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*be accepted as fulfilling this part of the requirements for the
degree of* MASTER OF SCIENCE

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**THE CONTAMINATION POTENTIAL OF THE FORMER COAL GASIFICATION
PLANT SITES IN SOUTHWESTERN OHIO**

A Thesis Submitted to the

**Division of Graduate Studies and Research
of the University of Cincinnati**

**in partial fulfillment of the
requirements for the degree of**

MASTER OF SCIENCE

**in the Department of Environmental Health
of the College of Medicine**

1988

by

C. R. Penniall

B.S., University of North Carolina, 1983

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A. SUMMARY

This study involved the investigation of the fate and potential environmental impact of coal tars and other wastes produced as by-products of the coal gasification industry. Ten former gas plant sites in southwestern Ohio were investigated by off-site methods. The ground water pollution potential around each former gas plant site was modeled using "DRASTIC: A Standardized System For Evaluating Groundwater Pollution Potential Using Hydrogeologic Settings" (Aller et al., 1987), and mapped. In addition, the potential worker hazards caused by gas plant contamination are addressed along with the industrial hygiene and worker safety concerns at former gas plant sites.

B. ACKNOWLEDGMENTS

The author would like to thank the Cancer Consortium of Ohio for funding this research project. I would also like to thank the two professors who helped me in this project: Dr. Scott Clark for providing the initial idea and motivation for the project, and Dr. Milovan Beljin for his expertise in the area of ground water hydrology. I would also like to thank Dr. Carol Rice for her guidance and David Benson for his help in locating information pertaining to the former gas plants in southwestern Ohio. Lastly, I would like to thank the Ohio Department of Natural Resources, Division of Water for letting me use their well log files.

C. ABSTRACT

From 1816 to 1950 it is estimated that between 1,100 to 1,500 manufactured gas plants existed in the United States. These plants produced approximately 15 trillion cubic feet of gas resulting in the production of 11 billion gallons of by-product tars (Eng, 1985). These plant sites have largely been forgotten due to the passage of time and many are still unlocated. Due to the large number former gas plants sites and the amount of waste they represent, these plants sites are one of the largest generic sources of wastes in the United States (Eng, 1985).

The interest in studying gas plant wastes stems from the discovery that coal tars potentially contain over 300 chemicals of which many (e.g. benzo[a]pyrene) are potent human carcinogens. The US EPA recommends a maximum concentration for carcinogens in drinking water as zero since any exposure to a carcinogen may result in cancer development.

It has been estimated that 76% of the tar wastes were sold (Eng, 1985). This estimate would leave 24% or 2.6 billion gallons of tars either dumped, used as fuel, or lost in poor work practices. It is generally believed that much of the coal tars produced at plant sites operating in the late 1800's were disposed of on site (EEI, 1984). These coal tars could have largely remained trapped in pools at or near the plant site and need locating. There is also the potential that over time coal tars and plant wastes have migrated away from plant sites contaminating both soils and ground water supplies. It is assumed that all gas plant sites have soil contamination and may contain buried wastes.

Besides tars, other wastes found at former gas plant are sludges, light aromatics, phenols, creosols, spent iron oxides, and ash. Gas plant wastes include several classes of chemical compounds:

- (1) polycyclic aromatic hydrocarbons (PAH)
- (2) phenolics
- (3) light aromatics (benzene, toluene, xylenes)
- (4) inorganic sulfur, nitrogen, and cyanide species
- (5) heavy metals

These chemical classes behave differently in the environment and offer different pollution potential and potential exposure risks.

Several former gas plant sites (Ames, Iowa; St. Louis Park, Minnesota; Stroudsburg, Pennsylvania; Pensacola, Florida; Burlington, Vermont; Seattle, Washington; and Plattsburgh, New York) have documented ground water pollution and/or serious environmental contamination stemming directly from the operations of former gas plants. The first hazardous waste site in the United States to receive emergency Superfund money was the former gas plant site in Stroudsburg Pennsylvania (Harkin et. al, 1987).

Additionally, several recently discovered pools of liquid tar wastes in Utah and California are considered potential hazardous waste sites. These sites were discovered when (1) tarry substances were noticed at a public playground area; (2) a hotel tried to dig down below ground level to construct a parking garage but encountered tars; and (3) a subway line had to be repositioned when it was discovered that the proposed tracks would run through a former gas plant site where there were pools of tar wastes. Unfortunately, many coal tar deposits have been discovered when excavations have encroached on old plant property, resulting in human exposures and contamination of water sources (Salvesen, 1984).

Ohio had 90 manufactured gas sites operating between 1830-1950. The estimated annual production from the plants in Ohio was 101×10^9 ft³ feet of gas with a corresponding estimated annual tar production of 74×10^6 gallons (Eng, 1985). Using the same conversion factor of 730 gallons of tar produced per million cubic feet of gas, the ten gas plants in southwestern Ohio produce an estimated 4.7×10^6 gallons of tars over their operational history. Since approximately 50% of Ohio's population uses ground water as their source of drinking water, it is important to investigate and determine the potential for ground water contamination at the former plant sites in Ohio.

D. OBJECTIVES

The following were the objectives addressed in the research:

- (1) Determine both the location and present-day use of former gas plant sites in southwestern Ohio.
- (2) Collect pertinent historical data on each plant's size, operations, generating capacity, waste disposal practices, and the amounts of gas and wastes produced.
- (3) Use the DRASTIC modeling system (Aller et al., 1987) to develop a ground water pollution potential map of the area immediately surrounding each plant site based on the geology and hydrology of the area.
- (4) Determine the availability and use of ground water near the former plant sites.
- (5) Assess the current potential worker hazards caused by wastes at each plant site.
- (6) Provide suggestions for future remedial actions at each plant site.
- (7) Compare the ground water contamination potential between the different former gas plant sites in southwestern Ohio.
- (8) Address the industrial hygiene concerns at former gas plant sites.

E. BACKGROUND

E.1 History of The Manufactured Gas Industry

E.1.a General

In 1792 in Great Britain William Murdoch lighted his home by producing coal gas and in effect started the coal gasification industry. Mr. Murdoch later began to set up coal gas operations for factories around Britain and he is generally credited with being the father of the coal gas industry (Rhodes, 1966).

The first coal gas plants were erected in 1815 in Paris, France. The first plants in the United States were built in 1816 in Baltimore, 1822 in Boston, and in 1825 in New York City. In the early years of the industry coal tars were treated as a nuisance which were hard to dump indiscriminately.

By 1838 coal tars were being used as a wood preserver and as a road tar in Great Britain, and by 1850 the value of coal tars were well established in England and Germany. Phenol was discovered in coal tar and was used as an antiseptic in surgery. In 1856 the dyestuffs industry was revolutionized in England when it was discovered that coal tars could be used to produce colorful dyes (Rhodes, 1966). By the late 1800's the Germans had established a large coal tar industry producing many varied and commercially important compounds. Coal tar yielded paint pigments, coatings, road tars, roofing and waterproofing materials, fiber pipe coating, carbon electrode binders, foundry compounds, industrial fuels, wood preservatives, and chemicals such as benzene (Rhodes, 1966). These new chemicals were the start of the synthetic chemical industry which began to produce many useful products such as drugs, insecticides, plastics, explosives, and many more products (Rhodes, 1966). The demand for coal tars grew to the point that whole plants were built to produce just coal tar with coke as the by-product (Rhodes, 1966).

In the earlier decades of the coal gas and coal tar industry, the coal was distilled in beehive coke ovens which were inefficient in terms of recovering coal tars. By the late 1800's the Germans had begun replacing their beehive ovens with by-product coke ovens which were built to recover the coal tars. By modernizing their coke ovens, the Germans gained superiority in such industries as synthetic chemicals, explosives, and insecticides.

Due to Germany's dominance in the coal tar industry at the start of WWI, the United States and England and the rest of Europe were dependent on Germany for most of the products produced from coal tars. Once the war started, the United States coal tar industry began to grow very rapidly (Rhodes, 1966).

The history of coal tar production and the importance of its derivative products follows an interesting and noteworthy path in the rise of the commercial empires of Europe and the United States. Coal tars and its derivative products even played an important role in the development of World War I.

E.1.b History of The Manufactured Gas Industry in The United States

E.1.b.1 Development of The Manufactured Gas Industry In The United States

The manufactured gas industry existed in the US from 1816 until the 1950's when the industry was driven out of business by electric and natural gas power companies (Eng, 1985). The gas produced was used to light street lamps, businesses, and homes, and was also used for cooking. There were several names for the gas produced; the most common were the following: "manufactured gas", "town gas", "artificial gas", "coal gas", "water gas", and "blue gas". Several of these names indicate how the gas was produced.

As mentioned earlier, the U.S. manufactured gas industry was born in the United States when a coal gas plant was erected in Baltimore in 1816 and in 1825 in New York City. All the early plants built in the mid-1800's were coal gas plants. In the late 1800's water gas and oil gas production methods were developed and by the early 1900's, water gas plants were the most common method of production used. Details of these gas production methods are provided in Section E.2. Up until 1918 the bulk of coal gas produced in the US was made in beehive ovens which were very inefficient and had no means to collect and separate the coal tars (Smith, 1966). No provisions were made to collect the valuable coal tar chemicals. These ovens were replaced by the by-product coke ovens in which the recovery of the coal tar, light oils, ammonia, and other products was incorporated (Smith, 1966).

