameters
(n=0.35 assumed for all sites).

| Site | V (m/yr) | $D_L/D_T$ ($m^2/yr$) | b (m) | L (m) | a (m) | Chemical | $C_o$ (mg/L) | R |
|---|---|---|---|---|---|---|---|---|
| Allied Chemical | 3.4 | 34/3.4 | 3.4 | 80 | 10 | Fe | 334 | 6,640 |
| | | | | | | Pb | 0.2 | 585 |
| Lehigh Valley RR | 66 | 660/66 | 2 | 420 | 60 | Fe | 120 | 6,990 |
| MacNaughton-Brooks | 180 | 1,800/180 | 4.7 | 240 | 8 | Fe | 341 | 6,640 |
| Madison Wire | 13 | 130/13 | 3 | 50 | 30 | Cu | 96.1 | 216 |
| | | | | | | Fe | 300 | 6,680 |
| | | | | | | Pb | 0.38 | 419 |
| West Seneca | 36 | 360/36 | 4 | 490 | 150 | Fe | 88.8 | 7,100 |
| | | | | | | Pb | 0.13 | 720 |

## 4.2 Method of Characteristics Model

### 4.2.1 Governing Equation and Solution

The Method of Characteristics (MOC) model was used to estimate pollutant loadings to the Buffalo River from the Buffalo Color site. This numerical model was developed by the U. S. Geological Survey (Konikow and Bredehoeft, 1978; Goode and Konikow, 1989) and is considered the industry-standard model for simulating two-dimensional solute transport in groundwater. The model solves the depth-averaged equations governing groundwater flow and solute transport, accounting for adsorption and reaction of the solute. A finite difference method is used to solve the flow equation, while a hybrid finite difference-characteristics method is used to solve the solute transport (advective-diffusive-reactive) equation. The governing equations, model assumptions, and numerical procedures are documented elsewhere (Konikow and Bredehoeft, 1978; Goode and Konikow, 1989).

To develop pollutant loadings to the Buffalo River, output from the MOC model was used to compute the pollutant flux along the perimeter of the Buffalo Color site bounded by the river, $B_1$, as

$$(4.14)\quad J(x,y,t) = \phi \,|\, V(x,y) \,|\, C(x,y,t) \quad \text{where} \quad x,y \in B_1$$

Pollutant loadings were then obtained by integrating J around the perimeter of the site bounded by the river and over the aquifer thickness. This area is designated as $A_1$. Thus,

$$(4.15)\quad F(t) = \int_{A_1} J dA = \int_{A_1} \phi \,|\, V(x,y) \,|\, C(x,y,t) dA \quad \text{where} \quad x,y \in B_1$$

Because of the spatial variations in aquifer thickness, average linear velocities, and concentrations, the integral defined by Equation (4.15) was computed by summing values over the finite difference cells forming $B_1$.

### 4.2.2 Parameterization

To simulate groundwater flow and pollutant transport at the Buffalo Color site using the MOC model, parameters describing the modeled domain, boundary and initial conditions, physical characteristics of the aquifer and chemical properties of the pollutants of concern were assigned using data given in the Remedial Investigation Report and from literature values. In developing the model, groundwater flow was assumed to be steady-state, and the aquifer of concern was taken to be the shallow, unconfined aquifer which consists of alluvial and fill deposits. Details of the construction and parameterization of the numerical model are given below.

**Domain, and boundary and initial conditions.** The portion of the Buffalo Color site which was modeled is shown in Figure 4.2. Because the site is located on the inside of a meander bend, most of the site perimeter is bounded by the Buffalo River. Groundwater flows are therefore highly dependent on the river elevation.

Along the boundary defined by the river, designated $B_1$, a constant-head boundary condition was specified, i.e.,

(4.16) $h(x,y) = h_0(x,y)$ where $x,y \in B_1$

A value of $h_0 = 562.7$ ft was prescribed based on river elevations reported in the Remedial Investigation. Along the remaining portion of the boundary, designated as $B_2$, a constant-flux boundary condition was specified, i.e.,

(4.17) $\frac{\partial h}{\partial n}(x,y) = \gamma(x,y)$ where $x,y \in B_2$

This boundary condition is simulated by MOC specifying the flux rate as a well recharge or discharge rate for nodes along $B_2$. Values of $\gamma$ were obtained by adjusting the recharge/discharge rates at these nodes until a good match between computed and observed hydraulic heads was achieved.

To obtain the pollutant transport solution, initial concentrations must be specified throughout the domain R. In this study, the aquifer was assumed to be initially free of contamination, or

(4.18) $C(x,y,0) = 0$ where $x,y \in R$

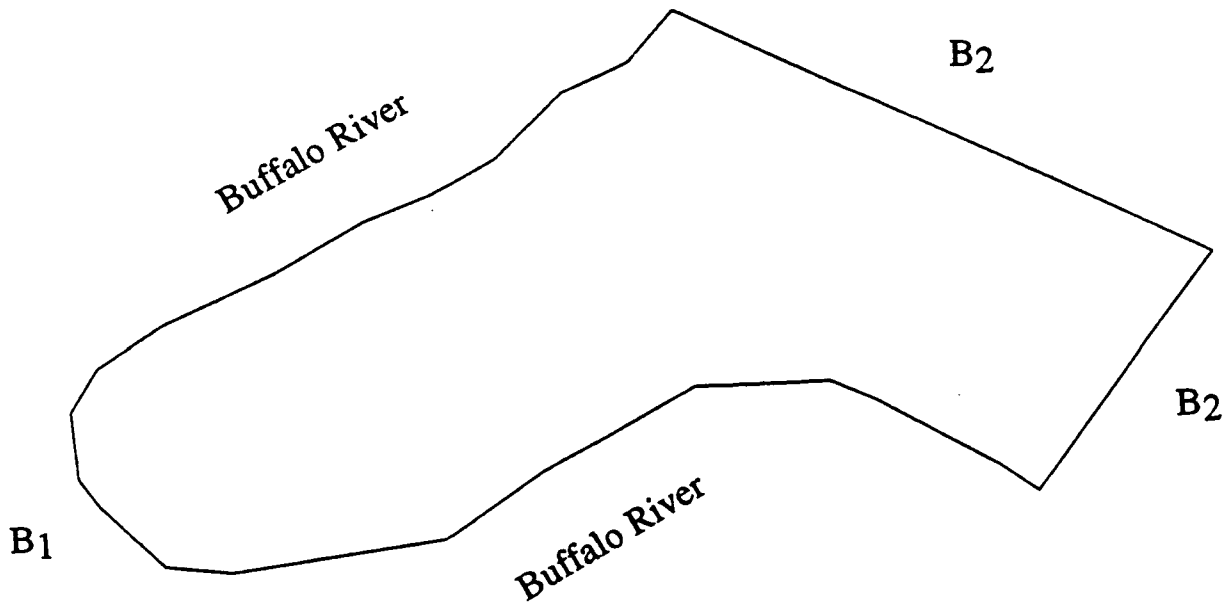



Fig. 4.2. Modeled domain and boundary conditions for the Buffalo Color Site.

**Hydrogeological parameters.** The physical parameters associated with groundwater flow and pollutant transport include: porosity ($\phi$), aquifer thickness (b), hydraulic conductivity (K), longitudinal and transverse dispersivity ($\alpha_L$ and $\alpha_T$), and the groundwater recharge rate (I). Porosity, dispersivity, and groundwater recharge were assumed to be constants over the site. The following values were assumed: $\phi = 0.35$ (Morris and Johnson, 1967), $\alpha_L = 25$ ft and $\alpha_T = 7.5$ ft (de Marsily, 1986), and I = 20.3 in/yr (Buffalo Color Remedial Investigation Report).

Aquifer thickness and hydraulic conductivity were allowed to vary spatially over the modeled domain. Nodal values of both quantities were estimated by the kriging procedure (de Marsily, 1986), using stratigraphic information from 12 borings and hydraulic conductivity measurements at 17 wells. The resulting spatial distributions of b and ln K are given in Figures 4.3 and 4.4, respectively.

**Adsorption constants.** Adsorption constants are required to quantify the partitioning of the pollutants between the groundwater and aquifer matrix. The usual procedure for determining these constants involves experimental determination of the isotherm constants via batch experiments using site soils, or experimental determination of the retardation factor via column breakthrough experiments using columns packed with site soils. No such studies have been conducted; therefore, magnitudes of these constants had to be estimated from literature values corroborated by a limited amount of field data.

The subsurface field investigation of the Buffalo Color site included the sampling and analysis of subsurface soils and groundwater. Borings were made to sample subsurface soils at 23 locations, and 8 of these borings were subsequently converted to groundwater quality monitoring wells. Groundwater was sampled from these wells on two dates (June 23-24, 1988 and August 17-18, 1988). Since soils were sampled over depths which were consistent with the screened depths of the subsequently installed wells, measured soils and groundwater concentrations at these wells could be used to estimate the equilibrium partitioning of the pollutants between these two phases. Sufficient information existed to perform this analysis for the metals, whereas PAHs were not detected with sufficient frequency to repeat this analysis for these organic chemicals.

Soil concentrations are plotted against groundwater concentrations for copper, iron, and lead in Figures 4.5, 4.6 and 4.7, respectively. Also plotted are the isotherms as fitted by least squares regression and isotherms obtained from literature sources. For copper the field data yield a robust estimate of the isotherm constants which indicates copper adsorption at this site is less than that reported by Mimides and Lloyd (1987). For iron, S and C were relatively poorly correlated, yet the isotherm obtained by Mimides and Lloyd (1987) passes through the data. The correlation between S and C for lead is very poor, but most of the data fall below the isotherm reported by LaBauve et al. (1988). For use in MOC, the estimated Freundlich constants for copper were adopted because of the good correlation achieved. The literature constants were adopted for iron, as there is likely no statistical difference between the estimated and literature constants. For lead the estimated constants were used over the literature values, because they are conservative with regard to contaminant retardation, i.e., they result in a smaller retardation factor. Isotherm constants are summarized in Table 4.2.

Fig. 4.3. Saturated aquifer thickness, b (ft).

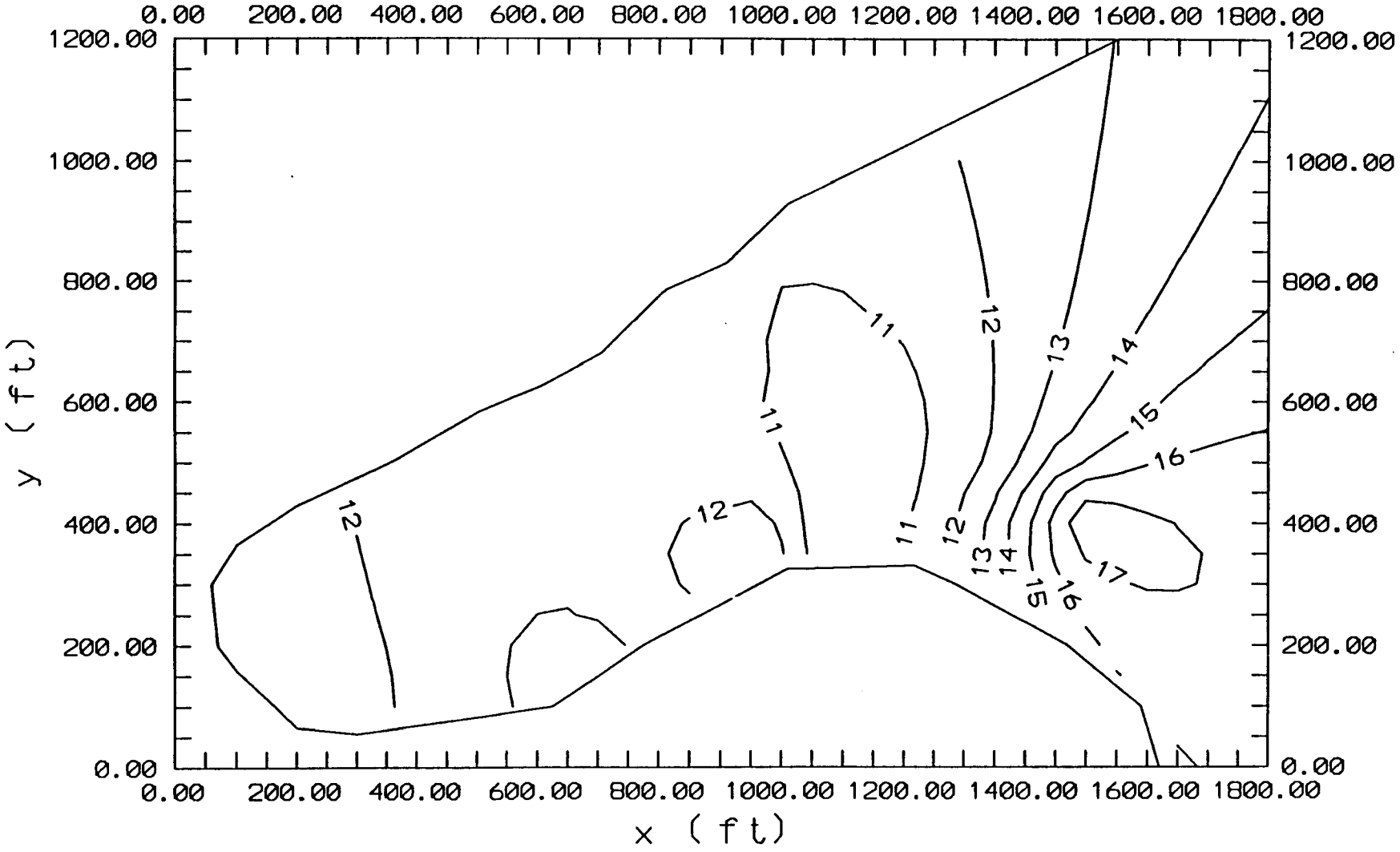
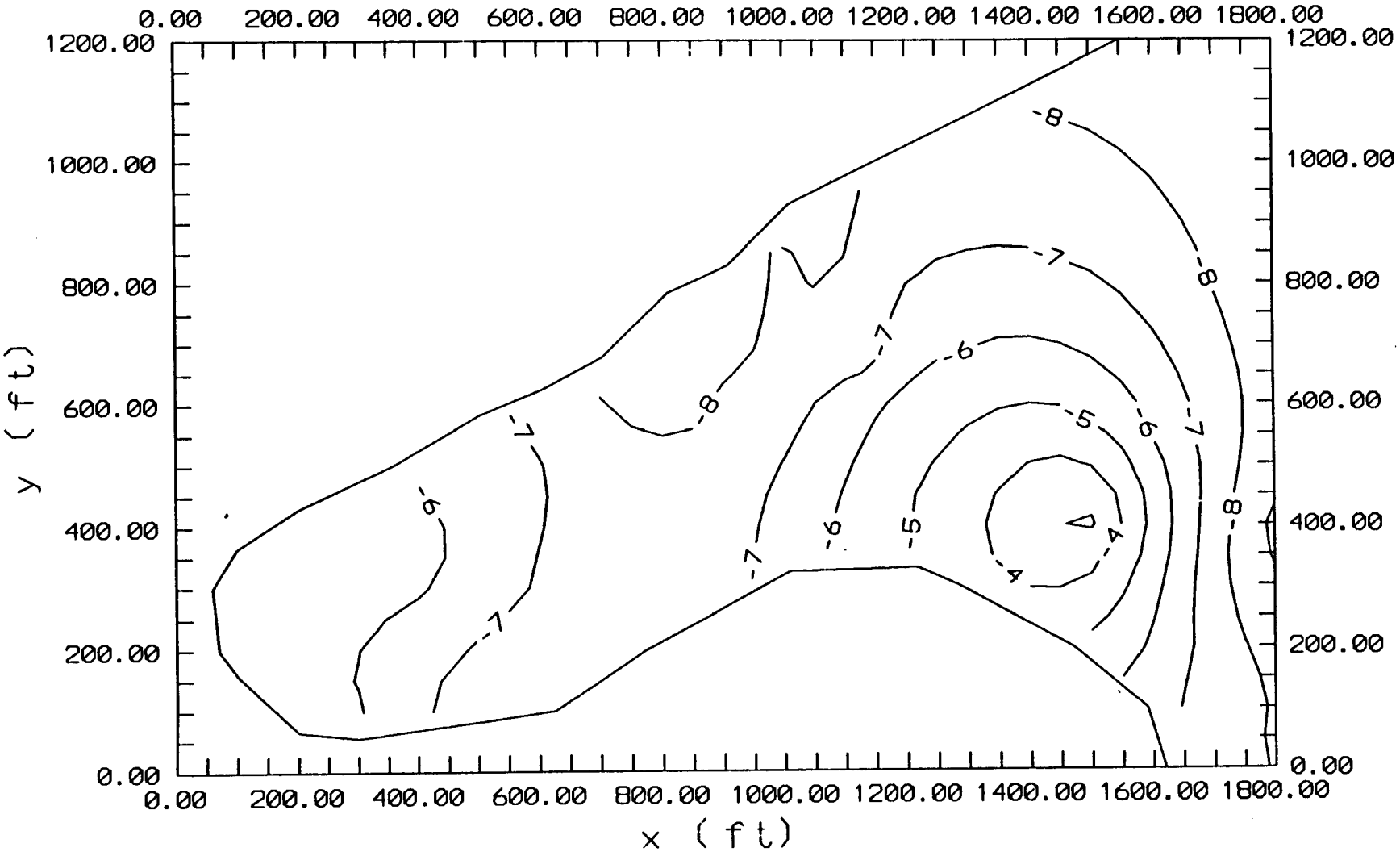


Fig. 4.4. Log hydraulic conductivity, ln K (cm/s).