Creosotes, pitch for roofing and waterproofing, and road tars were produced in the United States from coal tars; however, refined chemicals such as benzene, toluene, and xylene were not extracted since the U.S. obtained all these synthetic chemicals from Germany. During WWI coal tar and its products were in great demand since such materials as TNT and phenol were produced from coal tar. For the first time, the United States realized the importance of coal tar production and the lack of adequate production of synthetic chemicals in this country. Therefore, the coal tar industry underwent a rapid growing period. By 1929 the US production of coal tar has risen to 730×10^6 gallons per year; quite a staggering figure! However, by 1945 the synthetic chemical products of coal tar were being increasingly made from petroleum (Rhodes, 1966).

Before the commercial value of coal tar was established, gas plants usually either burned the tars on site as supplemental fuel or disposed of it near the plant in open lagoons or injected the tars into wells (Villaume, 1984). Many sites are contaminated from former gas plant activities and several sites have already been investigated and remediated after gas plant wastes contaminated ground water and/or surface waters. Some of the noteworthy sites are Ames, Iowa; St. Louis Park, Minnesota; Stroudsburg, Pennsylvania; Burlington, Vermont; Seattle, Washington; and Plattsburgh, New York. Several of these sites are National Priority List (NPL) Superfund Sites (Villaume, 1984).

In Ames Iowa coal tar wastes forced the closure of city wells due to taste and odor problems. In St. Louis Park Minnesota a coal tar recovery plant was responsible for creosote contaminated ground water resulting in the closure of seven city wells and threatened the other wells in the area. At this site there were PAHs found in drift and bedrock wells over an area of several miles and at depths of up to 700 feet (Villaume, 1984).

The major concern with coal tar wastes in the United States is that the vast majority of former plant sites have not been properly located, tested, or cleaned up. The coal gasification plant sites have largely been forgotten due to the passage of time. Unfortunately, there is usually no surface evidence of plant wastes.

E.1.b.2 Decline of The Manufactured Gas Industry In The United States

Ever since the discovery and use of both natural gas and electricity (both were developed in the late 1800's) the use of manufactured gas was in decline. Both electricity and natural gas were easier to produce and offered a much cleaner product. In 1949 the US Federal Power Commission decreed that certain pipe lines which had been used during WWII for the transmission of oil to coastal areas could now be used to transport natural gas around the country. This action signaled the beginning of the end of the gas industry and the establishment of the natural gas and electric utilities that we know today (Rhodes, 1966). By the early 1960's, there were few if any manufactured gas plants operating in the United States.

E.2 Types of Gas Production Methods

There were three common types of gas produced: Coal Gas, Water and Carburetted Water Gas, and Oil Gas. In each process, coal was heated white-hot (without oxygen) and then reacted with either steam and/or oil to produce a combustible gas. Each method of gas production resulted in wastes which were similar, but have slightly different physical characteristics as in tar density. The difference in physical characteristics helps determine to some degree the difference in contamination potential of wastes from different methods of production. In both the coal and water gas methods, the gas streams were cleaned in the same manner to remove unwanted by-products such as tars and light oils.

There are several well documented references which thoroughly describe the processes of producing artificial gas, the types and characteristics of wastes produced, and the means used to clean the gas streams. The two most complete references are Harkins (1987) and EEI (1984).

E.2.a Coal Gas

Coal gas was made from the carbonization of coal in the absence of oxygen, resulting in a methane/hydrogen gas with a heating value of 400-550 BTU's/ft³ of gas. Waste by-products were tar, coke, ash, iron oxides, and ammoniacal fluids (EEI, 1984).

In the 1800's coal gas was usually produced in retorts or beehive ovens with limited recovery of coal tars. Later, by-product coke ovens were used to efficiently recover coal tars.

E.2.b Water and Carburetted Water Gas

Water gas was produced by passing steam through hot coal or coke creating hydrogen and carbon monoxide with a heating value of approximately 300 BTU/ft³ of gas. Water gas was non-luminous when combusted, and it was therefore usually enriched by the addition of oil gas created by the cracking of oil (forming carburetted water gas) which resulted in a gas with a higher heating value (500-1000 BTU/ft³) and better luminosity. In water gas production tar, coke, and ammonia were formed, but in lesser amounts than in the coal gas process (EEI, 1984).

E.2.c Oil Gas

Oil gas was formed by spraying oil (usually naphtha and heavier hydrocarbons) onto hot brickwork or a catalyst bed and cracking the oil. The gas produced contained methane, ethane, hydrogen, and other light hydrocarbons and had a heating value of about 1,000 BTU/ft³ (EEI, 1984). Commonly water gas was enriched with oil gas to give it a higher heating value. By-products were oil derivatives, tar, and naphthalene. Again, the tars formed during oil gas manufacture differ from coal gas tars (EEI, 1984).

E.3 Types of Wastes Produced and Their Contamination Potential

Common by-products from gas plants included coke, ammonia, light crude oil, coal residues, spent iron oxides, ash, heavy metals, and spent lime. These gas plant wastes include several classes of chemical compounds: polycyclic aromatic hydrocarbons (PAH), phenolics, aromatics, inorganic sulfur, nitrogen, cyanides, and heavy metals. These chemical classes behave differently in the environment and offer different pollution and contamination potential.

Table 1 lists the toxic properties and environmental characteristics of gas plant wastes. Table 2 shows an analysis of some soil samples taken from the St. Louis Park, MI gas plant site.

TABLE 1
Gas Plant Wastes

<u>Chemical Compound</u>	<u>Toxic & Hazardous Properties</u>	<u>Mobility in Environment</u>
Phenolics	Acute Poison. Absorb easily through skin.	Highly mobile. Low level of volatility and adsorption. Water Soluble Biodegrades in aerated zone.
PAH	Toxic & Carcinogenic Exposure is by skin contact and ingestion.	Immobile and persistent. Solubility & Volatility decrease as molecular weight increases. Adsorb on soils.
Light Aromatics	Toxic & Carcinogenic* Inhalation & skin absorption hazard.	Highly volatile, biodegradable, low rate of adsorption on soils. Mobile and persistent in ground water.
Inorganic Sulfur	Toxic at High Conc. when ingested. H ₂ S formation.	Stable in environment. Mobile in ground water.
Inorganic Nitrogen	Acute Toxicity of (NH ₃ ,HCN,CN) gases. Nitrates cause methemoglobinemia in infants.	Stable in the environment. Cyanides transformed to ammonia, which forms nitrates in presence of bacteria.
Heavy Metals	Toxic at high levels.	Stable in the environment.

* Benzene is a carcinogen.

TABLE 2
Concentrations of Polynuclear Aromatic Hydrocarbons in a Well At St. Louis Park,
MI Contaminated By Wastes from a Coal Gasification and Coal Distillation Plant

Contaminant	Concentration, ug/l
Naphthalene	220,000
Acenaphthylene	< 5,250
Fluorene	110,000
Phenanthrene	630,000
Anthracene	66,000
Fluoranthene	420,000
Pyrene	500,000
Chrysene	< 360
1,2 Benzanthracene	300,000
Benzo(a)pyrene	160,000
1,2:5,6 Dibenanthracene	16,000
Indeno-(1,2,3,-c,d) pyrene	27,000
Benzo(g,h,i)perylene	92,000

Source: U.S. Environmental Protection Agency, Central Laboratory, Denver, CO,
 June 10, 1982.

Gas plant by-products commonly had some commercial value. The market for the selling of these wastes was dependent on the size and location of the plant, and the volume of the by-products the plant generated. However, until the late 1800's or early 1900's, there was little or no market for most of the waste products.

At different plant sites the waste disposal practices would vary considerably. At larger plants, it was sometimes economically feasible to sell some of the plant's by-products such as the tars and ammonia. Nearly all plants stored their wastes on site until they were perhaps later removed (EEI, 1984). Usually these wastes (tars, sludges, iron oxide fillings etc..) were stored in open lagoons or in containers in the ground (EEI, 1984).

The soils at former gas plants can be assumed to be contaminated with plant wastes for several reasons. The reason is that plants usually stored their coal tars and wastes in open lagoons or underground tanks. The tanks were constructed of either brick or wood, and both material would tend to leak over the passage of time (EEI, 1984). Commonly when former gas plants were demolished, these lagoons, pits, and tanks were covered over or fill in rather than excavated. Another reason for assuming that the plants contaminated the soils and ground water is that there were underground piping systems to move the gas stream and also the liquid wastes streams. These pipes would corrode over the years and leak. This leakage was common at plant sites and caused major problems since the pipes would need replacing. Finally, in the 1800's the work practices and environmental concerns were not sufficient to prevent the spread of wastes away from the gas plants.

The following paragraphs list the major types of gas plant contaminants and their physical and chemical characteristics. These data are from the Edison Electric Institute (EEI) 1984 reference which thoroughly documented the types of gas plant wastes and their characteristics.

The most important chemical class of compounds found at former gas plants are the polycyclic aromatic hydrocarbons (PAH) due to their toxic and carcinogen properties. There are hundreds of PAH compounds many of which are innocuous. PAH's are formed by the incomplete combustion of organic compounds. As a class of compounds, PAH have low volatility, low aqueous solubility, a strong tendency to absorb on soils, and moderate biodegradability. PAH usually have a high

molecular weight and contain four to six fused aromatic rings. The presence of the aromatic rings tends to decrease the chemicals mobility in soils. In general, PAH compounds tend to be relatively immobile and persistent in the environment particularly in non-aerated zones. PAH compounds have only moderate toxic effects, are unlikely to bioaccumulate in food chains, and are regularly ingested in the average diet from food stuffs.

The EPA water concentration criterion for carcinogenic PAH as a class is 28 ng/l (parts per trillion) versus approximately 10 ug/l (ppb) for noncarcinogenic PAH (WHO, 1971). Both of these exposure levels in water are set at the 10-5 excess lifetime cancer risk level.

Phenolic compounds are highly soluble and biodegradable with low volatility and adsorption. They are highly mobile in the ground and tend to biodegrade in aerated soils. The allowable level in drinking water for phenolic compounds is very low due to their ability to cause taste changes in water at extremely low levels. This taste change ability is heightened when drinking water is chlorinated. Phenolics can cause acute poisoning. Phenolic compounds are easily absorbed through the skin.

Light aromatics such as benzene, toluene, and the xylenes produced at gas plants are moderately soluble and biodegradable, are highly volatile, and only slightly adsorb on soils. Their fate in the environment is determined by their volatilization and biodegradation. Once in the ground water the light aromatics are very mobile and persistent. Benzene is considered a carcinogenic compound due to its ability to produce leukemia.

Iron oxide fillings were used to remove nitrogen-containing compounds from the gas stream. The fillings were commonly mixed with wood chips, sawdust, or other materials in absorber or purifier beds. These wastes contain concentrations of sulfur, cyanide, and ammonia compounds usually bound with iron. The spent oxide wastes have both a distinctive odor and blue-gray color which are very persistent and noticeable upon inspection. The spent oxides are usually toxic to plant life. If cyanide compounds from spent oxide wastes are exposed to acids, then HCN can be released.

Inorganic sulfur compounds (elemental sulfur, sulfide, and sulfates) are found in spent oxide wastes. They are relatively stable in the environment and

may be leached into the ground water. Sulfur species are mobile in ground water; however, they are relatively harmless unless found at very high concentrations.

The inorganic nitrogen species found at gas plant sites are ammonia and cyanide compounds. These species are generally stable in the environment and can be leached down through the soil. Simple cyanide compounds are readily biotransformed to ammonia in soils, and ammonia is in turn transformed by bacteria to nitrate which is a common ground water contaminant. Nitrate is known to cause methemoglobinemia in infants. Ammonia and cyanide are toxic in varying degrees to both aquatic and human life.

Ashes were commonly stored with coal fines and cinders. They could be contaminated with heavy metals.

E.4 History of The Manufactured Gas Industry in The State of Ohio

There were approximately 90 gas plant sites in Ohio between 1830-1950. Most of the gas plants were operated in the larger towns with populations greater than 2-3,000 people, and several cities such as Cincinnati and Cleveland, had more than one gas plant. Coal gas was the most common product due in large part to the nearby coal production areas. There were, however, plants which produced water gas and those producing oil gas, and others switched production methods over the years. Usually plants were located on the edge of a town's city limits along a river or some other water way. The plants were all small compared to today's standards, usually several acres in size.

Ohio was one of the first states to develop a manufactured gas industry. In the mid-1800's many towns and cities in Ohio built their first gas plants to serve local needs. Most of these first plants produced coal gas to light street lamps, and for the few businesses which could afford the cost of the gas. The lighting of the first street lamps was a very big occasion in a small town and was always a well attended and much heralded event in the papers and history books. The lighting of streets created a social revolution as people could stay out later. Streetlamps allowed people to meet at night outside - something unheard of before that time. Lamplighters were common figures in small towns and like clockwork they arrived at dusk and dawn to light and extinguish the street lamps.

People also got their first experience with unregulated utility companies and their operations. Many a protracted battle were fought in the 1800's over the quality of the gas provided and the cost of the service. As opposed to today, the quality of the gas product could vary considerably and did not always give the same lighting qualities depending on the production methods. Few residential homes could afford the cost of the gas in those days (usually \$3/1000 ft³ of gas) but as time passed more and more homes began to use manufactured gas for lighting purposes. Around 1880 gas plants started advertising the use of manufactured gas for cooking purposes.

It is estimated that the 90 gas plants in Ohio produced approximately 101×10^9 ft³ of gas and 74×10^6 gallons of tar annually from 1880-1950 (Eng, 1985). Even though this estimated volume seems incredible large, Ohio only ranked 18th in production in the US from 1880-1950.

In the early days of the industry from 1830-1880, there was little or no market for the tars and other by-products produced at plants, and the wastes were commonly disposed of on site and at other dump sites. In the late 1800's/early 1900's there began to develop a market for coal tars and in the larger towns and cities. It became economically feasible to sell the tars for later use in treating wood, making creosote, and spreading on roads. However, in the small towns (2-10,000 people) where many of the Ohio plant sites existed, there was only a limited market for the coal tars, if any, and the wastes were disposed of as a nuisance by-product.

E.5. History of The Manufactured Gas Industry in Southwestern Ohio

The former gas plants located in southwest Ohio are listed in Table 3. The results of the historical information searches for each site are given in Section G.1.

TABLE 3
Coal Gasification Plant Sites in Southwestern Ohio

<u>Plant</u>	<u>Years of Operation</u>	<u>Type of Gas Production</u>
Cincinnati (West)	1842 - 1909	Coal
Cincinnati (East)	1882 - 1909	Coal
Hamilton (Public)	1890 - 1910*	Coal and Oil
Hamilton (Private)	1856 - 1910*	Coal
Hillsboro	1875 - 1949	Coal
Lebanon	1879 - 1940*	Oil and Water
Middletown	1873 - 1905	Coal
Ripley	1860 - 1920*	Coal
Wilmington	1873 - 1927	Coal
Xenia	1845 - 1906	Coal

*Denotes the start of the last decade of plant operation

F. METHODS

To meet the objectives of the thesis, a historical search for old plant records was conducted simultaneously with a search for the geological data concerning the towns in southwestern Ohio which contained former gas plant sites. The following sections provide descriptions of the methods used to gather needed information and the way in which the data were used.

F.1 Historical Investigation of Plant Operations

In the spring and summer of 1987, letters were written to the libraries in towns of Ohio where gas plants were located to find any information relating to each plant's operations. Visits were made to local libraries, historical societies, and museums to locate information on the operations of the gas plants, and follow any leads received from the library responses. Contacts were made in town governments and with local historians to incorporate any information relating to the plants. Ads were placed in local newspapers in two of the towns to locate former workers and others with knowledge of the plants.

The historical searches were conducted to locate old maps such as insurance atlases and to determine the dates of plant operation, plant location, and the officers in the company. In particular, efforts were made to determine the waste disposal practices of the plants.

Visits were made to the neighborhoods of each former gas plant site in southwestern Ohio to determine the present day use of the site. Photographs were taken to record the appearance of the site in the spring of 1988.

F.2 Ground Water Pollution Potential Mapping

F.2.a Explanation of The DRASTIC Model

The potential for ground water pollution was assessed using "DRASTIC: A Standardized System For Evaluating Groundwater Pollution Potential Using Hydrogeologic Settings" (Aller et al., 1987). The model was developed by the

National Well Water Association with USEPA support and has been used for the assessment of ground water pollution potential in several areas of the country.

Several of the federal agencies which are using DRASTIC to map areas are the USEPA Office of Pesticide Programs and Drinking Water and the USEPA Office of Ground Water Protection. In addition, many state agencies have begun using DRASTIC, and several companies which produce pesticides and herbicides have begun mapping various areas of the country. The State of Ohio Department of Natural Resources has decided to map the whole of Ohio county by county. A typical size county will take one man one full month to produce a DRASTIC map.

The DRASTIC model yields a DRASTIC Index score which expresses the relative ground water pollution potential of an area. DRASTIC pollution potential rankings can only be compared to other areas which have also been mapped using DRASTIC. The model yields only a relative ranking for the ground water pollution potential of an area; it does not define if there is or is not ground water pollution.

DRASTIC is a quick and inexpensive model to apply, and therefore provides an excellent first look at the problem of ground water pollution potential in an area. DRASTIC is not a site specific model since it is realized that sites require a more intensive look for more final-definitive decisions. There are several basic assumptions in DRASTIC: (1) that the pollution is introduced at the ground surface; (2) the pollution is flushed into the soil by water; (3) the pollution has the mobility of water and is not a two-phase transport system; and (4) the map area is greater than 100 acres. DRASTIC requires that a chemical of interest have a mobility close to that of water. Coal tars commonly have a density slightly greater than water and would tend to flow quicker than water under the force of gravity. Some coal tars have been found to have densities equal to or less than water's density. The usual density for coal tars is approximately 1.2 g/cc as opposed to water density of 1.0 g/cc.