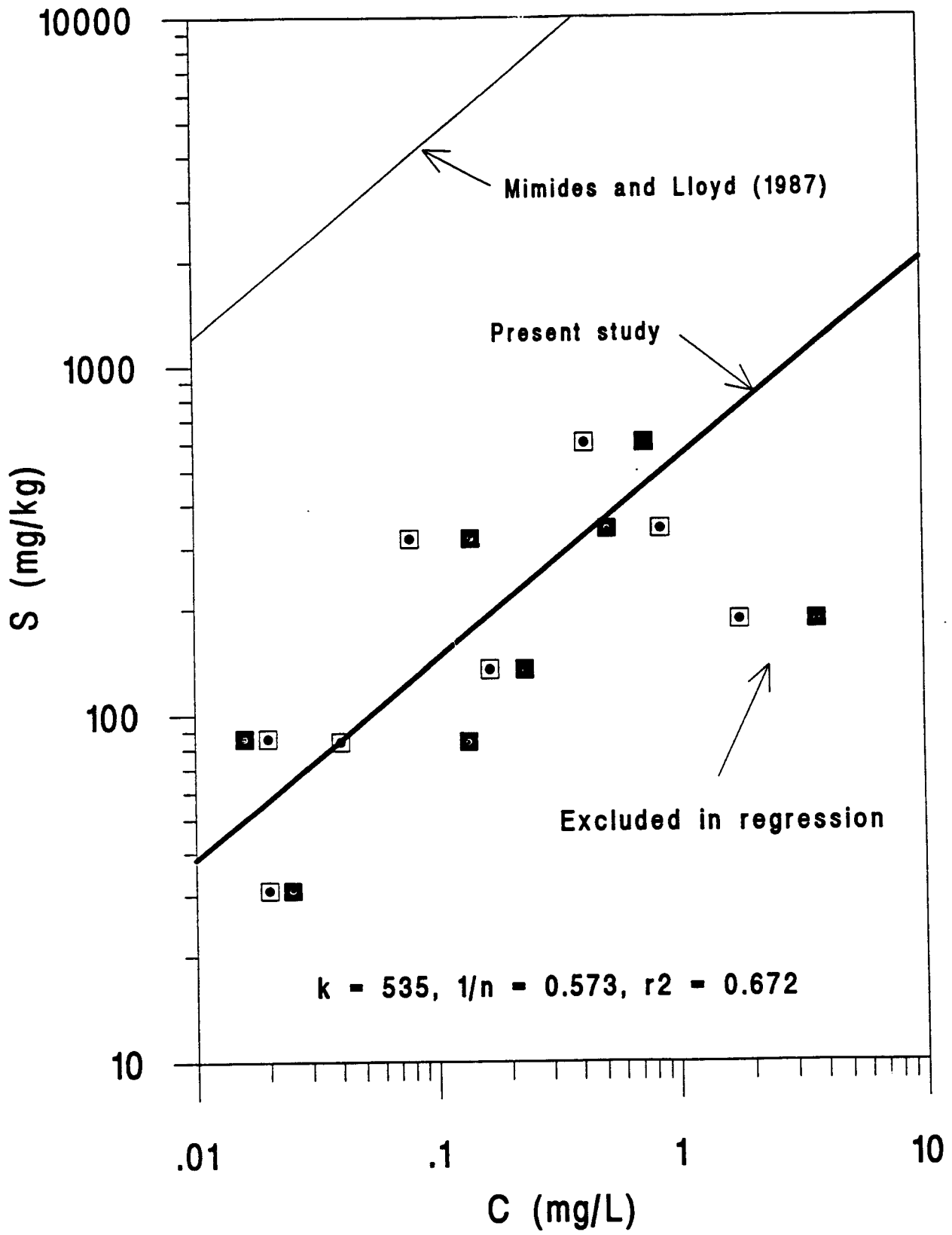



Fig. 4.5. Freundlich isotherm for copper (Buffalo Color Site data).

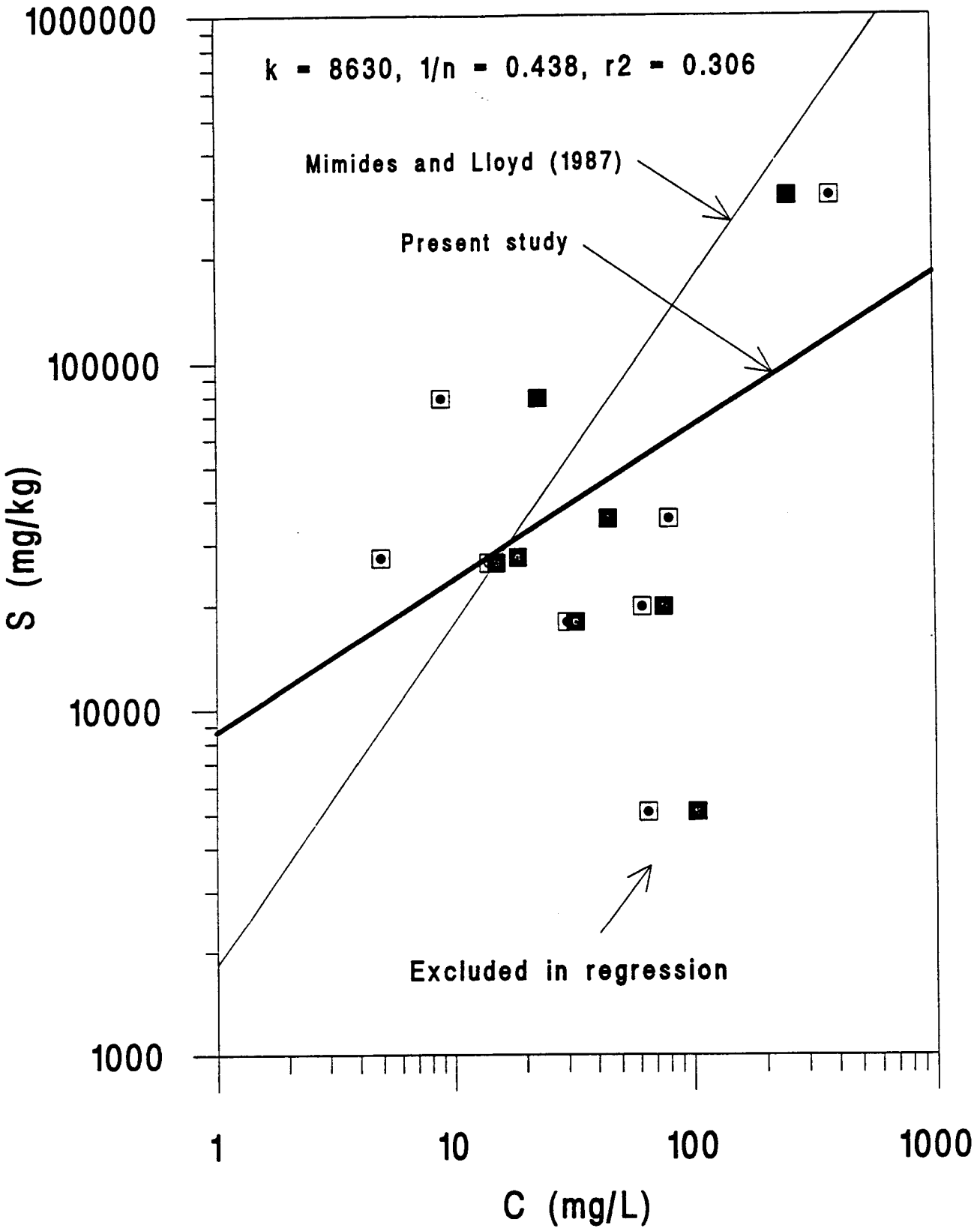



Fig. 4.6. Freundlich isotherm for iron (Buffalo Color Site data).

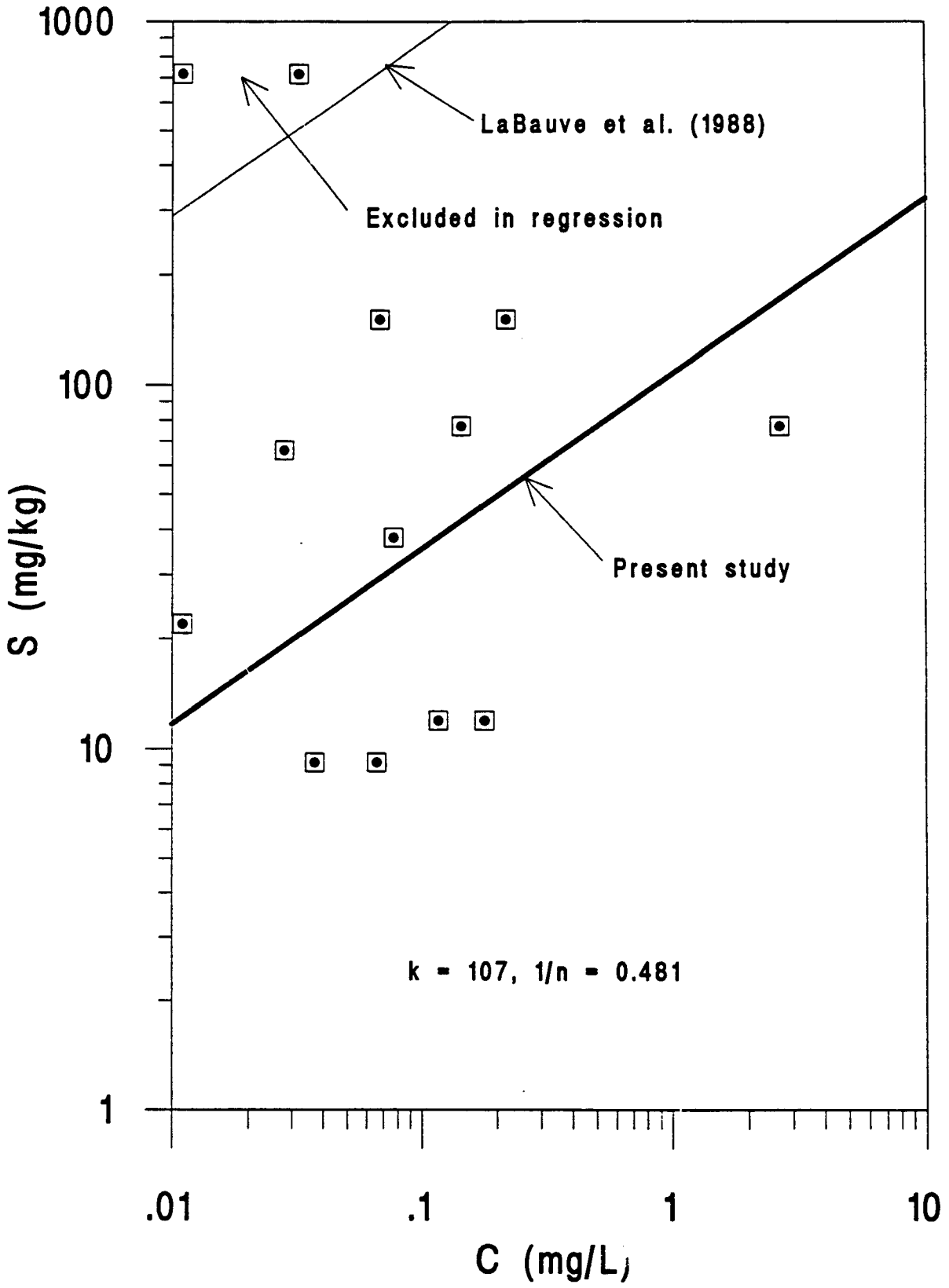



Fig. 4.7. Freundlich isotherm for lead (Buffalo Color Site data).

Table 4.2. Freundlich isotherm constants for C[mg/L] and S[mg/kg]. Adopted values are in bold.

| Metal | Source | k | 1/n |
|---|---|---|---|
| Copper | Mimides and Lloyd (1987) | 15,700 | 0.57 |
| | Present study | **535** | **0.573** |
| Iron | Mimides and Lloyd (1987) | **1,900** | **0.95** |
| | Present study | 8,630 | 0.438 |
| Lead | LaBauve et al. (1988) | 2,660 | 0.48 |
| | Present study | **107** | **0.481** |

Adsorption constants for the PAHs were initially estimated by applying equilibrium partitioning theory for hydrophobic organic chemicals as described by Karickhoff (1984). For relatively low water phase pollutant concentrations, the equilibrium adsorption isotherm is linear, i.e.,

$$(4.19)\quad S = K_p C/\rho_w$$

where:

$K_p = 0.63\ K_{ow}\ f_{oc}$ = partition coefficient;
$K_{ow}$ = octanol-water partition coefficient;
$f_{oc}$ = fraction organic carbon; and
$\rho_w$ = mass density of water.

The corresponding retardation factor may be obtained as

$$(4.20)\quad R = 1 + \frac{(1-\phi)\rho_s K_p}{\phi}$$

Using the $K_{ow}$ given in Table 1.1 and assuming $f_{oc}$ = 1 %, retardation factors were computed for the PAHs and are summarized in Table 4.3.

Retardation factors on the order of $10^4$ to $10^5$ result, suggesting that the PAHs are essentially immobile under the equilibrium assumption. However, experimental and theoretical investigations have shown that hydrophobic organic chemicals having octanol-water partition coefficients in excess of $10^5$ may require on the order of months to years to obtain true equilibrium (Wu and Gschwend, 1986; Coates and Elzerman, 1986). Given the proximity of the PAH sources to the Buffalo River and the relatively short groundwater residence times, PAHs introduced into the groundwater probably will not achieve sorption equilibrium. Hence, the assumption of equilibrium partitioning is likely invalid and the retardation of the PAHs will be much less than indicated in Table 4.3. For purposes of estimating PAH loadings, it was therefore assumed that no retardation of the PAHs would occur.

Table 4.3. PAH partition coefficients and retardation factors.

| PAH | $K_p$ | R |
|---|---|---|
| Benzo(a)anthracene | 2,570 | 12,600 |
| Benzo(b)fluoranthene | 23,400 | 115,000 |
| Benzo(k)fluoranthene | 43,600 | 215,000 |
| Benzo(a)pyrene | 6,020 | 29,600 |
| Chrysene | 2,570 | 12,600 |

**Pollutant Sources.** To simulate pollutant loadings to the Buffalo River, pollutant source locations, source concentrations, and source flux rates are required. Pollutant sources were identified from the observed surface and subsurface soil and groundwater pollutant concentrations given in the Remedial Investigation Report. Potential source areas are shown in Figure 4.8 and concentrations are mapped in Figures 4.9 through 4.20 for a selected PAH (benzo(a)anthracene), copper, iron, and lead. Maximum pollutant concentrations for these source areas are summarized in Tables 4.4 and 4.5.

Comparison of potential source areas with observed soil and groundwater concentrations show that several sources of these pollutants likely exist within the Buffalo Color site. PAH sources are found within the Weathering Area, the West Shore Area, Tank Parks 910 and 912, and the Iron Oxide Sludge Lagoon Area. The Tank Park 910 source is notable because a layer of light NAPL, approximately 6 ft thick and partially comprised of PAHs, floats atop the groundwater at this location. Copper sources are found within the Iron Oxide Sludge Lagoon Area, the Incineration Area, the Weathering Area. Principal iron sources include the Iron Oxide Sludge Lagoon Area, the Weathering Area, and the West Shore Area. Lead sources are found in the Weathering Area, the Incineration Area, Tank Park 912, the Iron Oxide Sludge Lagoon Area, and the West Shore Area. An extremely high level of soil lead was detected in Tank Park 912 (83,200 mg/kg).

The source concentration for any given PAH was taken to be its water solubility (see Table 1.1 for magnitudes). Source concentrations for metals were determined in accordance with Equation (4.13), i.e., the greater of the maximum observed groundwater concentration or the groundwater concentration in equilibrium with the maximum soil concentration. The pollutant flux rate was taken to be the mean annual infiltration rate ($I = 20.3$ in/yr), because groundwater contamination occurs primarily by the infiltration of soil leachate.

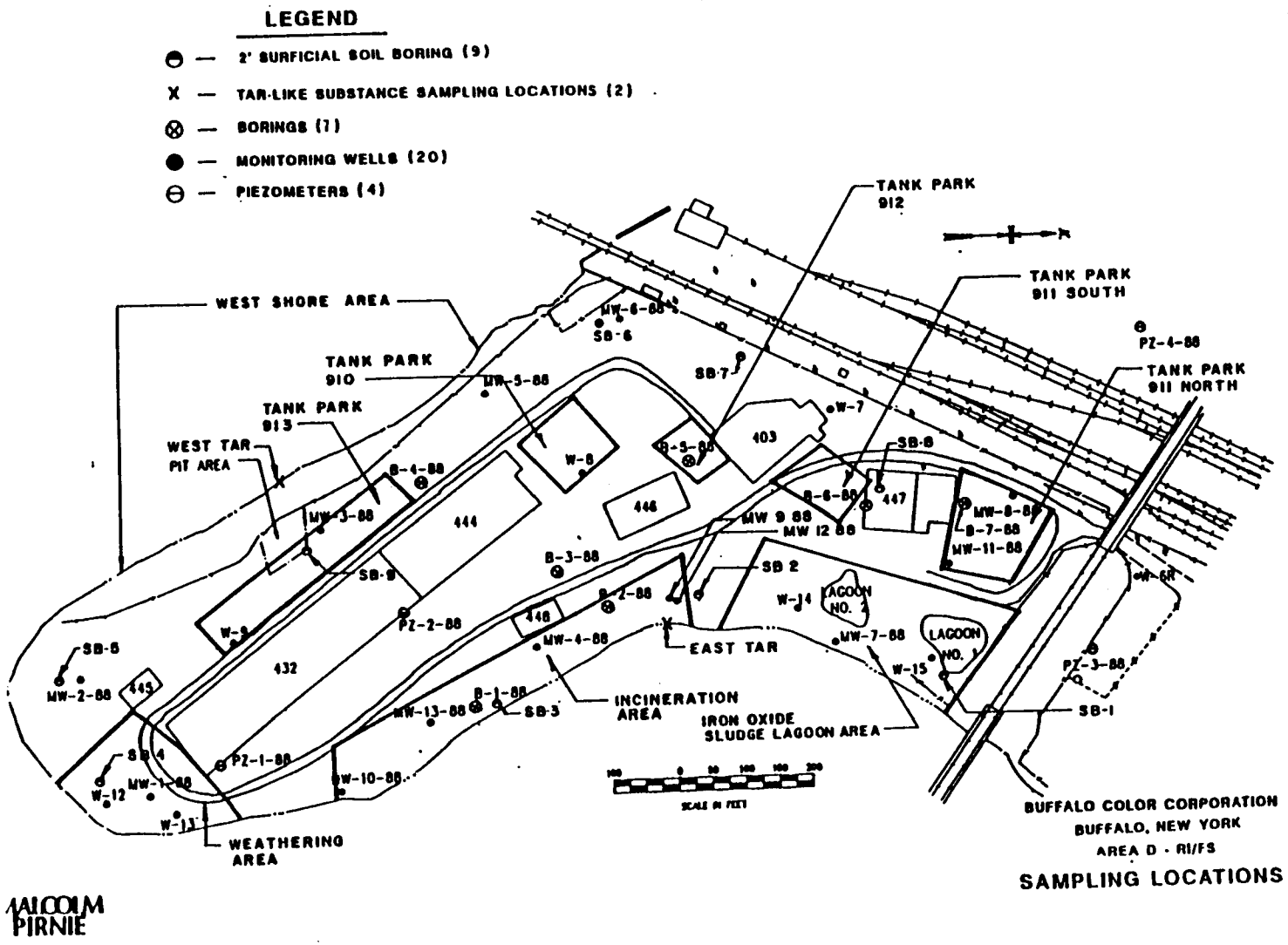



Fig. 4.8. Potential pollutant source areas at the Buffalo Color Site (from Buffalo Color Corporation Remedial Investigation Report).

Fig. 4.9. Surface soil PAH concentrations (mg/kg).

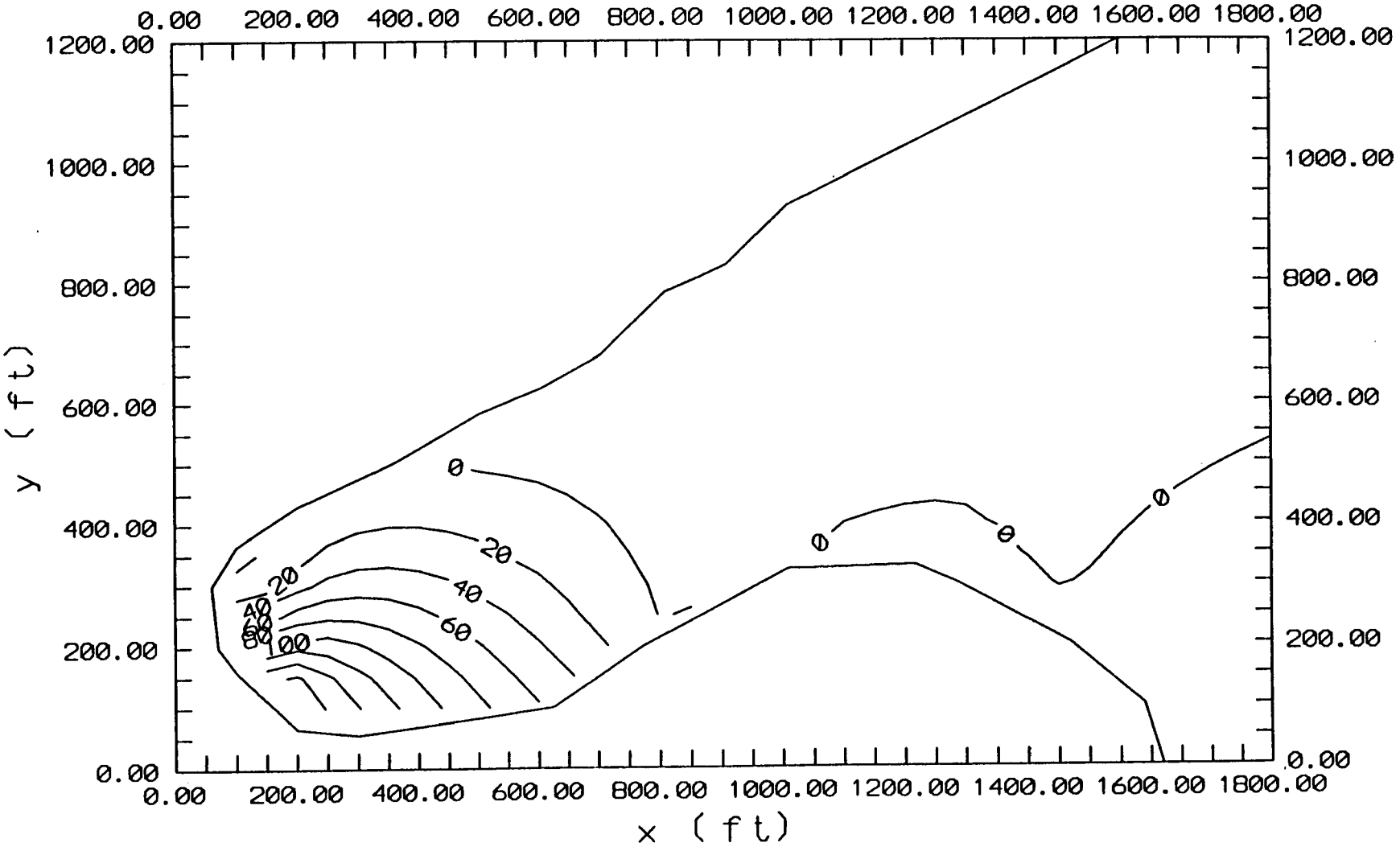


Fig. 4.10. Subsurface soil PAH concentrations (mg/kg).

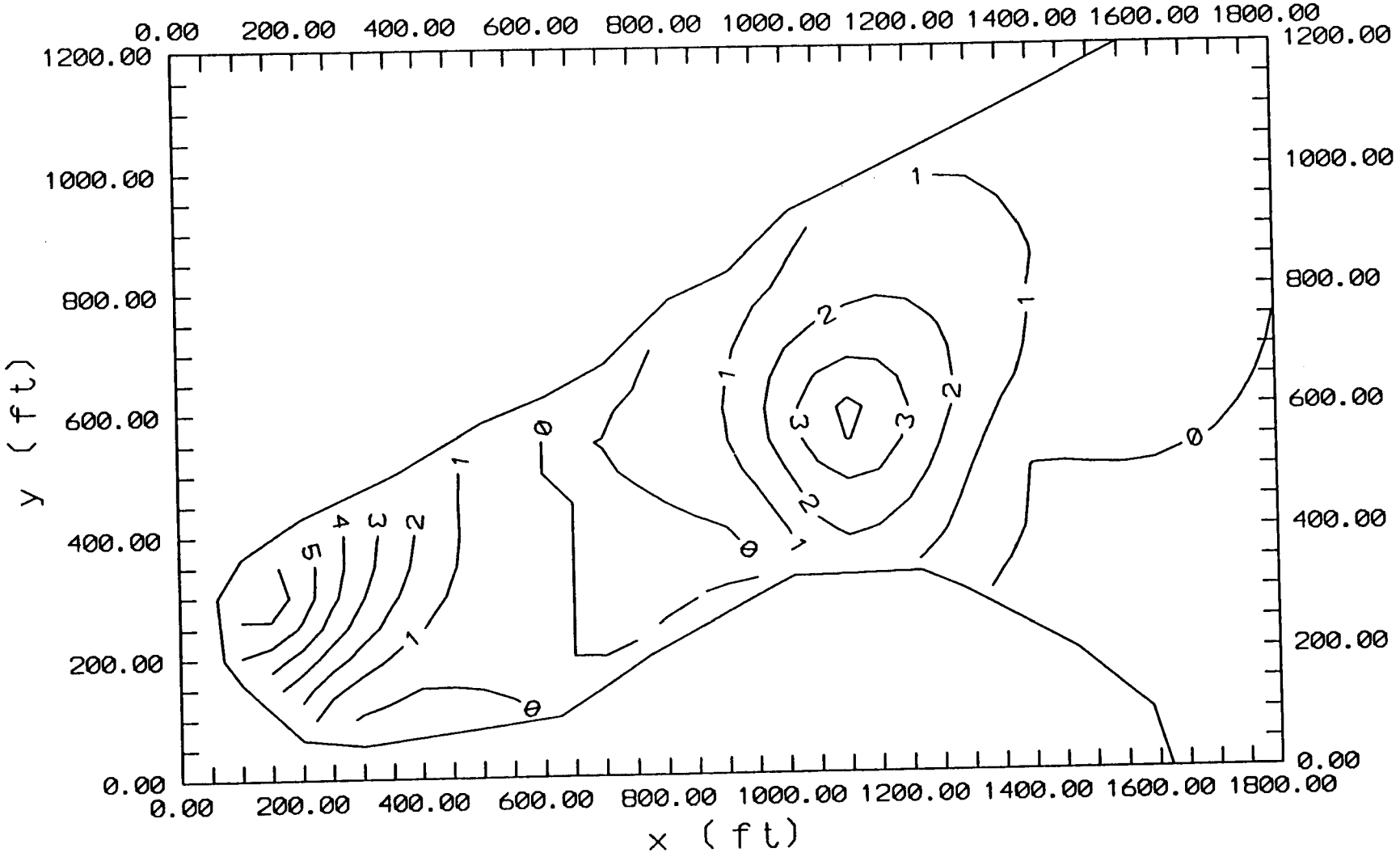


Fig. 4.11. Groundwater PAH concentrations (ug/L).

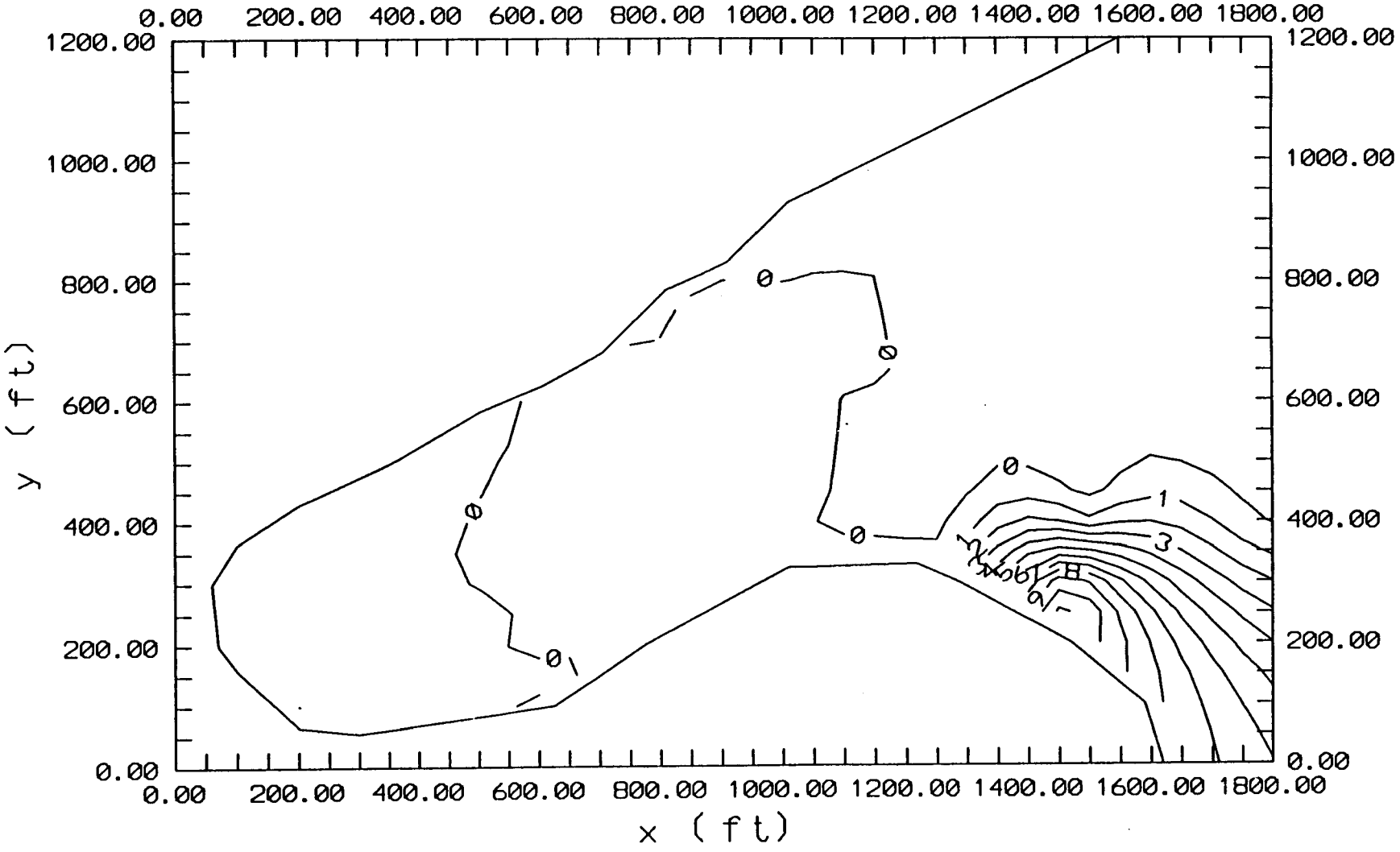


Fig. 4.12. Surface soil copper concentrations (mg/kg).