There are no toxicological factors applied in DRASTIC. DRASTIC does not include such factors as the importance of the aquifer, the number of people served, the distance to population centers, and the land use. These sociographic factors are used in other more definitive models such as the EPA uses at hazardous waste sites.

Finally, a DRASTIC map is made up of two parts. The first part is a mappable unit or hydrogeologic setting which defines each area and the second part is relative ranking of the site. These two define the DRASTIC model. The reader is encouraged to read the DRASTIC manual which explains the model and how it is applied (Aller et. al, 1987).

F.2.b Factors Used in The DRASTIC Model

The seven factors used in DRASTIC are:

- | | |
|--------------------|-----------------------------|
| (1) Depth to Water | (5) Topography |
| (2) Net Recharge | (6) Impact of Vadose Zone |
| (3) Aquifer Media | (7) Hydraulic Conductivity. |
| (4) Soil Media | |

The data for the DRASTIC factors are found in published well logs, topographic maps from the U.S. Geological Survey, Department of Agriculture-Soil Conservation Service, and various published and unpublished geological reports.

F.2.c Method of Mapping Each Former Gas Plant Site

DRASTIC maps were produced for each of the towns in southwest Ohio which contain a former gas plant site. The DRASTIC model was applied to the area of each town or city where the plant was located and for the immediate surrounding area. These areas were chosen to be larger than the 100 acre minimum-sized map called for in DRASTIC.

The first area to be mapped was the city of Hamilton Ohio which contains both two former coal gasification plant sites and the Chem-Dyne hazardous waste site. The Chem-Dyne hazardous waste site is a nationally known hazardous waste site on the National Priority List (NPL) which had already undergone Superfund remedial cleanup. The ground water under Chem-Dyne is contaminated with industrial chemicals (primarily VOC's) which migrated from the storage and processing of liquid wastes at the Chem-Dyne plant. One of the former gas plant sites in Hamilton is located within several hundred yards of the Chem-Dyne site.

The Hamilton area yielded a DRASTIC Index score which reflects the ground water pollution potential of the area. Since the Chem-Dyne site has documented ground water pollution, this thesis compared the DRASTIC Index score from the area around the Chem-Dyne site with the DRASTIC Index scores from other towns having former gas plant sites in southwest Ohio. The result is the prioritization of former coal gasification plant sites by their respective ground water pollution potential as compared to the Chem-Dyne/Hamilton area. This prioritization may be of use for allocating resources when investigating these sites.

Other factors being equal, one would generally want to investigate a site which is characterized by a higher DRASTIC Index score, since the potential for ground water pollution would be greater in that area as compared to areas with lower DRASTIC Index scores. DRASTIC Index scores are relative to one another and therefore the model allows comparison between mapped areas, since each area was mapped using the same geological factors applied in the same model. Through the comparison of DRASTIC Index scores, one can make a determination of which town and sites have a greater risk of ground water pollution.

There are of many other mitigating factors which will determine the potential for pollution at the former gas plant sites. Such factors are the number of years the gas plant was in operation, the type of gas produced, the waste practices of each plant, and the use of the plant site since operation ceased. Also important is the plant's location in relation to well fields and/or surface water supplies, and the use of ground water in the area. These factors must be considered along with the DRASTIC Index scores to determine which sites merit investigation.

G. RESULTS

G.1 Historical Investigation of Plant Operations

After searching for company records in historical libraries and talking to local officials in some of the areas, it was concluded that plant information is hard to locate if the plant went out of business in the early 1900's or before. Records on plant operations are either lost, in private possession, or perhaps in the files of the current utility companies that usually took over the former gas plants. It is hypothesized that companies operating in the 1800's and into the early 1900's may not have kept records on the wastes generated or how they were disposed of, unless they were sold for profit.

The one set of company records found (the minutes from the Ripley Gas Light and Coke Company's entire company history) did not contain any reference to wastes generated or how the wastes were disposed. The one former employee located, now 80 years old, worked for Hillsboro Gas and Electric Company from 1942-1949. He could only offer us the information that during 1942-49, the plant sold their coal tars to be used as roofing tar in Dayton, Ohio.

As mentioned earlier, approximately 90 gas plants existed in Ohio between 1830 to 1950. In 1901 there were at least 82 plants operating; by 1915 there were approximately 21 operating plants in existence (Brown's Directory of American Gas Companies, 1915).

The following sections list the results of the historical searches and observations made in the vicinity of the sites for each of the former gas plant sites in southwestern Ohio. Information is given on each plant's formation, location, present day use of the facility, any presence of surface contamination, the size of the plant and quantity of wastes generated, and the plant's waste disposal methods. Each plant's proximity to aquifers and wells is also addressed with the potential for contamination represented by each site.

Nearly all the gas production figures presented in the following sections for each plant are from different editions of the annually-published Brown's Directory of American Gas Companies. The tar production rates used to determine the quantity of wastes each plant generated are based on a conversion factor of 730 gallons of tars created per one million (1×10^6) cubic feet (ft^3) of coal gas

produced (Eng, 1985). Therefore, all the tar production rates given in the following sections are estimates.

6.1.a City of Cincinnati, Hamilton County

6.1.a.1 Formation and Development:

The era of the manufactured gas industry in Cincinnati lasted from 1843 to 1909, a period of 66 years. The industry really began in 1825 with Thomas Lawson, a tin and coppersmith on Main Street in downtown Cincinnati, who manufactured artificial gas to light his shop. Mr. Lawson designed animal shaped gas burners and attracted large crowds to his business at nightfall to see the new spectacular device. In 1831 there was a fire at Mr. Lawson's business and the city ordered him to cease his lights.

In 1837 James F. Conover started the Cincinnati Gas Light and Coke Company (CGL&CC) with offices at Fourth and Plum Streets. The gas plant was built on Front and Rose Streets on a plot of land known since early settler days as Hobson's Choice. On January 14, 1843 the streets of Cincinnati were lit for the first time. Cincinnati used this new "city gas" for lighting streets and businesses since the cost was too much for most homeowners. The cost of the gas was \$3.50 per thousand cubic feet, by 1862 the price had decreased to \$2.50 per thousand cubic feet (CG&E Story). The president of CGL&CC for much of the mid to late 1800's was General Andrew Hickenlooper.

In 1850, CGL&CC had 1,375 private customers, 486 street lamps, and Cincinnati had a population of 115,000 people. By 1862 the figures had risen to 8,200 private customers and 2,450 street lamps. In 1874 the gas was being used for cooking in the homes in addition to heating.

In 1882 CGL&CC built a second gas plant at 2817 Eastern Avenue between Main and Spencer Streets which became known as the East End Station while the downtown site became known as the West End Station. It also was around this time that Edison created the electric light. In 1883 the Cincinnati Electric Light Company and the Brush Electric Company began generating electricity in Cincinnati. Shortly thereafter, the Cincinnati Edison Electric Company was also formed. CGL&CC bought both the Cincinnati Electric Light Company and the Brush

Electric Company and in 1901 merged with the Cincinnati Edison Electric Company into the Cincinnati Gas and Electric Company which exists today. In 1909, Brown's Directory Of American Gas Companies still has the two Cincinnati plants operating under The Union Gas and Electric Company. It is believed that the plants went out of operation in 1909.

The West End Station operated from 1843-1909 (66 years), while the East End Station operated from 1882-1909 (27 years). Both plants produced coal gas, and both plants operated in a period when there was little market for resale of gas plant wastes.

6.1.a.2 Location and Present Day Use of the Former Plant Sites:

The West End Station gas plant was built on Front and Rose Streets where the former plant site is today occupied by buildings of the former West End Electric Power Plant and a substation operated by the Cincinnati Gas and Electric Company (CG&E). Several buildings which may have been a part of the gas plant are still in use and the foundation of one or more others can be seen on the site. Dark colored soil near one of the foundations can be observed; however, the sites are enclosed with fencing. At the West End Station, there appears to be no visible surface contamination; however, plant wastes may be trapped below the surface and the soils below ground level can be assumed to be contaminated. Upon visiting the vicinity of the plant site, workers were using a bulldozer to dig on part of what may have been the old plant property.

The East End Station gas plant was located on the south side of Eastern Avenue between Main and Spencer. Today the former plant site is located between Corbin and St. Andrews Streets on Eastern Avenue beside the Ohio River. CG&E still owns the property and appears to have a maintenance/storage area there. It appears that some of the original foundations of the gas holders are still visible from Eastern Avenue. One end of the plant site is now a playfield. At the East End Station plant wastes may be trapped below the surface and the soils below ground level can be assumed to be contaminated.

The East End Station is several miles upstream from the former West End Station. Both plant sites are within several hundred yards of the Ohio River. Old atlas maps of both plants are shown in the Appendix.

G.1.a.3 Size of Plants and Quantities of Wastes Generated:

It is known that Cincinnati with its two gas plants produced more manufactured gas than any other city in Ohio except for Cleveland. Relative to other cities and their gas plants, the gas plants in Cincinnati were large in their capacity and overall production.