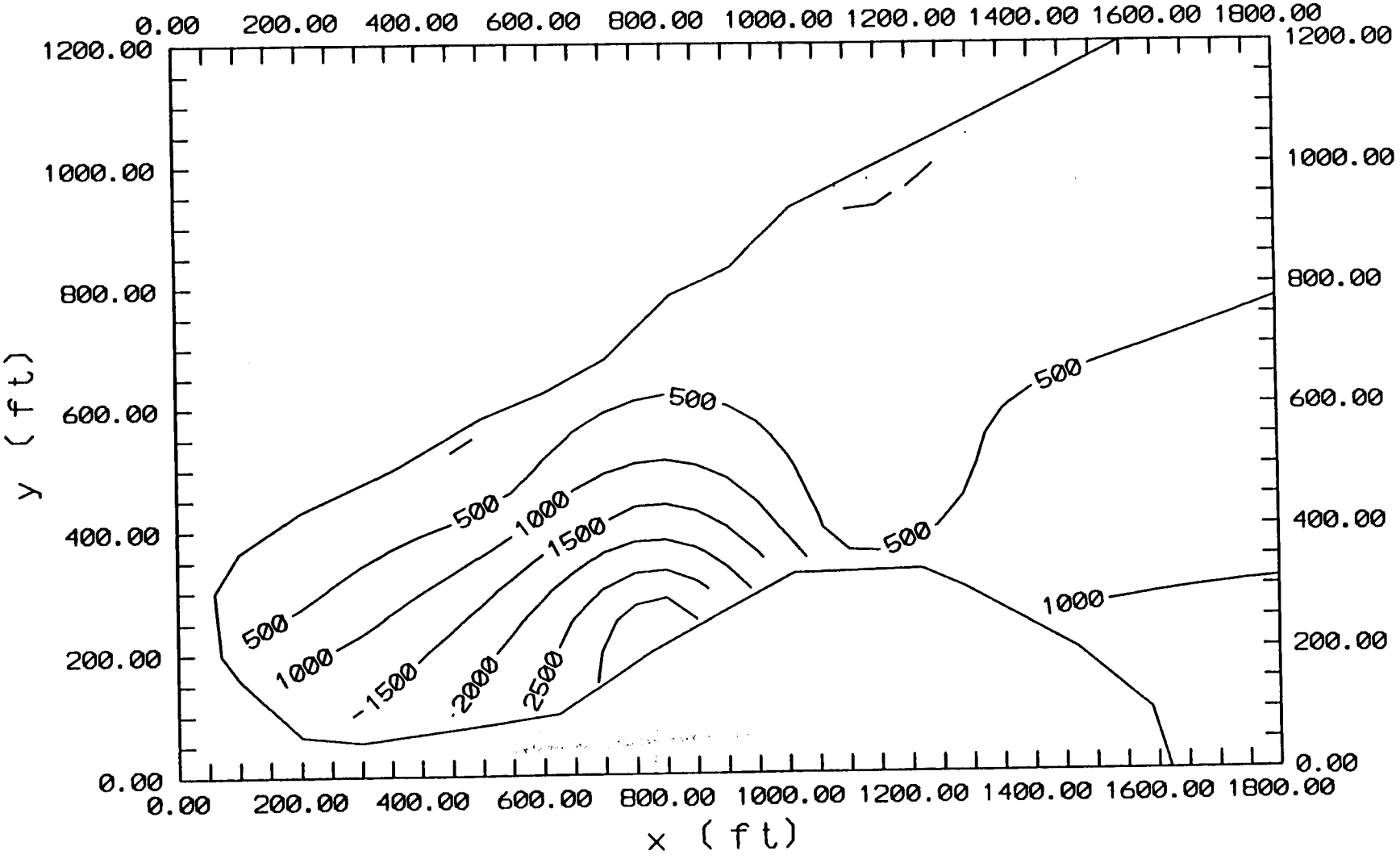


Fig. 4.13. Subsurface soil copper concentrations (mg/kg).

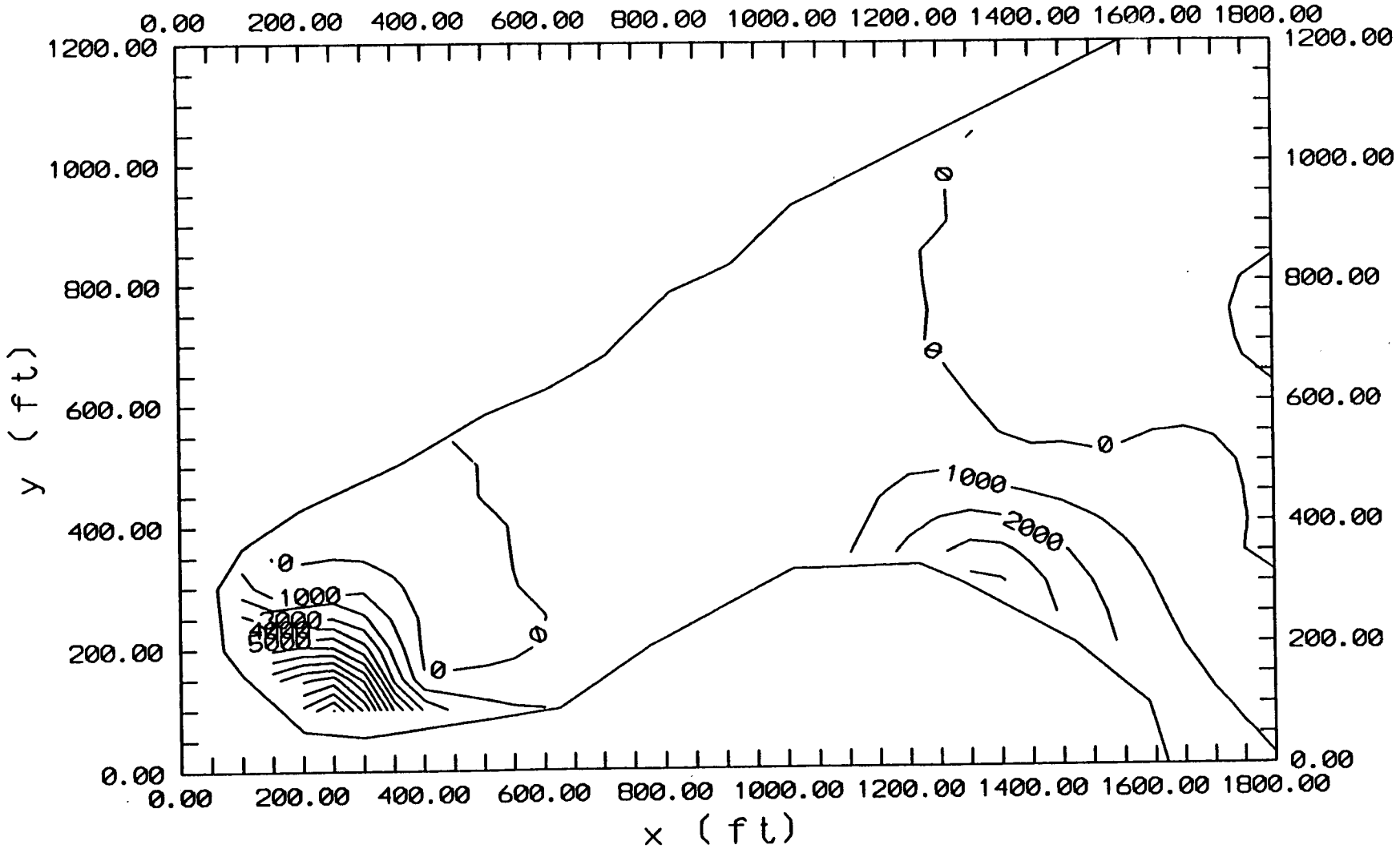


Fig. 4.14. Groundwater copper concentrations (ug/L).

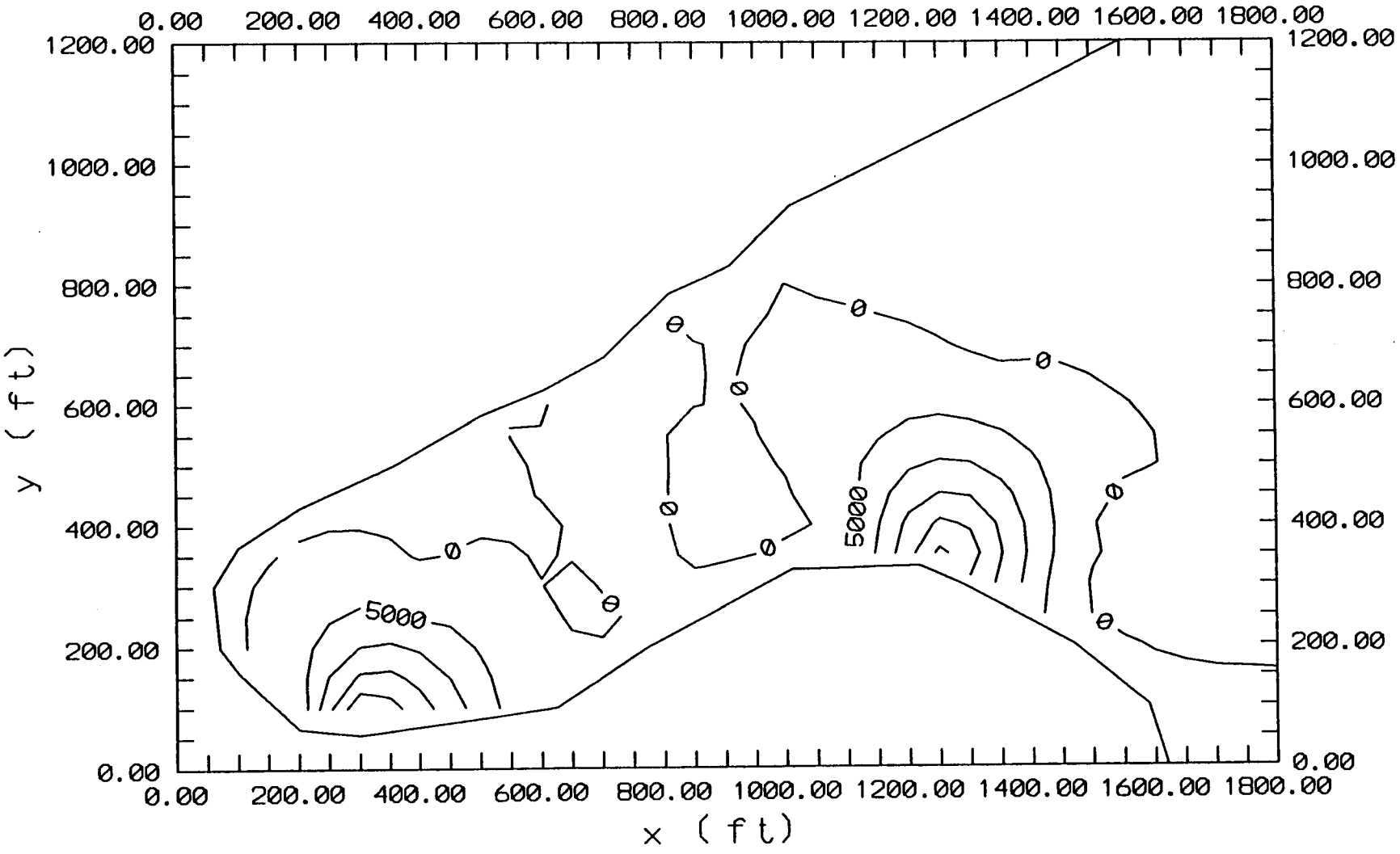


Fig. 4.15. Surface soil iron concentrations (mg/kg).

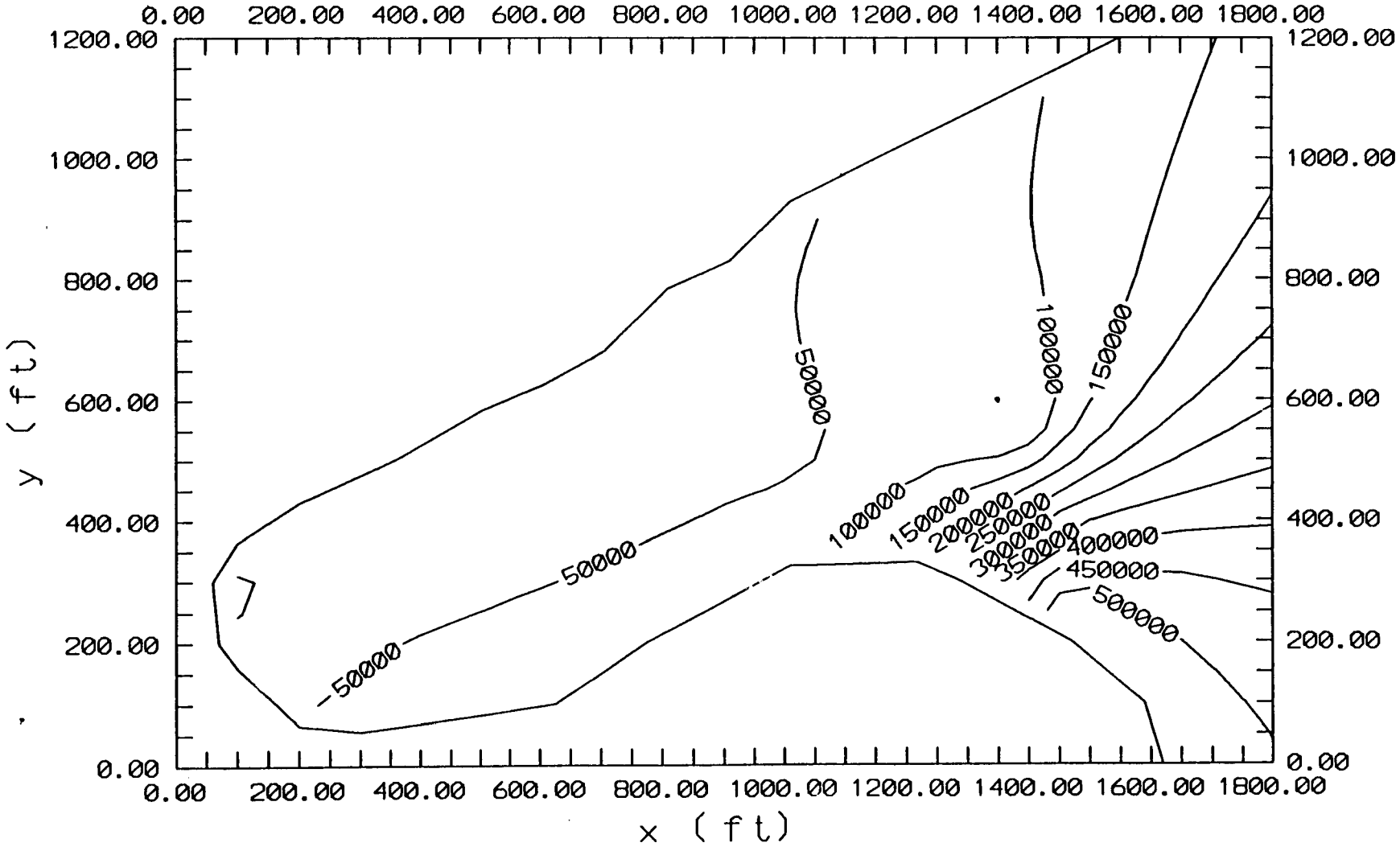


Fig. 4.16. Subsurface soil iron concentrations (mg/kg).

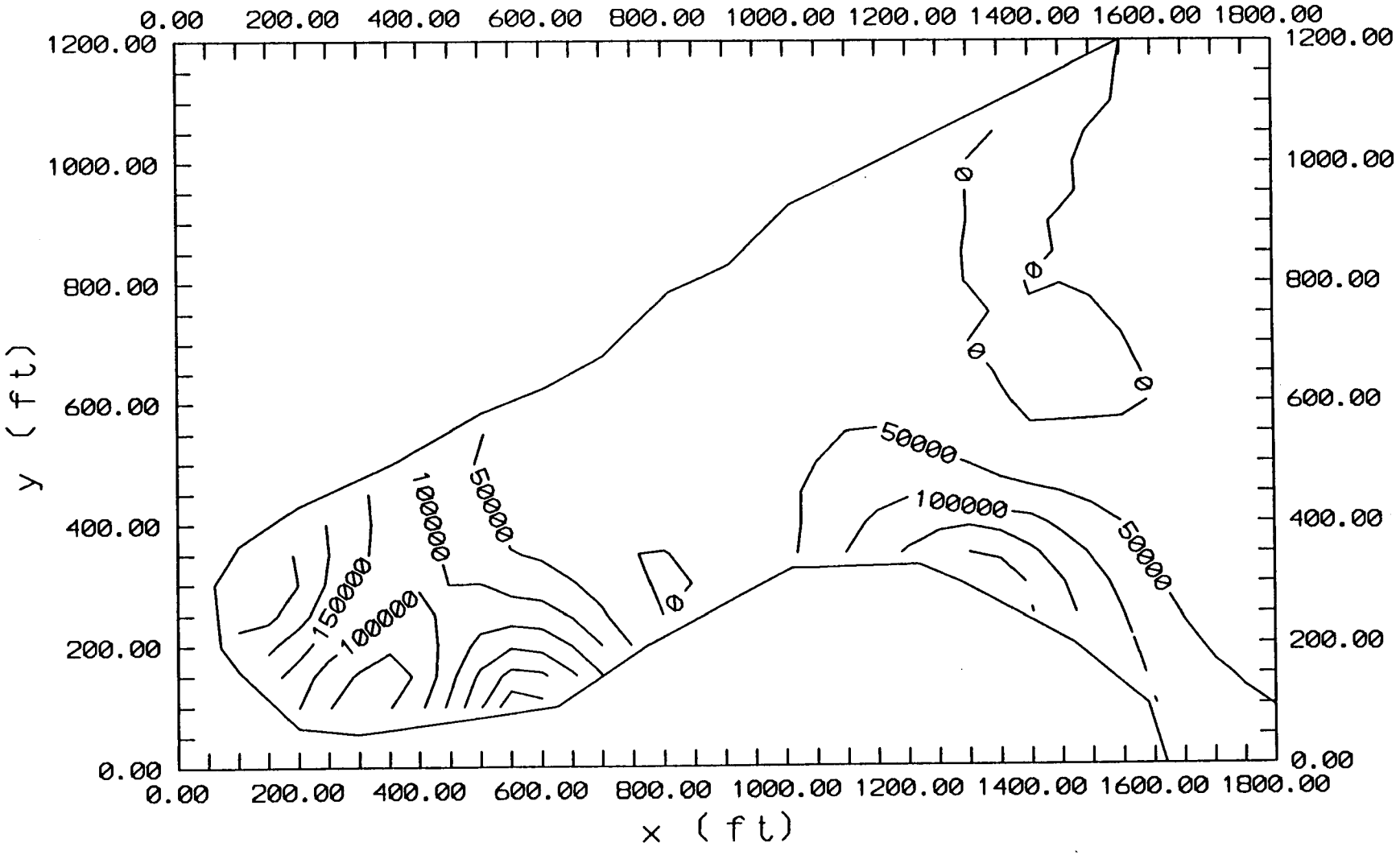


Fig. 4.17. Groundwater iron concentrations (ug/L).

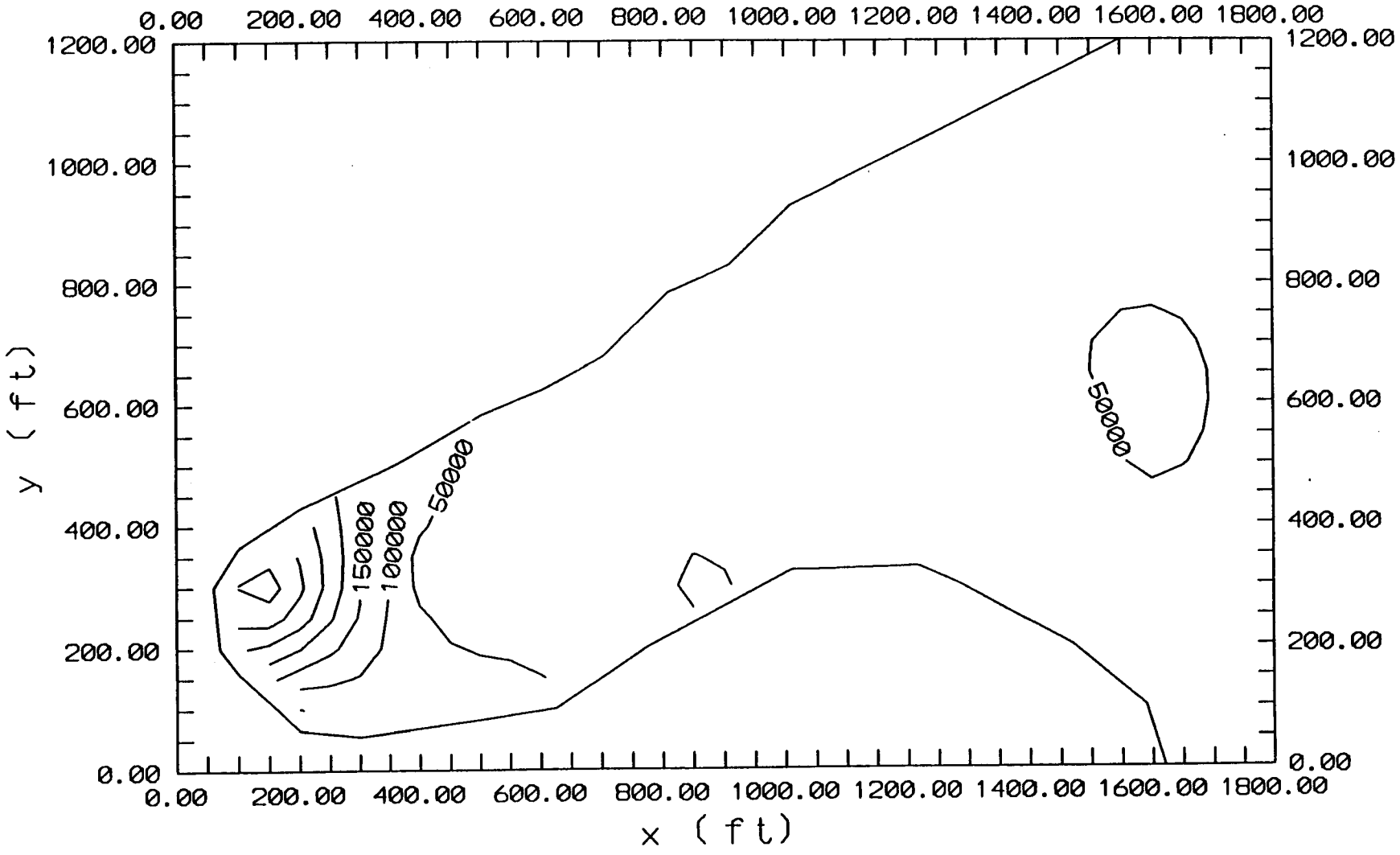


Fig. 4.18. Surface soil lead concentrations (mg/kg).

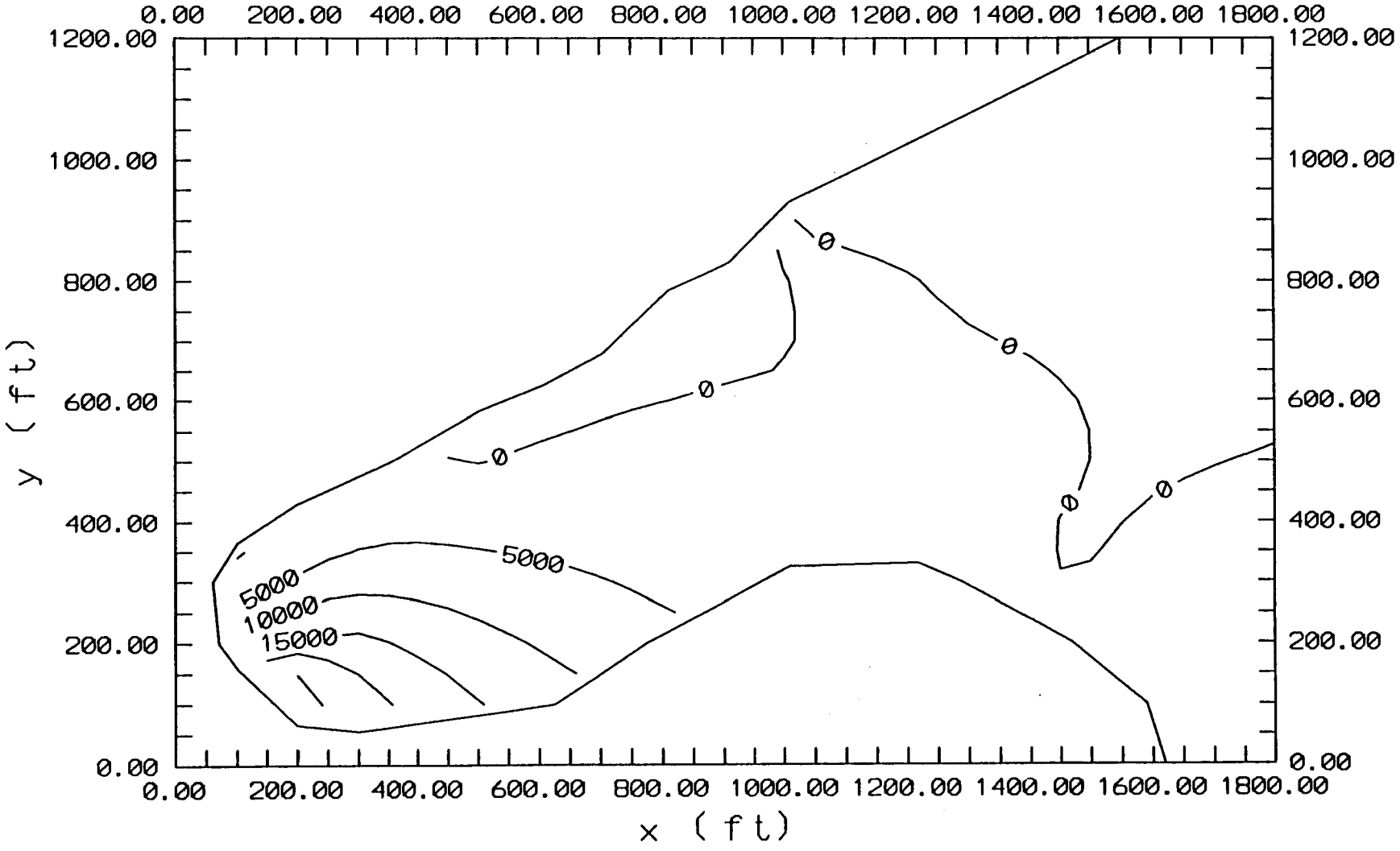


Fig. 4.19. Subsurface soil lead concentrations (mg/kg).

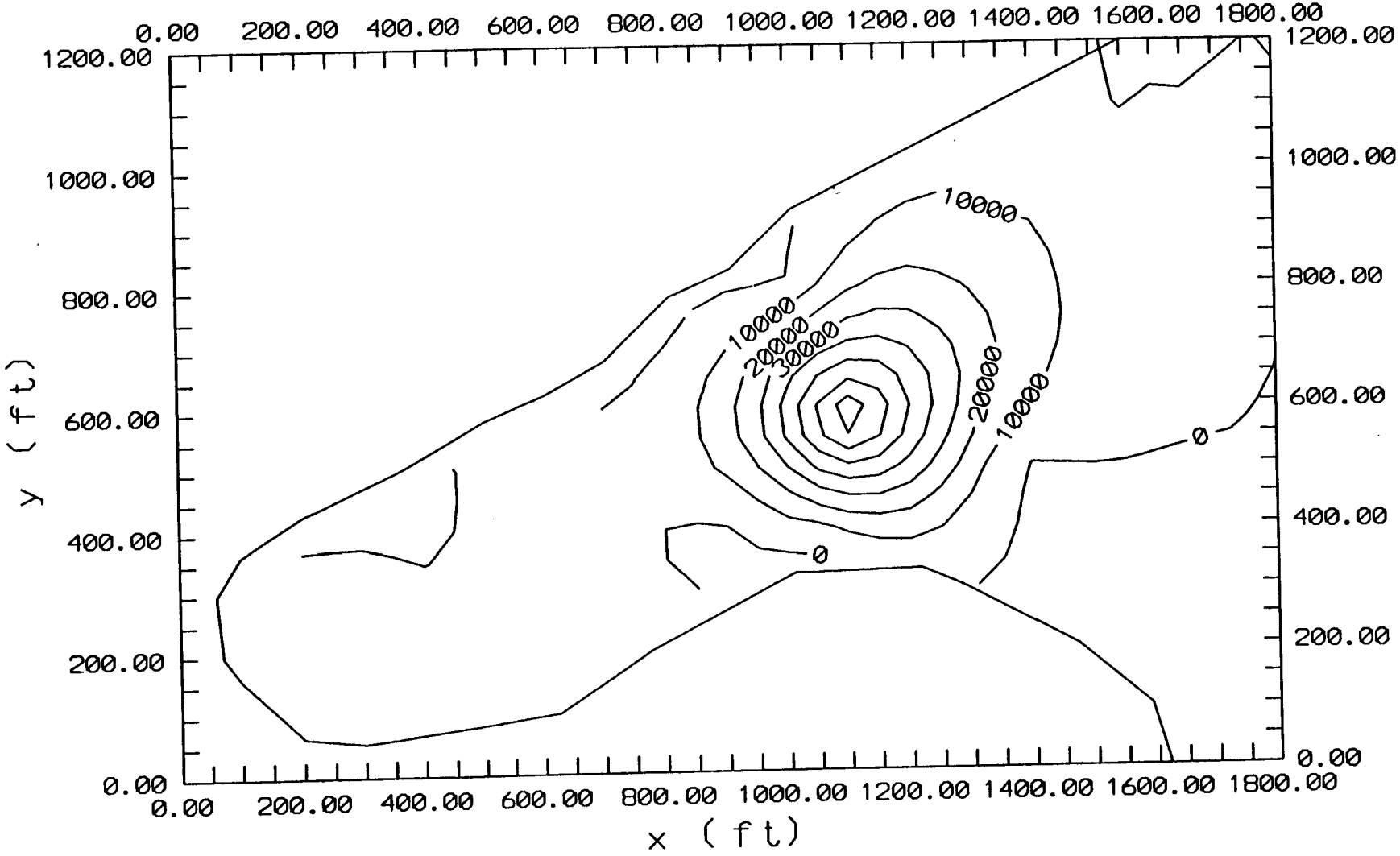


Fig. 4.20. Groundwater lead concentrations (ug/L).