In 1854 the West Station gas plant of CGL&CC produced 23×10^6 cubic feet (ft^3) of coal gas annually with $20 \times 10^6 \text{ ft}^3$ being sold and $3 \times 10^6 \text{ ft}^3$ being unaccounted. At a minimum production rate of $23 \times 10^6 \text{ ft}^3$ of coal gas per year, the West End Station produced an estimated 17,000 gallons of coal tar. It is assumed that the plant increased its production of coal gas (and therefore coal tars) during the late 1800's as the demand for coal gas increased.

In 1901 and 1909 Brown's Directory Of American Gas Companies has the two plants listed together. In those years the two plants produced 3.8×10^9 and $2.8 \times 10^9 \text{ ft}^3$ of gas, respectively, which corresponds to an estimated 2.8×10^6 and 2.6×10^6 gallons of coal tar, respectively.

G.1.a.4 Waste Disposal Practices:

No records were located pertaining to what was done with the by-product coal tars and other wastes produced by the two Cincinnati gas plants. With such big plants, CGL&CC probably was able to sell most of the tars they generated. However, there was no market for tars until the late 1800's when people began using tars to treat wood, make creosote, and use the tars to cover roads. At both the East and West Stations there were tar pits, which can be seen on old atlas maps, which were built to hold waste tars until they could be disposed. These pits were usually built out of wood or concrete, were underground, and would invariably leak over time.

6.1.b City of Hamilton, Butler County

6.1.b.1 Formation and Development:

The first utility company in Hamilton, which was a private company, was the Hamilton Gas Light and Coke Company which was established in 1856 at 531 High Street. It appears that in Hamilton the coal gas industry got off to a rough start in that the residents of the city became perhaps the first community in America to fight with a utility company over rate hikes. After several years of charging apparently exceedingly high rates for its coal gas (\$5.00 per 1,000 ft³ versus a usual state-wide average of \$2-\$3 per 1,000 ft³) the company was found to operate unsatisfactorily and the city argued all the way to the United States Supreme Court over the right to establish its own gas works.

In April 1890 the city opened its own gas plant, The Hamilton City Gas Works, which stood near the Ford Hydraulic Canal where the present day City of Hamilton electric generating station operates. It appears the Hamilton Gas Light and Coke Company operated on High Street without the city's business for another several decades.

In 1901, the Ohio Fuel and Supply Company began furnishing the city with natural gas. In addition to the two gas companies, another private company, the Hamilton Otto Coke Company, also furnished coal gas to private customers. In 1927, the city reached agreement with the Columbia Gas Supply Company to furnish the city with a gas made of two parts natural gas to one part coke oven gas. As of 1935 the agreement still stood and the city was receiving the mixed gas.

The Hamilton Gas Light and Coke Company and The Hamilton City Gas Works both went out of business between 1909 - 1915. The Hamilton Gas Light and Coke Company had by 1909 quit producing coal gas and was purchasing gas from the Hamilton-Otto Coke Company which produced coal gas from their coke oven operations. Both plants operated in a period when there was little market for resale of gas plant wastes.

The other plant producing coal gas in Hamilton was the Hamilton Otto Coke Company located directly north of Hamilton between the tracks of the Penn Central Railroad which bordered on the west and the Cincinnati, Hamilton, Dayton Railroad

which bordered on the east. This large coke plant produced both electricity and coal gas for the city of Hamilton and surrounding communities. Work began on the plant in 1900 when 50 coke ovens were built. Shortly thereafter, another fifty ovens were built producing 350 tons of coke per day. As of the 1960 the plant was producing around 175,000 tons of coke per year resulting in $160 \times 10^6 \text{ ft}^3$ of coal gas. Tar and ammonia are also produced and sold in large quantities. Today the plant is still in operation and is owned by the Armco Steel Corporation.

6.1.b.2 Location and Present Day Use of the Former Plant Sites:

The Hamilton City Gas Works was located where today stands the City of Hamilton electrical power plant beside the Ford Hydraulic Canal. The Chem-Dyne hazardous waste site is located adjacent to the property. At the Hamilton City Gas Works plant site tars and other plant wastes may be trapped below the surface and the soils below ground level can be assumed to be contaminated.

The Hamilton Gas Light and Coke Company was located at 531 High Street. Today the site is a an open field near the railroad track which cross over High Street. In January of 1988 the remaining structure on the property was demolished. The lot appears to be owned by CG&E; however, the building demolished in January 1988 was registered to The Hamilton Service Company. There are the remains of some building foundation on the lot which may be from the old gasometer structure. The edge of the property has what appears to be oil or tar contaminated soils at the surface where the soil has been scraped off to the side. Human exposure risks are existent due to possible surface contamination of the soils. A residential neighborhood exists just to the south of the site with access to the site. Tars and other plant wastes may be trapped below the surface and the soils below ground level can be assumed to be contaminated. Old atlas maps of both plants are shown in the Appendix.

6.1.b.3 Size of Plants and Quantities of Wastes Generated:

The Hamilton Gas Light and Coke Company produced $13 \times 10^6 \text{ ft}^3$ of coal gas per year in 1890 and $50 \times 10^6 \text{ ft}^3$ of coal gas per year in 1901. At a production rate out to $50 \times 10^6 \text{ ft}^3$ of coal gas per year, the Hamilton Gas Light and Coke Company produced an estimated 36,000 gallons of coal tar annually.

The Hamilton City Gas Works produced $50 \times 10^6 \text{ ft}^3$ of coal gas per year in 1890, $60 \times 10^6 \text{ ft}^3$ of oil gas per year in 1900, and $73 \times 10^6 \text{ ft}^3$ of oil gas per year in 1910. Averaging the production rate out to $60 \times 10^6 \text{ ft}^3$ of gas per year, the Hamilton Gas Light and Coke Company produced an estimated 44,000 gallons of coal tar annually.

G.1.b.4 Waste Disposal Practices:

Extensive search for historical documents relating to plants operations (e.g. wastes disposal practices) found only references to the years of operation and plant locations.

G.1.c City of Middletown, Butler County

G.1.c.1 Formation and Development:

In 1871 the Middletown Gas Light and Coke Company was formed and in 1873 the streets of Middletown were lit for the first time. In 1887 the company went bankrupt and was sold. The new owners kept the same name but also went bankrupt nine years later. Another company bought the works and the plant again operated until around 1905. The plant was located on N. Broad Street. The plant operated from 1873 to 1905 in a period when there was little market for resale of gas plant wastes.

G.1.c.2 Location and Present Day Use of the Former Plant Site:

The plant was located on N. Broad Street and bordered on the Miami-Erie Canal which today has been covered over by the Verity Parkway. One portion of the former plant site is covered by a electrical substation of the Cincinnati Gas and Electric Company while the other part is a vacant lot. Train tracks can still be seen on the empty lot, but the plant site has been cleared of all old buildings. There appears to be some oil or coal ash in the surface soil near the old railroad tracks on the property, but it appears not to be extensive. Human exposure risks appear to be minimal except for possibly contaminated soils near railroad tracks on the former plant site. Tars and other plant wastes may be trapped below the surface and the soils below ground level can be assumed to be contaminated. An old atlas map of the plant is shown in the Appendix.

6.1.c.3 Size of Plant and Quantity of Wastes Generated:

The gas plant in Middletown produced approximately $10 \times 10^6 \text{ ft}^3$ per year of coal gas, resulting in the estimated production of 7,000 gallons of coal tar annually. In 1901 the plant produced $15 \times 10^6 \text{ ft}^3$ of coal gas which corresponds to an estimated 11,000 gallons of coal tars.

6.1.c.4 Waste Disposal Practices:

Extensive search for historical documents and conversations with a local historian relating to the plant's operations (e.g. wastes disposal practices) found only references to the years of operation and plant location. The local historian thought that companies may not have kept any records pertaining to wastes disposal means. It was reported by a local historian in Middletown (although unverified) that a private engineering firm in the fall of 1987 performed testing on the former plant site but did not find any contamination.

6.1.d City of Hillsboro, Highland County

6.1.d.1 Formation and Development:

In 1874 Frank Picard built a plant to furnish coal gas for the city of Hillsboro, and the streets of the city were lit for the first time on September 12, 1875. The cost of the coal gas was one cent per seven hours of light.

In 1893 another company was formed to furnish electricity, and in 1899 the two companies were consolidated into the Hillsboro Light and Fuel Company. Mr. Irvin McD. Smith was the president and A.E. Hough, secretary. The Ohio Utilities Company took charge in 1916 and furnished light and fuel until 1930 when the Southern Ohio Electric Co. bought them out. In 1937 The Columbus and Southern Ohio Electric Co. bought the plant. On January 27, 1941 an ordinance was passed and the city of Hillsboro bought the Hillsboro Gas Company from The Columbus and Southern Ohio Electric Co. The gas plant continued to operate until 1949. The former plant buildings were torn down in 1975 to make way for a public works facility. Coal gas was manufactured in Hillsboro from 1875-1949, a period of 74 years.