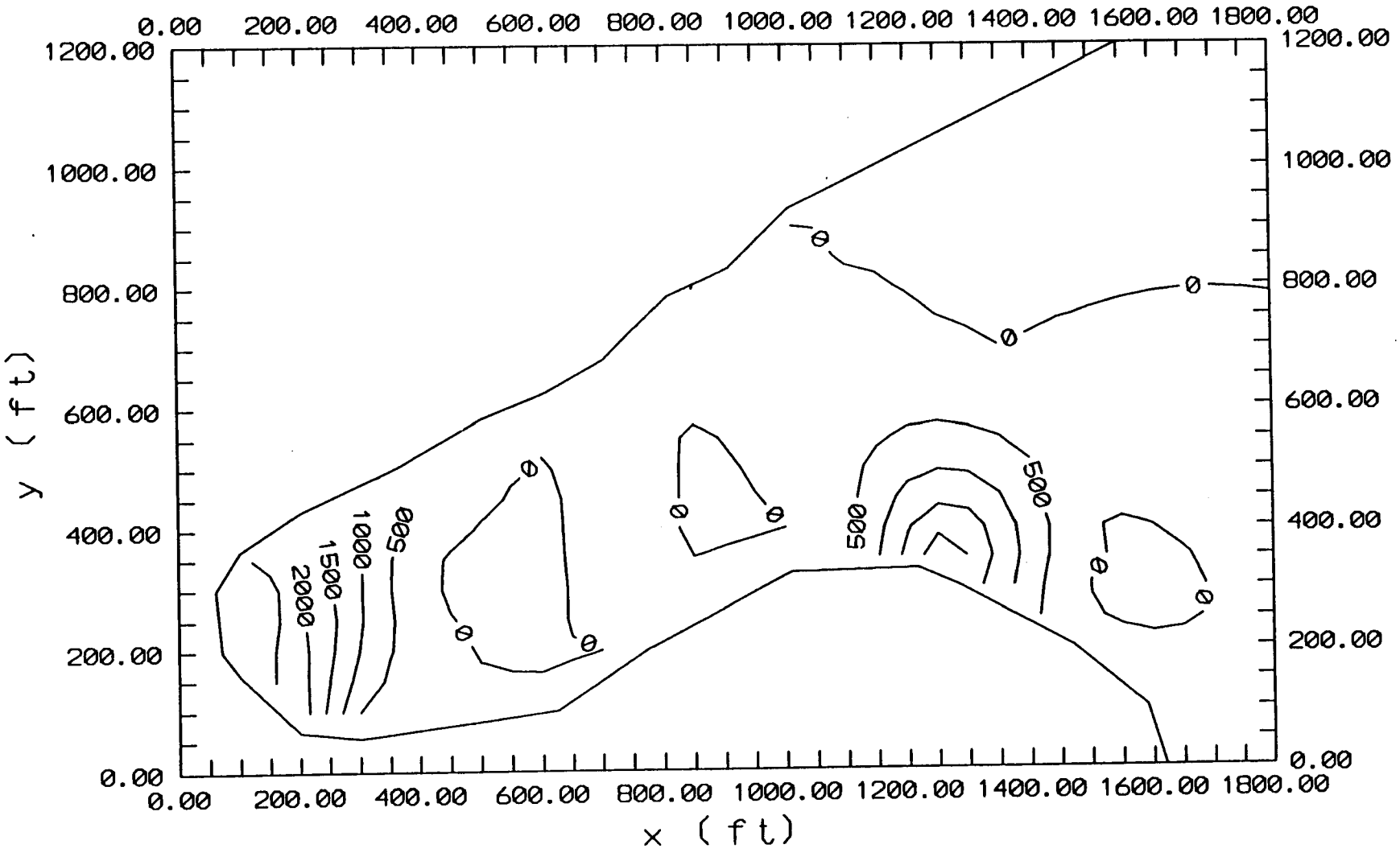


Table 4.4. Maximum observed PAH concentrations in source areas of the Buffalo Color Site (ND = not detected).

| Source | Benzo(a) anthracene | Benzo(b) fluoranthene | Benzo(k) fluranthene | Benzo(a) pyrene | Chrysene |
|---|---|---|---|---|---|
| Lagoon Area | | | | | |
| Soil (mg/kg) | ND | ND | ND | ND | ND |
| Water (μg/L) | 12 | ND | ND | 7 | 11 |
| Incineration Area | | | | | |
| Soil (mg/kg) | 1.9 | 3.1 | ND | 1.7 | 2.1 |
| Water (μg/L) | 1 | ND | ND | ND | 0.9 |
| Weathering Area | | | | | |
| Soil (mg/kg) | 180 | 150 | 140 | 140 | 180 |
| Water (μg/L) | ND | ND | ND | ND | ND |
| West Shore Area | | | | | |
| Soil (mg/kg) | 6.7 | 9.7 | ND | 5.5 | 8.2 |
| Water (μg/L) | ND | ND | ND | ND | ND |
| Tank Park 912 | | | | | |
| Soil (mg/kg) | 4.6 | 6.1 | ND | 3.5 | 5 |
| Tank Park 910 | | | | | |
| Water (μg/L) | 1 | 0.3 | 0.6 | 0.6 | 1 |

Table 4.5. Maximum observed metal concentrations in source areas of the Buffalo Color Site.

| Source | Copper | Iron | Lead |
|---|---|---|---|
| Lagoon Area | | | |
| Soil (mg/kg) | 4,630 | 537,000 | 187 |
| Water (μg/L) | 27,800 | 405,000 | 3,030 |
| Incineration Area | | | |
| Soil (mg/kg) | 3,580 | 360,000 | 5,520 |
| Water (μg/L) | 3,710 | 80,500 | 77 |
| Weathering Area | | | |
| Soil (mg/kg) | 14,500 | 38,900 | 27,300 |
| Water (μg/L) | 78,700 | 233,000 | 2,390 |
| West Shore Area | | | |
| Soil (mg/kg) | 341 | 300,000 | 77 |
| Water (μg/L) | 860 | 381,000 | 2,670 |
| Tank Park 913 | | | |
| Soil (mg/kg) | 134 | 26,500 | 221 |
| Water (μg/L) | 20 | 30,500 | 28 |
| Tank Park 911 N | | | |
| Soil (mg/kg) | 135 | 11,900 | 28 |
| Water (μg/L) | 234 | 104,000 | 179 |
| Tank Park 912 | | | |
| Soil (mg/kg) | 644 | 46,400 | 83,200 |
| Tank Park 911 S | | | |
| Soil (mg/kg) | 640 | 43,000 | 323 |
| Tank Park 910 | | | |
| Water (μg/L) | 25 | 9,450 | 51 |

## 5. RESULTS

### 5.1 Allied Chemical, Lehigh Valley, MacNaughton-Brooks, Madison Wire, West Seneca

Loadings of copper, iron, and lead to the Buffalo River were computed as a function of time for the named sites using the Plane Dispersion model and parameters described in the preceding section. Results are presented in Figures 5.1, 5.2 and 5.3 and show that loadings increase with time and asymptotically approach a steady-state value. Fifty percent breakthrough times, i.e., the time required for the loading to reach one-half the steady value, are seen to be in excess of 100 years for all metals. For copper 50% breakthrough occurs in about 700 years at the Madison Wire site. Fifty percent breakthrough times for iron are as follows: 8,000 years for MacNaughton-Brooks; 20,000 years for Madison Wire; 40,000 years for Lehigh Valley Railroad; 60,000 years for West Seneca Transfer Station (not shown); and 125,000 years for Allied Chemical (not shown). For lead 50% breakthrough times were estimated to be as follows: 1,300 years for Madison Wire; 9,000 years for West Seneca Transfer Station; and 12,000 years for Allied Chemical (not shown).

The results presented in Figures 5.1 through 5.3 show that the time-scales for the breakthrough of copper, iron and lead to the Buffalo River from sources within the named sites are on the order of 1,000 to 100,000 years, i.e., these metals are essentially immobile. These large breakthrough times are consistent with the magnitudes of the estimated retardation factors which are summarized in Table 4.1. These retardation factors are in turn a function of the Freundlich isotherm constants which were derived for the Buffalo Color site and assumed to apply to the named sites. If site-specific values for the retardation factors are significantly less than those assumed in the present study, breakthrough will occur significantly quicker. Steady-state loadings will be the same; the retardation factor affects only the transient behavior.

### 5.2 Buffalo Color

Loadings of the PAHs, copper, iron, and lead to the Buffalo River were computed for the Buffalo Color site using the MOC model and parameters discussed previously. Loadings are plotted as a function of time for these chemicals in Figures 5.4 through 5.7.

The PAH loading curves shown in Figure 5.4 indicate 50% breakthrough to the Buffalo River occurs in about 3 years and steady-state loading is reached in about 15 years. Because the PAHs were assumed to be non-sorbing over the relatively short groundwater residence times at this site and all PAH retardation factors were taken to be unity, relative breakthrough is the same for all PAHs. Also, because contaminant efflux from the site must equal the contaminant influx at steady-state, the steady-state loadings are proportional to the PAH source concentrations (see water solubility values in Table 1.1).

Figures 5.5 through 5.7 indicate that the loadings of copper, iron, and lead will be unsteady for time-scales of environmental interest to the Buffalo River (e.g., 10 to 100 years). In contrast to the other sites studied, there is some breakthrough of these metals to the Buffalo River because several of the metal sources are adjacent to the river shoreline. While simulations were not run beyond 100 years, it is likely that 50% breakthrough would require well in excess of 100 years as was determined for the Allied Chemical, Madison Wire, Lehigh Valley Railroad and West Seneca Transfer Station sites.

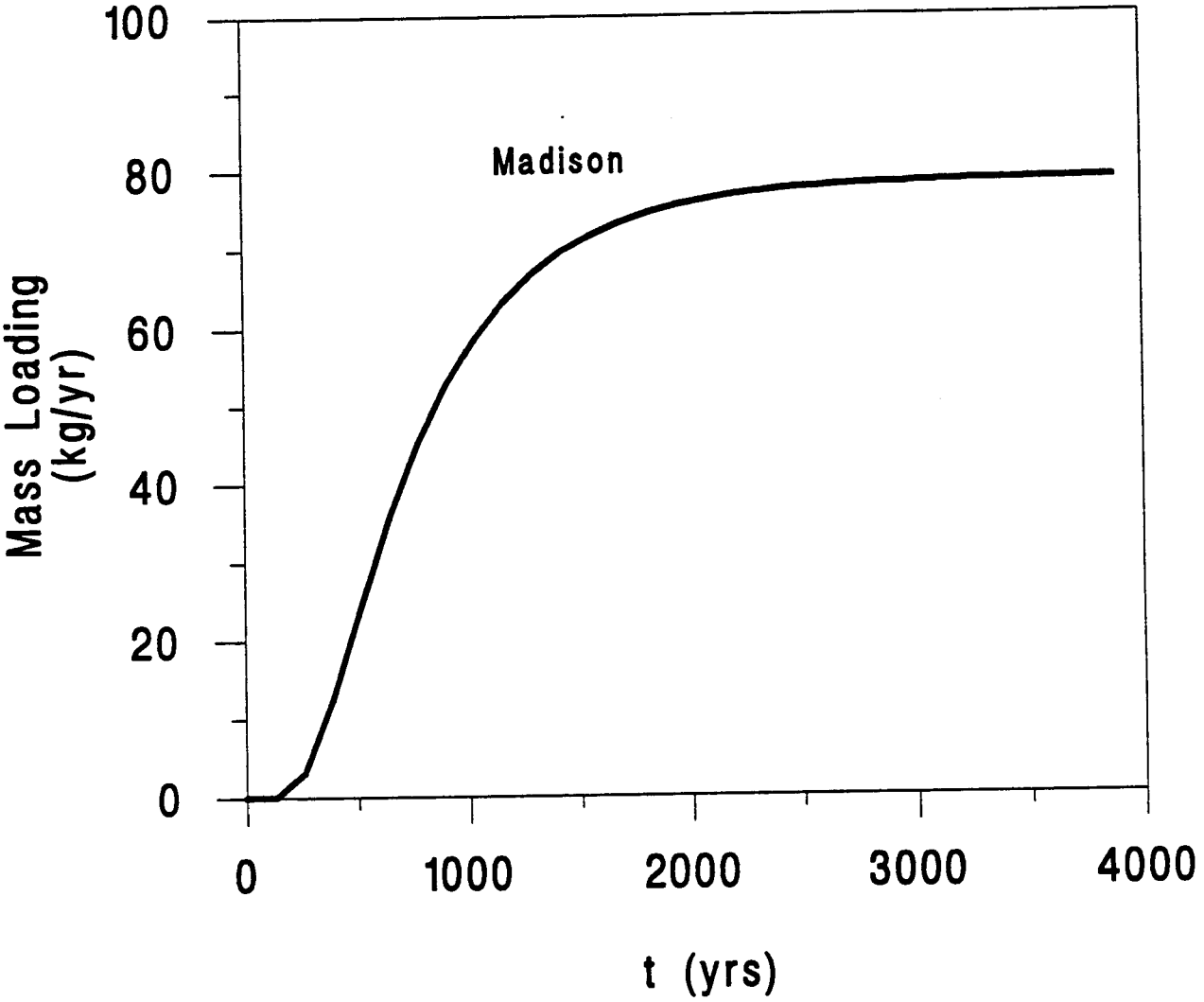



Fig. 5.1. Copper loadings to Buffalo River.

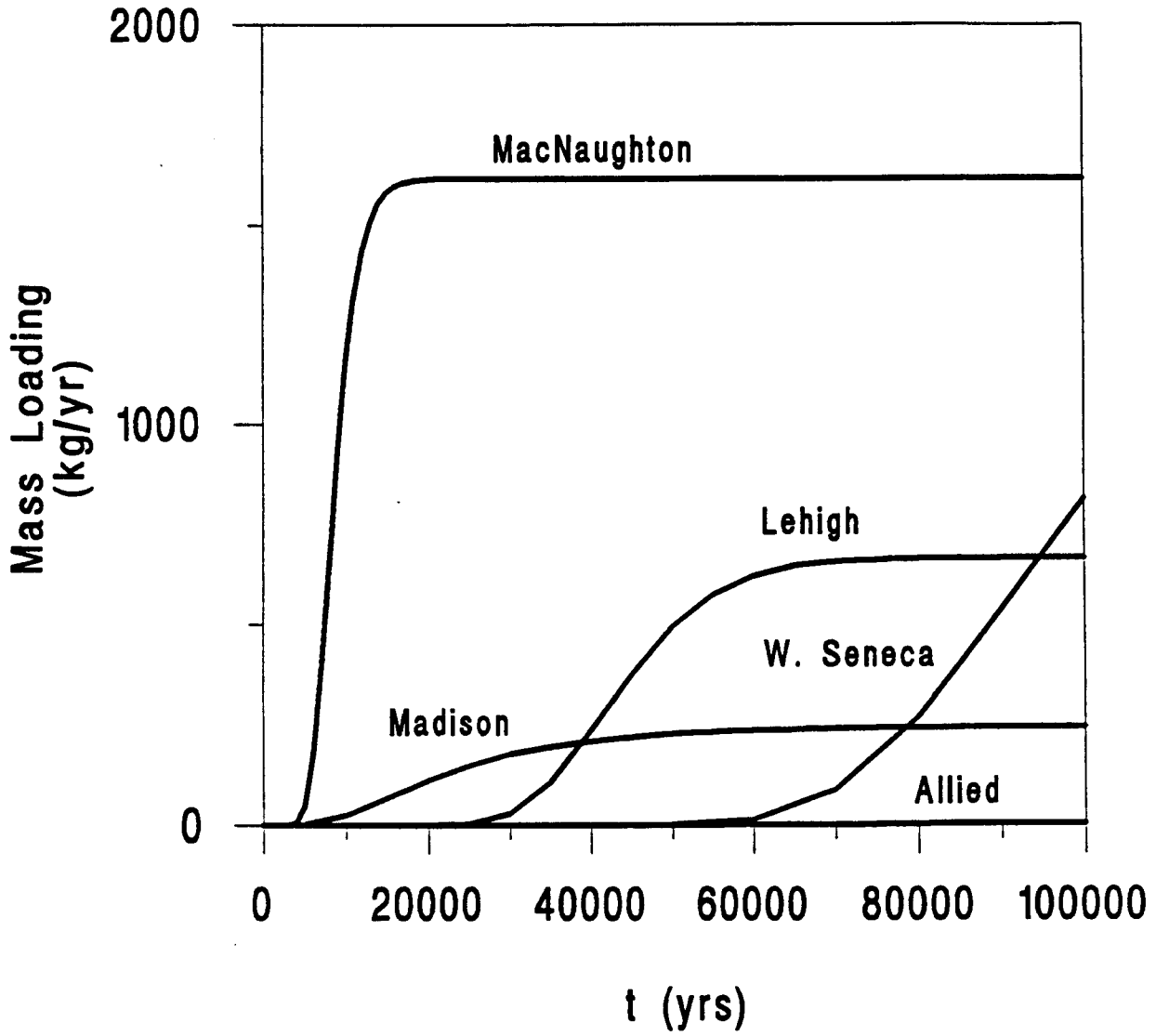



Fig. 5.2. Iron loadings to Buffalo River.