G.1.d.2 Location and Present Day Use of the Former Plant Site:

The plant was located at the southwest corner of Railroad and W. North Streets. Today the city has a garage on this site and there are no buildings or structures remaining from the former plant. A good portion of the former plant site is covered by asphalt and several new buildings. The former lagoon on the site is no longer there. Tars and other plant wastes may be trapped below the surface and the soils below ground level can be assumed to be contaminated. There is a playground located directly across the street about 20 feet lower in elevation than the former gas plant site. An old atlas map of the plant is shown in the Appendix.

G.1.d.3 Size of Plant and Quantity of Wastes Generated:

The gas plant in Hillsboro produced between 4 to 12 x 10⁶ ft³ per year of coal gas, resulting in an estimated 3,000 to 9,000 gallons of coal tars.

G.1.d.4 Waste Disposal Practices:

A former employee who worked at the gas plant from 1942-1949, remembers that for the period of years during the war, the plant sold their coal tars to a man who would transport the coal tars to Dayton, Ohio to be used to coat roofs. Other extensive search for historical documents relating to plants operations (e.g. wastes disposal practices) found only references to the years of operation and plant location.

G.1.e City of Wilmington, Clinton County

G.1.e.1 Formation and Development:

In 1873 the Wilmington Gas Light and Coke Company began producing coal gas under the direction of a Mr. Cloverdale. The plant was located adjacent to the railroad line on the edge of the property of H.W. Hale. The plant operated until 1927 (a period of 54 years) at which time it began to produce natural gas. It is believed that a fire destroyed the original gas works.

G.1.e.2 Location and Present Day Use of the Former Plant Site:

The plant was located off Mulberry Street on the edge of the property of H.W. Hale near the railroad. Today the former plant site has been cleared and there are no buildings or structures remaining. Tars and other plant wastes may be trapped below the surface and the soils below ground level can be assumed to be contaminated. An old atlas map of the plant is shown in the Appendix.

G.1.e.3 Size of Plant and Quantity of Wastes Generated:

In the years 1901, 1905, and 1909, the gas plant in Wilmington produced 5×10^6 , 10×10^6 , and 12×10^6 ft³ of coal gas. At a production rate of 8×10^6 ft³ per year of coal gas, the plant produced an estimated 6,000 gallons coal tar annually.

G.1.e.4 Waste Disposal Practices:

No records were found concerning how plant wastes were disposed.

G.1.f City of Ripley, Brown County**G.1.f.1 Formation and Development:**

In 1860 the Ripley Gas Light and Coke Company began producing coal gas at the corner of Front and Sycamore Streets. (Some references and maps have the location incorrectly given as the corner of Front and Locust Streets). F.A. Steivers was the first and only president of the company which had its offices in the Citizen's National Bank in Ripley. The company operated until the 1910's.

G.1.f.2 Location and Present Day Use of the Former Plant Site:

The plant was located at the northeast corner of Front and Locust Streets where today an auto parts and auto repair shop is located. No buildings or structures from the former plant remain. Tars and other plant wastes may be trapped below the surface and the soils below ground level can be assumed to be contaminated. An old atlas map of the plant is shown in the Appendix.

6.1.f.3 Size of Plant and Quantity of Wastes Generated:

In the years 1901, 1905, and 1909 the coal gas plant in Ripley produced approximately $2 \times 10^6 \text{ ft}^3$ per year of coal gas. Using the conversion factor of 730 gallons of coal tars produced per $1 \times 10^6 \text{ ft}^3$ of gas yields an estimated yearly coal tar production of 1,500 gallons.

6.1.f.4 Waste Disposal Practices:

No records were found which detailed the waste disposal methods used by the Ripley Gas Light and Coke Company. However, the entire minutes from the company's history were discovered but did not contain any mention of the wastes generated or how they were disposed. These records were in the possession of a descendent of an officer of the company.

6.1.g City of Lebanon, Warren County

6.1.g.1 Formation and Development:

In 1879 the streets of Lebanon were lit for the first time with manufactured gas. The plant furnished first oil gas and then water gas to the city of Lebanon from 1879 until the late 1940's. The town of Lebanon operated the gas plant.

6.1.g.2 Location and Present Day Use of the Former Plant Site:

The plant was located at the west end of W. South Street. Today the buildings from what appear to be the former gas plant are used by the town's small electric power station. The plant is located beside a small creek which empties into Turtle Creek. Tars and other plant wastes may be trapped below the surface and the soils below ground level can be assumed to be contaminated. An old atlas map of the plant is shown in the Appendix.

6.1.g.3 Size of Plant and Quantity of Wastes Generated:

The gas plant in Lebanon produced oil gas until the 1940's at around $4 \times 10^6 \text{ ft}^3$ per year. In the 1940's the company produced water gas at $2 \times 10^6 \text{ ft}^3$ per

year. Using the conversion factor of 730 gallons of tars produced per $1 \times 10^6 \text{ ft}^3$ of gas yields an estimated yearly tar production of approximately 3,000 gallons when the plant was producing oil gas, and an estimated yearly tar production of approximately 1,500 gallons when the plant was producing water gas. In 1927, the plant produced $4 \times 10^6 \text{ ft}^3$ of oil gas yielding an estimated 3,000 gallons of tar.

G.1.g.4 Waste Disposal Practices:

No information was found on the waste disposal practices at the plant in Lebanon. Although contacts were made in the town government and no plant records were found, if such information does indeed exist, it may be stored within town records.

G.1.h City of Xenia, Greene County

G.1.h.1 Formation and Development:

The Xenia Gas and Coke Company was in operation from 1845-1906 (61 years) producing coal gas for the town of Xenia. The plant operated in a period when there was little market for resale of gas plant wastes. The company's office was at 36 East Main and its gas works were at the end of Sycamore Street by the Shawnee Creek. The 1875-76 Xenia Directory shows the above address for the company and gives the officers names as follows: D. McMillian-President; M.C. Allison-Secretary and Treasurer; and John P. Jennings-Superintendent.

G.1.h.2 Location and Present Day Use of the Former Plant Site:

The Xenia Gas and Coke Company's gas plant was located at the end of Sycamore Street by the Shawnee Creek. Today the plant site is used by a company in the business of rebuilding car parts. Two of the original building are in use by the present day site users. The ground on the former site is today covered by oils from the dismantling of car parts. Tars and other plant wastes may be trapped below the surface and the soils below ground level can be assumed to be contaminated. An old atlas map of the plant is shown in the Appendix.

G.1.h.3 Size of Plant and Quantity of Wastes Generated:

The gas plant in Xenia produced around $10 \times 10^6 \text{ ft}^3$ per year of coal gas, resulting in an estimated yearly coal tar production of 7,000 gallons.

G.1.h.4 Waste Disposal Practices:

Extensive search for historical documents relating to the plant's operations (e.g. wastes disposal practices) found only references to the years of operation and plant location.

G.1.i City of Glendale, Hamilton County

In historical documents concerning early Cincinnati and Ohio history, there are several references to a gas plant being located in Glendale Ohio. After considerable research, no corroborating information was located concerning a gas plant site in Glendale Ohio on the outskirts of Cincinnati. No maps of the area show any gas works and no local history book mentioned any gas plant. Also, there is no mention in the 1901 edition of Brown's Directory of American Gas Companies to a plant in Glendale Ohio.

G.2 Ground Water Pollution Potential Mapping – DRASTIC Maps

The following sections present for each former gas plant site in southwestern Ohio the pertinent geological data used to produce the DRASTIC maps, the resulting DRASTIC maps, a conclusion on each site's ground water pollution potential, and the distances to ground water well sites and/or surface water supplies used as drinking water. The DRASTIC map results are presented in Table 4. Photographs of the DRASTIC maps are given in the Appendix.

TABLE 4
DRASTIC Mapping Results

<u>Plant Location</u>	<u>DRASTIC Index Scores¹</u>	<u>Hydrogeologic Setting²</u>
Cincinnati (West)	140-160	Buried Valley
Cincinnati (East)	160	Buried Valley
Hamilton (Both Public & Private Sites)	161-181	Buried Valley
Hillsboro	81-95	Glacial Till Over Sedimentary Rock
Middletown	165-181	Buried Valley
Wilmington	55-84	Glacial Till Over Sedimentary Rock
Ripley	131	Buried Valley
Xenia	70-94	Glacial Till Over Sedimentary Rock
Lebanon	130-154	Buried Valley

1. Gives range of ground water pollution potential scores for area immediately surrounding the former gas plant site relative to other areas mapped with DRASTIC

2. As defined in the DRASTIC model

6.2.a Cincinnati Sites

6.2.a.1 West End Station – Downtown Cincinnati

6.2.a.1.a Location and Geology:

Cincinnati Ohio, with a population of around 400,000 (1.4×10^6 in the greater metropolitan area), is located in Hamilton County in the southwest corner of Ohio. Cincinnati fronts the Ohio River.