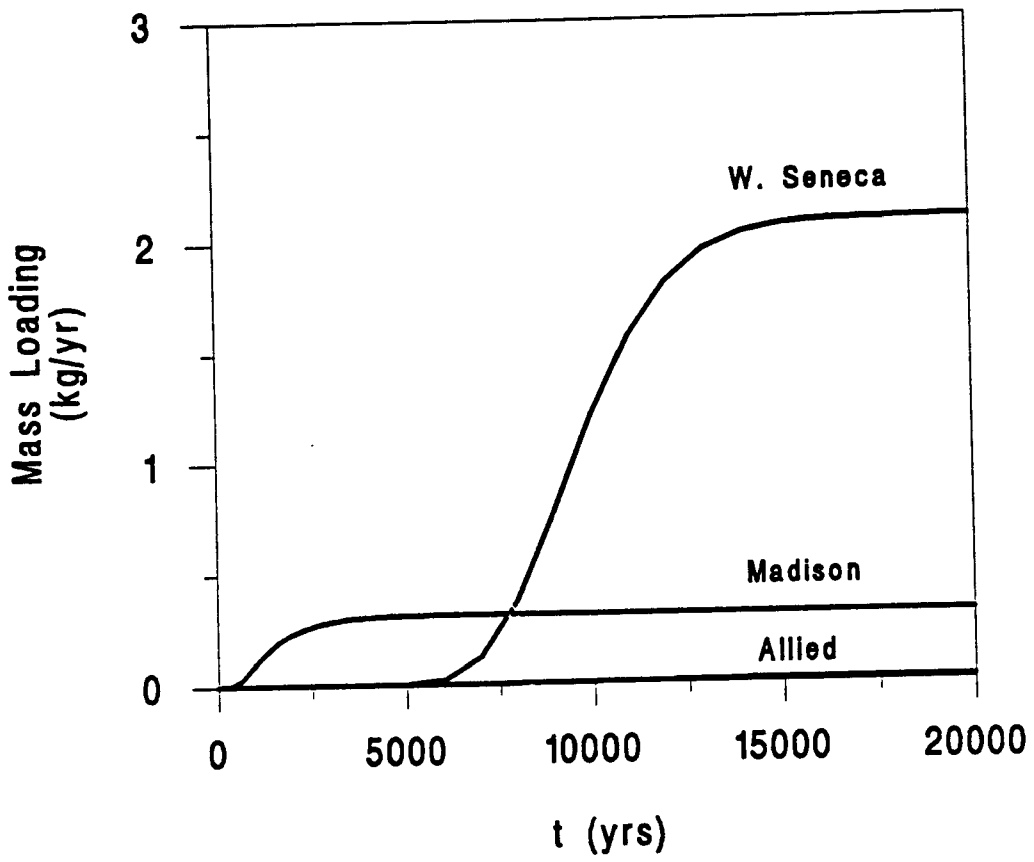



Fig. 5.3 Lead loadings to Buffalo River.

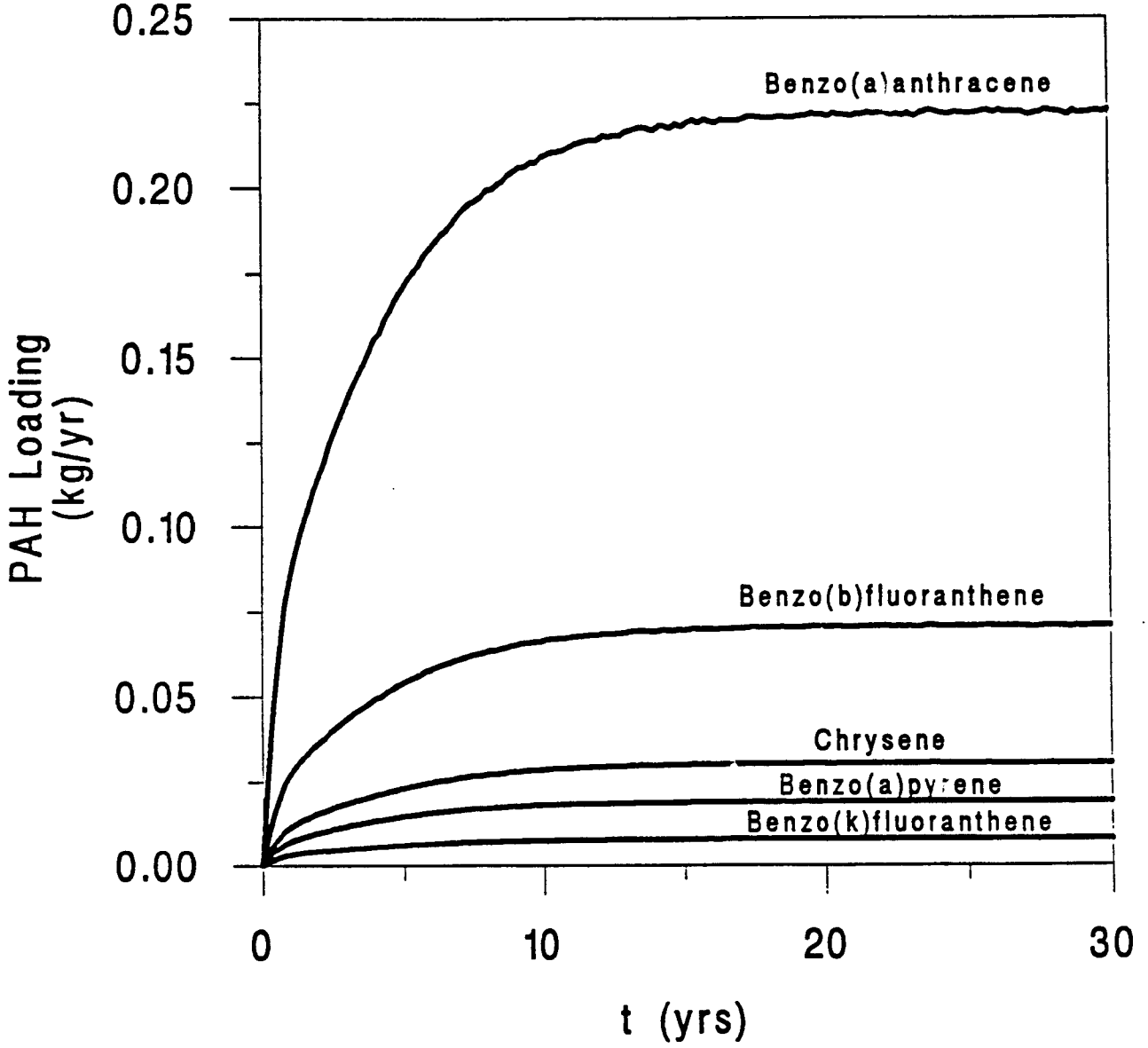



Fig. 5.4. PAH loading to Buffalo River from Buffalo Color.

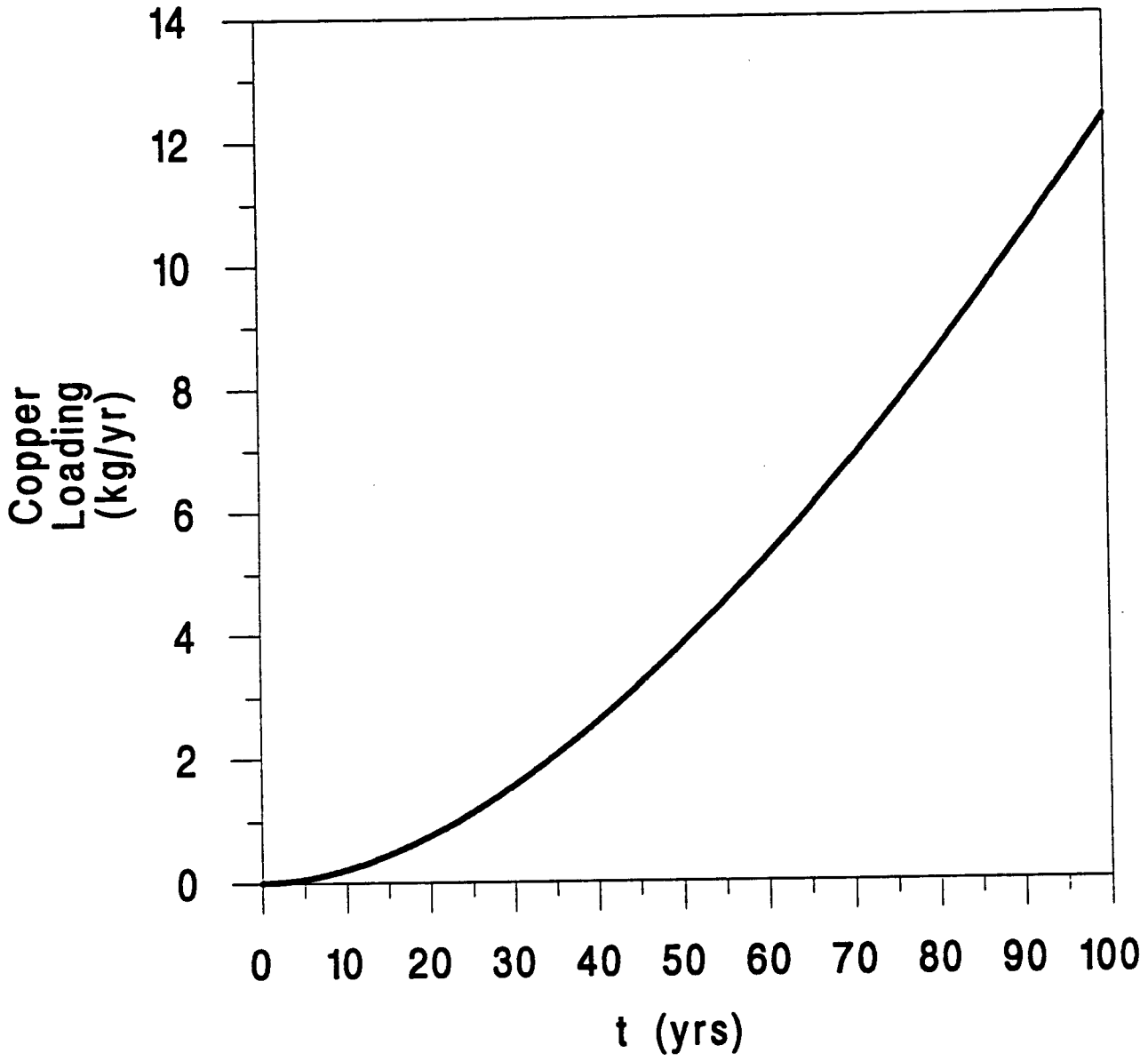



Fig. 5.5. Copper loading to Buffalo River from Buffalo Color.

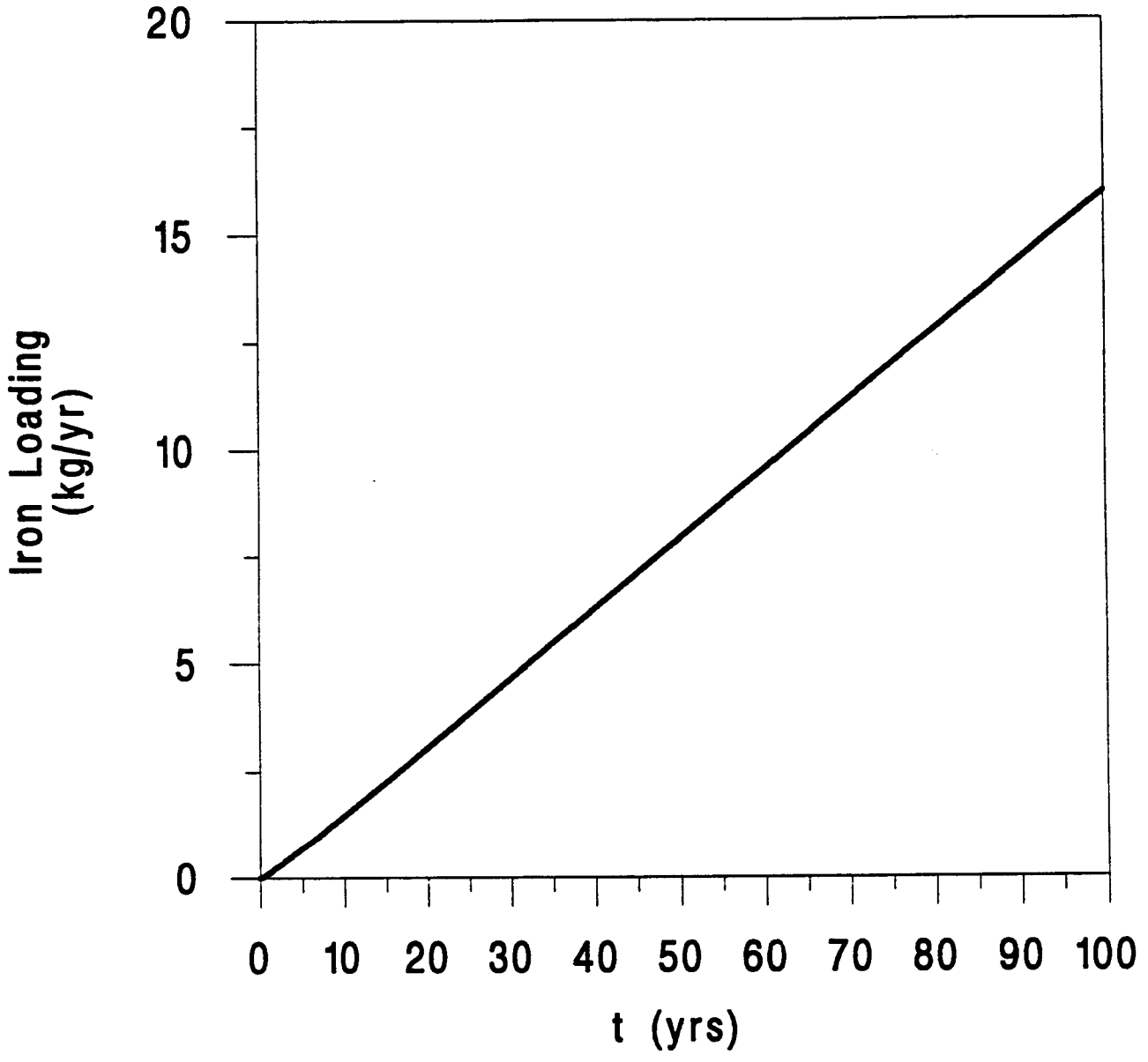



Fig. 5.6. Iron loading to Buffalo River from Buffalo Color.