Hamilton County and Cincinnati lie in the Till Plains section of the Central Lowland physiographic province. The Till Plains area is characterized by structural and sedimentary basins, domes, and arches formed during Paleozoic time (Bloyd, 1974). Prominent in the area is the Cincinnati geanticline or "Cincinnati Arch". Cincinnati lies on the dissected Lexington peneplain within the border of the Illinoian drift on the flood plain of the Ohio River. The area was glaciated by the Illinoian ice sheet and by the Wisconsin ice sheet to the north. Buried valleys pass through the Cincinnati area (Stout, 1943).

The underlying bedrock are the Utica, Eden, and Maysville Formation which consist of dense shales and hard limestone which contain little or no ground water (Stout, 1943). The shale and limestone bedrock are of Mid to Late Ordovician age. Glacial outwash deposits consisting of sand, gravel, and clay are up to 400 feet deep on the valley floors. These preglacial river valleys filled with glacial outwash are important sources of groundwater.

The downtown Cincinnati area is covered primarily by the Illinoian glacial outwash deposits. In downtown Cincinnati where the Cincinnati Gas Light and Coke Company West End Station coal gas plant was located, the hydrogeologic system consists of glacial outwash deposited in a buried valley. Under downtown Cincinnati, the buried valleys underlying Mill Creek and the Ohio River join in downtown Cincinnati (Bernhagen, 1947).

The downtown area is characterized by sand and gravel glacial outwash and shale and limestone bedrock on the local hillsides surrounding the city. The local aquifers are located in the sand and gravel deposits in the stream valley, which have interbedded thin to thick lenses of clay. The geology of the aquifer in the

downtown Cincinnati area is very similar to the aquifer along the Great Miami River Valley in Hamilton and Middletown.

The Ohio River Valley overlies and follows a buried valley which has been filled with 70-180 feet of sand and gravel deposits containing local deposits of clay (Bernhagen, 1947). The Ohio River is in hydraulic contact with the permeable sand and gravel aquifers which receive recharge by infiltration through the river bed.

Water Supply: The major sources of water for the city of Cincinnati are the Ohio River (100×10^6 gallons per day [gpd]) and the Great Miami River Valley (20×10^6 gpd). The water from the Great Miami River aquifer is pumped from wells in Fairfield Ohio south of Hamilton Ohio. The lower Great Miami River has very little pumping and is a potential source of groundwater. In downtown Cincinnati, the local industrial and hotel ground water pumpage has reversed the normal hydraulic gradient towards the river (Water Inventory Report 18, 1964).

The aquifer in the area is supplied by precipitation which averages 38 inches/year. The valley floor in downtown Cincinnati is heavily paved and rains flow into the ground but also into the sewer system. In downtown Cincinnati the soils are loam, silty loam, with some clayey loam mixed in, and on the hills the soils are silty/clayey loam.

Potential Pollution Problems: It was reported in the 1964 Water Inventory report from the Ohio Department of Natural Resources (ODNR), Division of Water that the Mill Creek in Cincinnati was polluted during 1959 and 1960 when the creek water turned a black color, became moderately mineralized, contained high amounts of phenols and cyanides, and was nearly devoid of dissolved oxygen.

6.2.a.1.b DRASTIC Parameters

Depth to Ground Water: Information on the depth to ground water was collected from published well logs obtained from the ODNR, Division of Water. The depth to ground water in the sand and gravel outwash deposits in downtown Cincinnati ranges from 20-100 feet deep. In the surrounding hillside the depth to water was assumed to be 75-100 feet yielding a DRASTIC value of 10.

Net Recharge: The value of approximately 6 inches of net recharge per year which Ward (1987) used in his study in the sand and gravel glaciofluvial deposits in the Great Miami Valley in Hamilton, was used as the net recharge value. The sand and gravel deposits received a net recharge DRASTIC value of 24.

A net recharge value of 0-2 inches per year was assumed for the bedrock hillsides surrounding the city. This low recharge value was chosen due to the nature of the vadose zone materials (impermeable, dense shale and limestone) and the slopes of the hillsides. The shale and limestone bedrock received a net recharge DRASTIC value of 4.

Aquifer Media: Information on the aquifer media was collected from published well logs obtained from the ODNR, Division of Water. The aquifer media in the buried valley glaciofluvial deposits is sand and gravel. In the bedrock surrounding Cincinnati, the aquifer media is shale and/or shale and limestone. The sand and gravel aquifers received a DRASTIC value of 24, while the shale and limestone aquifers received a DRASTIC value of 15.

Soil Media: Information on the soil media was collected from the Soil Survey of Hamilton County, Ohio published in 1982 by the Ohio Soil Conservation Service. The soils are loams which are defined in areas as either sandy, silty, or clayey loam. The DRASTIC values for the loams range from 6 to 12 depending on the amount or lack of clay and/or silt. A value of 6 means the loam contains significant silt and/or clay and is somewhat to moderately impermeable. A DRASTIC value of 12 means the loam is sandy and relatively permeable. A soil DRASTIC value of 18 represents areas which have been filled in with debris material which is usually highly permeable.

Topography: The degrees slope were calculated using USGS 7.5 Minute Series Topography Maps of Hamilton County, Ohio. Along the Ohio River, above the sand and gravel deposits, the degrees slope is usually between 2-6° which yield DRASTIC values of 9. On the immediate hillsides surrounding the Ohio River, the degrees slope was between 6-18° yielding DRASTIC values of 5 or 3.

Impact of the Vadose Zone: Information on the vadose zone material was collected from published well logs obtained from the ODNR, Division of Water. The vadose zone materials in the glaciofluvial deposits in the buried valley are sand

and gravel with small lenses of silt and clay. In the bedrock surrounding Cincinnati, the vadose zone materials are interbedded shale and limestone.

Where the sand and gravel deposits contain no clay lenses, the DRASTIC value assigned was 40, where there was significant clay and/or silt the value was 35. For the bedrock shale and limestone deposits, a value of 20 was assigned since they are bedded sedimentary rock, but there are no sandstone beds.

Hydraulic Conductivity: The value of 2,608 gallons per day per foot squared (gpd/ft²) (Ward, 1987) was used for the sand and gravel deposits which cover downtown Cincinnati. This high aquifer conductivity value results in a DRASTIC value of 30. For shale and limestone bedrock aquifers, the hydraulic conductivity was assumed to be approximately 1 gpd/ft² as per the charts published by Freeze and Cherry (1979).

Hydrogeologic Settings

The glacial outwash sand and gravel deposits are classified by DRASTIC in the DRASTIC Hydrogeological Settings as 7D - Buried Valley. The typical DRASTIC score given in DRASTIC for Buried Valley areas is 156.

The shale and bedrock area is classified by DRASTIC in the DRASTIC Hydrogeological Settings as 7Aa - Glacial Till Over Bedded Sedimentary Rock. The typical DRASTIC score given in DRASTIC for Glacial Till Over Bedded Sedimentary Rock areas is 103.

G.2.a.1.c DRASTIC Scores For West End Station Plant Site:

Score	D	R	A	S	T	I	C	SETTING
64	15	4	15	6	1	20	3	7Aa
70	15	4	15	8	5	20	3	7Aa1

DRASTIC Scores For West End Station Plant Site (continued . . .)

<u>Score</u>	<u>D</u>	<u>R</u>	<u>A</u>	<u>S</u>	<u>T</u>	<u>I</u>	<u>C</u>	<u>SETTING</u>
160	25	24	24	12	10	35	30	7D
156	25	24	24	8	10	40	30	7D1
150	15	24	24	8	10	40	30	7D2
140	5	24	24	8	10	40	30	7D3

The DRASTIC map produced for the downtown Cincinnati area is shown in Figure 1 in Appendix B.

G.2.a.1.d Conclusion:

The potential for ground water pollution potential is relatively high in the sand and gravel deposits along the Ohio River as evidenced by the DRASTIC scores ranging from 140-160. This is a result of the permeable vadose zone and aquifer media sand and gravels. The former coal gas plant is located in the high ground water pollution potential area.

Conversely, there is a relatively small risk of ground water pollution potential on the surrounding hillsides due to both the glacial till soils, and the fairly impermeable vadose zone and aquifer shale and limestones.

G.2.a.1.e Distance to Water Supplies:

The former gas plant site is located right on the Ohio River less than several hundred yards from the river. The site is several miles downstream from where the Cincinnati Waterworks pumps water from the Ohio River. The former gas plant site is located directly above the Mill Creek aquifer system which at upgradient positions provides water for local businesses. The nearest surface water is the Ohio River which is located one hundred yards downgradient to the south.

G.2.a.2 East End Station – Eastern Avenue

G.2.a.2.a Location and Geology:

The location and geology of the East End Station is identical to the information provided in the description of the Cincinnati West End Station in the previous sections.

G.2.a.2.b DRASTIC PARAMETERS

Depth to Ground Water: Information on the depth to ground water was collected from published well logs obtained from the ODNR, Division of Water. Since there were no available well logs within 2500 yards of the gas plant site, the depth to ground water in the glaciofluvial deposits was inferred from wells drilled upstream several thousand yards in the same sand and gravel deposits. The depth to ground water was assumed to be 50-75 feet deep. Due to lack of well logs in the area, the depth to water was assumed to be 75-100 feet yielding a DRASTIC value of 10.