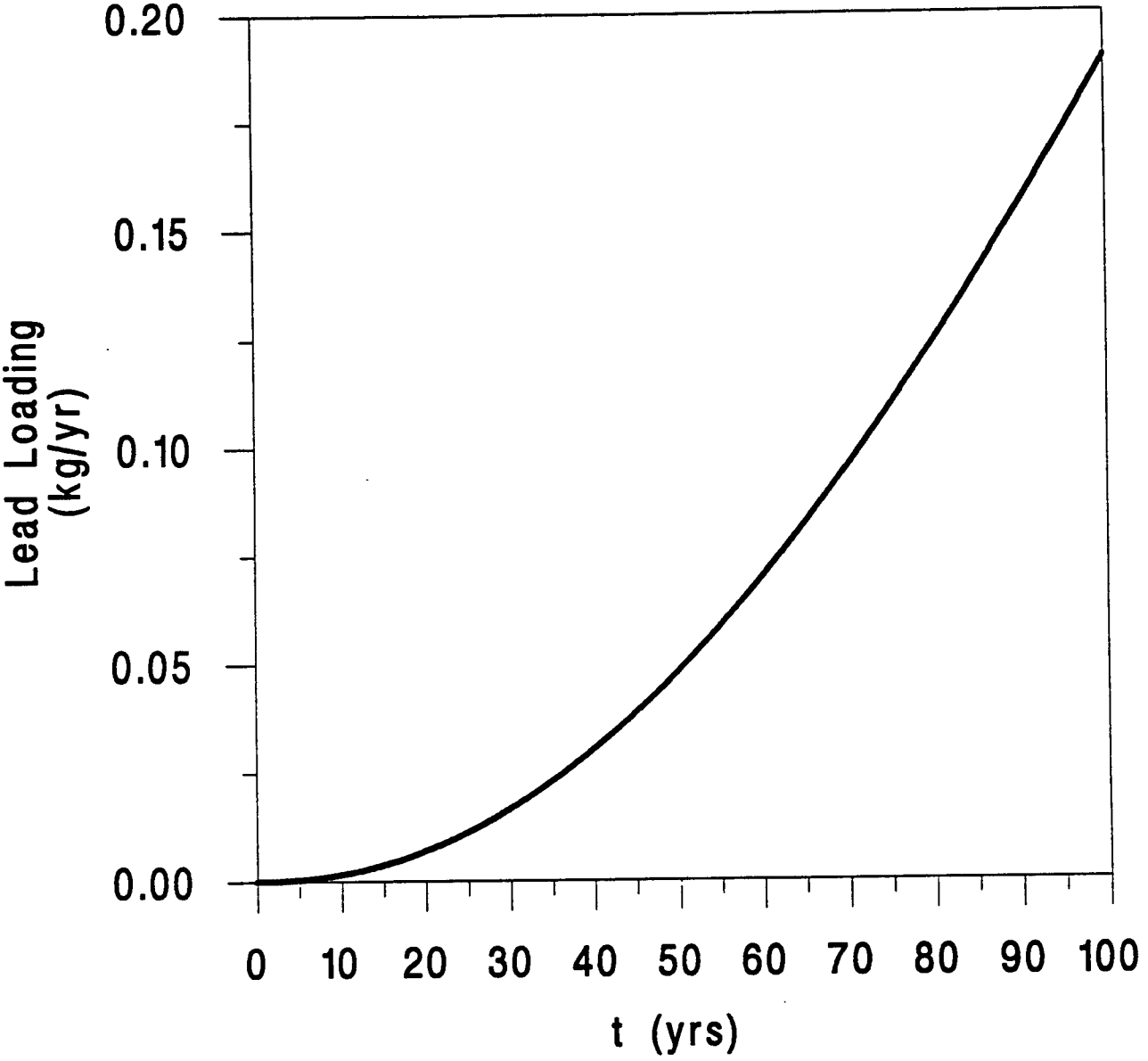



Fig. 5.7. Lead loading to Buffalo River from Buffalo Color.

## 6. DISCUSSION

### 6.1 Pollutant Loadings via Groundwater

**Allied Chemical, Lehigh Valley, MacNaughton-Brooks, Madison Wire, West Seneca.** Results obtained from the Plane Dispersion model suggest that the pollutants of interest (copper, iron, lead) are essentially immobile. However, these results were obtained without the benefit of site-specific adsorption data, and breakthrough could occur significantly earlier if the true retardation factors are significantly smaller than those estimated with the best available information. Given this uncertainty, loadings of these metals can only be bracketed between zero and the steady-state values, which are summarized in Table 6.1.

Table 6.1. Lower and upper limits of metal loadings to Buffalo River as computed by the Plane Dispersion model.

| Site | Lower Loading Limit (kg/yr) | Upper Loading Limit (kg/yr) |
|---|---|---|
| Allied Chemical | | |
| Fe | 0 | 26.9 |
| Pb | 0 | 0.0161 |
| Lehigh Valley Railroad | | |
| Fe | 0 | 665 |
| MacNaughton-Brooks | | |
| Fe | | 1,620 |
| Madison Wire | | |
| Cu | 0 | 78.6 |
| Fe | 0 | 245 |
| Pb | 0 | 0.310 |
| West Seneca | | |
| Fe | 0 | 1,340 |
| Pb | 0 | 2.09 |

**Buffalo Color.** Results obtained for the Buffalo Color site using the MOC model indicate that loadings will be transient for time-scales ranging from 1 to 100 years. For purposes of utilizing the groundwater pollutant loading data in a mass balance model for the Buffalo River to assess river management alternatives, dates must be assigned to the loadings given in Figures 5.4 through 5.7. In assigning these dates it is assumed that contamination of the subsurface commenced at the same time in history as the solid waste handling operations commenced at the Buffalo Color site.

According to the Remedial Investigation Report, heavy metal sludges were de-watered in the Weathering Area and in the Iron Oxide Sludge Lagoon Area from 1916 to 1976, and flammable solid and liquid chemical wastes were burned in the Incinerator Area from 1922 to 1972. These areas are the principal sources of copper, iron, and lead contamination at this site. The history of metallic sludge handling indicates that copper and iron sludges were handled as early as 1916 and lead sludge as early as 1922. Hence, for copper and iron the time $t = 0$ in Figures 5.5 and 5.6 corresponds to 1916, and for lead $t = 0$ in Figure 5.7 corresponds to 1922.

While the history of metals handling is relatively complete, the Remedial Investigation Report makes reference only to the burning of PAHs (napthalene) in the Incinerator Area. However, there is little evidence of PAH contamination of this source area (see Figures 4.9, 4.10, 4.11). No other reference to the use or disposal of these chemicals is made. It is supposed that PAHs were likely introduced into the West Shore, Weathering and Iron Oxide Sludge Lagoon Areas along with metallic sludges which may have originated from the steel industry, PAHs being a common component of the steel-making waste-stream. If this hypothesis is correct, then PAHs may have been discharged as early as 1916 to 1922. Given that complete breakthrough of PAHs to the river was predicted to occur in about 20 years, PAH loadings to the Buffalo River are likely at their steady-state values. These values, which are recommended for PAH loadings to the Buffalo River, are summarized in Table 6.2.

Table 6.2. PAH loadings to Buffalo River from the Buffalo Color site as computed by the MOC model.

| PAH | Loading (kg/yr) |
|---|---|
| Benzo(a)anthracene | 0.223 |
| Benzo(b)fluoranthene | 0.0709 |
| Benzo(k)fluoranthene | 0.00810 |
| Benzo(a)pyrene | 0.0192 |
| Chrysene | 0.0304 |

## 6.2 Uncertainty Associated with Loading Estimates

**Allied Chemical, Lehigh Valley, MacNaughton-Brooks, Madison Wire, West Seneca.** Most of the uncertainty associated with the loading analysis is due to lack of or insufficient data on sorption and source characterization. Transient loading depends primarily on the average linear velocity (V) and the retardation factor (R), and secondarily on the dispersion coefficients ($D_L$ and $D_T$). Velocities were estimated with site-specific data, whereas no such data were available for retardation or sorption. Improvements in the transient loadings would therefore require better characterization of retardation factors or sorption isotherms. The steady-state loading, the maximum loading rate achievable, is directly proportional to the average linear velocity (V), the aquifer thickness (b), the source width (2a), and the source concentration ($C_0$). Of these parameters, the source width and source concentration are known with the least certainty. Hence, any improvement in the estimates of the steady-state loadings would require environmental measurements to better characterize pollutant sources.

**Buffalo Color.** The hydrogeology of the Buffalo Color site is relatively well-characterized, i.e., the groundwater velocities and directions are known with a reasonable amount of confidence. The chemical characterization of the site is less well-established. The greatest uncertainty is associated with the adsorption of the PAHs, which was conservatively neglected in this analysis, followed by adsorption of the metals. Improving the reliability of the transient loading estimates would require environmental sampling of aquifer materials and establishment of sorption isotherms or retardation factors in a laboratory setting.

### 6.3 Pollutant Loadings via Other Pathways

The Remedial Investigation Report for the Buffalo Color site suggests that mechanical erosion of fill comprising the river banks may be an important pathway for river contamination in addition to the groundwater pathway. An erosion potential of about 579 $yd^3/yr$ (443 $m^3/yr$) is reported. If this bank material has significant levels of organics and metals, bank erosion may be a direct contributor to the contaminated sediments in the vicinity of the Buffalo Color site. Presently, insufficient soils data exists to estimate pollutant loadings from this source.

## 7. SUMMARY AND RECOMMENDATIONS

An analysis was conducted to identify inactive hazardous wastes sites which may be contributing one or more targeted pollutants (PCBs, pesticides, PAHs, metals) to the Buffalo River AOC via groundwater flows and estimate the associated pollutant loadings. Based on a screening of hydrogeological and groundwater quality data given in published Phase I, Phase II and Remedial Investigation Reports for the NYSDEC, six sites were identified for which the existing data indicates pollutant migration to the Buffalo River. The contributing sites include Allied Chemical, Buffalo Color, Lehigh Valley Railroad, MacNaughton-Brooks, Madison Wire, and West Seneca Transfer Station. Other sites were identified (Tifft Farm Nature Preserve and Houghton Park) which might potentially be contributing one or more of the targeted pollutants to the Buffalo River, but data were not sufficient to allow estimation of loadings from these sites.

The principal targeted pollutants present at the identified sites include copper, iron, lead, and PAHs. PCBs were detected at low levels in the soils at three sites (Lehigh Valley Railroad, Tifft Farm Nature Preserve, West Seneca Transfer Station), but were not present in the groundwater. The pesticide chlordane was detected at low concentration in one soil sample of the MacNaughton-Brooks site, but not in the groundwater. Based on the available data, PCB and pesticide pollution of the Buffalo River via the groundwater pathway does not appear to be significant and no loading estimates were evaluated for these chemicals. It was also noted that some of the identified sites are likely contributing significant quantities of non-targeted volatile and semi-volatile organic and metal pollutants to the Buffalo River in addition to those targeted by the USEPA.

Pollutant loadings to the Buffalo River were estimated using mathematical models for contaminant transport by groundwater. An analytical model was applied at the Allied Chemical, Lehigh Valley Railroad, MacNaughton-Brooks, Madison Wire and West Seneca Transfer Station sites, while a numerical model was applied at the Buffalo Color site. These models were parameterized using data published in reports to the NYSDEC and literature values. The resulting loadings recommended for the Buffalo River Mass Balance Project are summarized in Tables 6.1 and 6.2, and Figures 5.5, 5.6 and 5.7. The locations of these loadings with respect to the river reach are as shown in Figure 7.1.

Because this study was conducted using only existing data, due to resource limitations, there is considerable uncertainty associated with the loading estimates at sites where intensive Remedial Investigations have not be conducted (Remedial Investigation Reports have been published only for the Buffalo Color and Madison Wire sites). Increasing the reliability of these estimates would require site-specific field investigations to better characterize the hydrogeology, pollutant source areas and strengths, and sorption isotherms/retardation factors. It is also

recognized that mass balance models constructed for the Buffalo River may or may not be sensitive to the groundwater pollutant loadings presented in this report, e.g., loadings from upstream tributary sources or combined sewer outfall sources might be more significant. Therefore, it is recommended that the sensitivity analyses be conducted using the mass balance model to identify the inactive hazardous waste sites, if any, which are critical to the mass balance modeling effort. Once these sites are identified, resources can be better allocated to decrease uncertainty with respect to groundwater pollutant loads.

It is also recommended that groundwater pollutant loadings be updated with evolving NYSDEC investigations, including an assessment of newly listed sites and publication of Remedial Investigation Reports. Newly listed sites, e.g., Niagara Transformer and Bern Metal (NYSDEC, 1991), might be pollutant sources for the Buffalo River. Sites at which only Phase II Investigations are complete and insufficient data exists to assess pollutant migration potential (e.g., Tifft Farm Nature Preserve) should be re-examined if Remedial Investigation Reports or any other additional data are published.

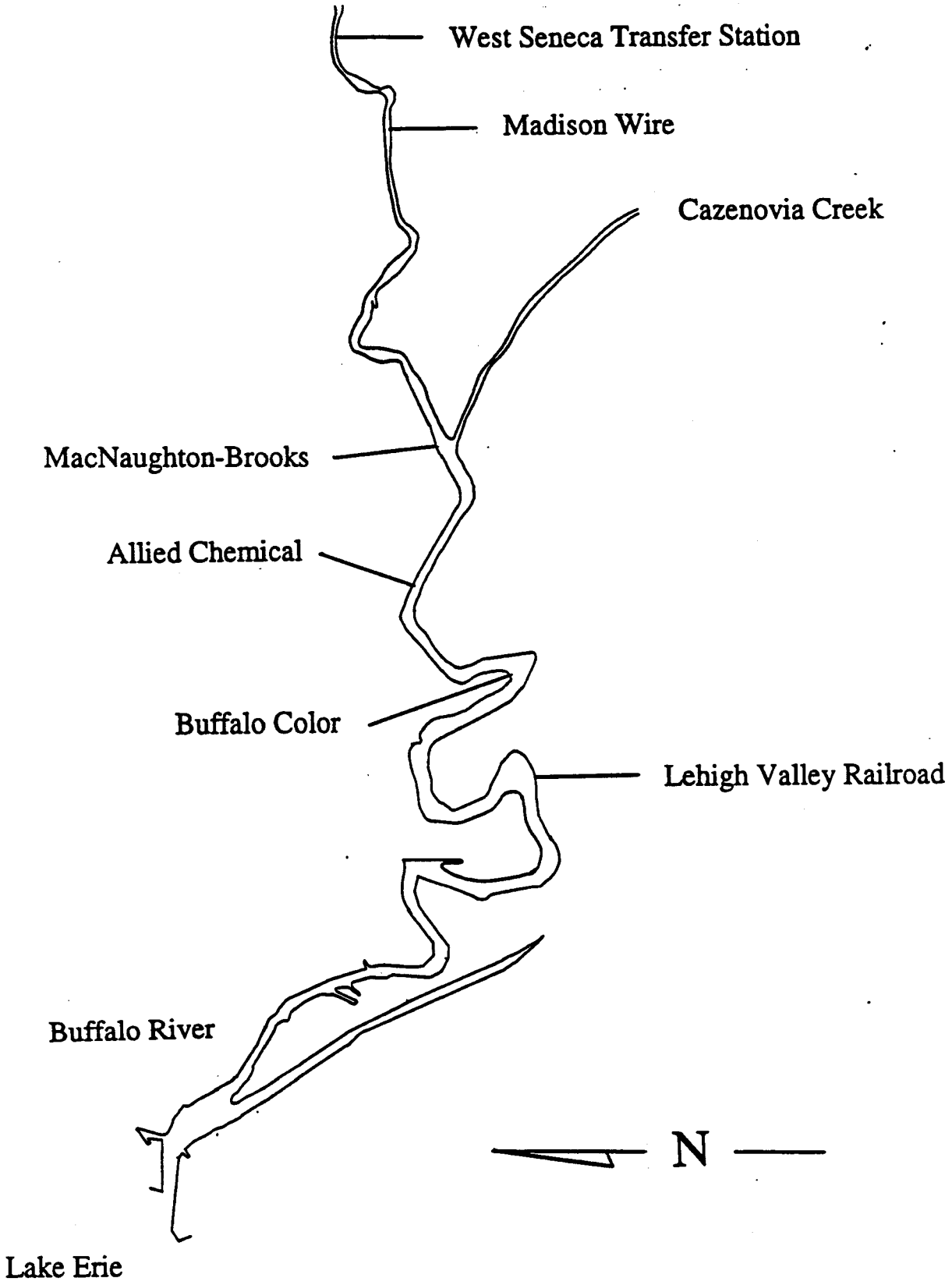



Fig. 7.1. Locations of groundwater pollutant sources along the Buffalo River.

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