Net Recharge: The value of approximately 6 inches net recharge per year in the glaciofluvial deposits which was determined in similar deposits in Hamilton (Ward, 1987) was used as the net recharge value. The sand and gravel deposits received a net recharge DRASTIC value of 24.

A net recharge value of 0-2 inches per year on bedrock hillsides surrounding the city was assumed. This low recharge value was chosen due to the nature of the vadose zone materials (impermeable, dense shale and limestone) and the slopes of the hillsides. The shale and limestone bedrock received a net recharge DRASTIC value of 4.

Aquifer Media: Information on the aquifer media was collected from published well logs obtained from the ODNR, Division of Water. The aquifer media in the buried valley glaciofluvial deposits is sand and gravel. In the bedrock surrounding Cincinnati, the aquifer media is shale and/or shale and limestone. The

sand and gravel aquifers received a DRASTIC value of 24, while the shale and limestone aquifers received a DRASTIC value of 15.

Soil Media: Information on the soil media was collected from the Soil Survey of Hamilton County, Ohio published in 1982 by the Ohio Soil Conservation Service. The soils are loams which are defined in areas as either sandy, silty, or clayey loam. The DRASTIC values for the loams range from 6 to 12 depending on the amount or lack of clay and/or silt. A value of 6 means the loam contains significant silt and/or clay and is somewhat to moderately impermeable. A DRASTIC value of 12 means the loam is sandy and relatively permeable. A soil DRASTIC value of 18 represents areas which have been filled in with debris material which is usually highly permeable.

Topography: The degrees slope were calculated using USGS 7.5 Minute Series Topography Maps of Hamilton County, Ohio. Along the Ohio River, above the sand and gravel deposits, the degrees slope is usually between 2-6° which yield DRASTIC values of 9. On the immediate hillsides surrounding the Ohio River, the degrees slope was greater than 18° yielding DRASTIC values of 1.

Impact of the Vadose Zone: Information on the vadose zone material was collected from published well logs obtained from the ODNR, Division of Water. The vadose zone materials in the glaciofluvial deposits in the buried valley are sand and gravel with small lenses of silt and clay. In the bedrock surrounding Cincinnati, the vadose zone materials are interbedded shale and limestone.

Where the sand and gravel deposits contain no clay lenses, the DRASTIC value assigned was 40, where there was significant clay and/or silt the value was 35. For the bedrock shale and limestone deposits, a value of 20 was assigned since they are bedded sedimentary rock, but there are no sandstone beds.

Hydraulic Conductivity: Bloyd (1974) stated that the Ohio River valley outwash and alluvial aquifers have hydraulic conductivities ranging from 400-8,400 gpd/ft². Used the value of 2,608 gpd/ft² from Ward (1987) determined in the sand and gravel deposits which cover downtown Hamilton Ohio. This high aquifer conductivity value of 2,608 gpd/ft² resulted in a DRASTIC value of 30. For shale and limestone bedrock aquifers, the hydraulic conductivity was assumed to be approximately 1 gpd/ft² as per the charts published by Freeze and Cherry (1979).

DRASTIC Hydrogeologic Settings:

The shale and bedrock area is classified in the DRASTIC Hydrogeological Settings as 7Aa - Glacial Till Over Bedded Sedimentary Rock. The typical DRASTIC score given in DRASTIC for Glacial Till Over Bedded Sedimentary Rock areas is 103.

The sand and gravel deposits are classified in the DRASTIC Hydrogeological Settings as 7D - Buried Valley. The typical DRASTIC score given in DRASTIC for Buried Valley areas is 156.

G.2.a.2.c DRASTIC Scores For East End Station Plant Site:

<u>Score</u>	<u>D</u>	<u>R</u>	<u>A</u>	<u>S</u>	<u>T</u>	<u>I</u>	<u>C</u>	<u>SETTING</u>
59	10	4	15	6	1	20	3	7Aa
69	10	4	15	8	9	20	3	7Aa1
160	25	24	24	8	9	40	30	7D

The DRASTIC map produced for the Cincinnati (East) area is shown in Figure 2 in Appendix B.

G.2.a.2.d Conclusion:

The potential for ground water pollution potential is relatively high in the sand and gravel deposits along the Ohio River as evidenced by the DRASTIC score of 160. This is a result of the permeable vadose zone and aquifer media sand and gravels. The former coal gas plant site (Cincinnati East End Works) is located in the this high ground water pollution potential area.

Conversely, there is a relatively small risk of ground water pollution potential on the surrounding hillsides due to both the glacial till soils, and the fairly impermeable vadose zone and aquifer shale and limestones.

G.2.a.2.e Distance To Water Supplies

The former East End gas plant is located approximately 3 miles downstream from the where the Cincinnati Waterworks pumps water from the Ohio River. The former gas plant site is located directly above the sand and gravel aquifer which follows the Ohio River. The nearest surface water is the Ohio River which is located one hundred yards downgradient to the south.

G.2.b Hamilton Sites (Public and Private Plant Sites)

G.2.b.1 Location and Geology:

Hamilton Ohio, which has a population of about 63,000, is located in Butler County on the terraced flood plain of the Great Miami River. Both the Illinoian and Wisconsin ice sheets passed over the area leaving thick fill in the valley and thin fill on the surrounding uplands. In the valley, the glacial outwash of sand, gravel, and silt is 180-220 feet deep, while on the uplands, the fill averages 25 feet deep (Stout, 1943).

The underlying bedrock are the dense shales and hard limestone of the Maysville Formation which offer very little, if any, water supplies. The town gets its water from wells drilled in the glacial outwash (Stout, 1943).

The hydrogeologic system consists of a thick sequence of glaciofluvial sand and gravels deposited in a buried valley system through which the Great Miami River flows today. Surrounding the Great Miami Valley, are hillsides of Ordovician shale and limestone beds covered by glacial tills of Illinoian and Wisconsin age.

The sand and gravel deposits average 150 feet in thickness and 2 miles in width (Ward et. al, 1987). The sand and gravel aquifer appears as a single water bearing formation. At the Chem-Dyne site, downtown Hamilton beside the Ford Hydraulic Canal, there is 150-200 feet of sand and gravel drift, a lack of interstratified clay layers, and the Great Miami River for induced infiltration recharge to the aquifer (Ward et. al, 1987).

Water Supplies: In Hamilton, ground water is used by both industry and the town for drinking water. The city takes water (19×10^6 gallons per day) from 9

wells located in Fairfield and from 5 wells located in St. Clair Township. Local businesses pump ground water from wells located in downtown Hamilton.

Hamilton obtains its water supply from deep wells drilled in the glacial fill of the Great Miami River Valley. At Hamilton, the glacial fill is 180 to 217 feet deep and the well yields commonly are greater than 500 gallons per minute (gpm). Besides the city, numerous industries also withdraw ground water from around Great Miami River.

Groundwater is found (1) in the glacial sand and gravel on valley floor, and (2) in the shales and limestones on hillsides. The annual rainfall is approx. 37 inches/year. Because the valley floor is mostly paved, rain water flow into the ground but also in the sewer system as runoff. In the valley the soils are loam, silty loam, with some clayey loam mixed in. On the hills the soils are silty/clayey loam.

6.2.b.2 DRASTIC Parameters

Depth to Ground Water: The depth to ground water in the glaciofluvial deposits in the flood plain of valley floor is typically 20-50 feet deep yielding a DRASTIC value of 35 or 25. On the surrounding hillsides, the depth is typically 60-100 feet deep yielding a DRASTIC value of 15.

Net Recharge: The net recharge value is approximately 6 inches per year. (Ward et. al, 1987, uses 6.1 inches per year in his study on the sand and gravel glaciofluvial deposits in the Great Miami Valley in Hamilton). The sand and gravel deposits received a net recharge DRASTIC value of 24.

A net recharge value of 0-2 inches per year was assumed on bedrock hillsides surrounding the city. This low recharge value was chosen due to the nature of the vadose zone materials (impermeable, dense shale and limestone) and the slopes of the hillsides. The shale and limestone bedrock received a net recharge DRASTIC value of 4.

Aquifer Media: Information on the aquifer media was collected from published well logs obtained from the ODNR, Division of Water. The aquifer media in the buried valley glaciofluvial deposits is sand and gravel. In the bedrock

surrounding the Great Miami Valley, the aquifer media is shale and/or shale and limestone. The sand and gravel aquifers received a DRASTIC value of 24, while the shale and limestone aquifers received a DRASTIC value of 15.

Soil Media: Information on the soil media was collected from the Soil Survey of Butler County, Ohio published in 1980 by the Ohio Soil Conservation Service. The soils are loams which are defined in areas as either sandy, silty, or clayey loam. The DRASTIC values for the loams range from 6 to 12 depending on the amount or lack of clay and/or silt. A value of 6 means the loam contains significant silt and/or clay and is somewhat to moderately impermeable. A DRASTIC value of 12 means the loam is sandy and relatively permeable. A soil DRASTIC value of 18 represents areas which have been filled in with debris material which is usually highly permeable.

Topography: The degrees slope were calculated using USGS 7.5 Minute Series Topography Maps of Butler County, Ohio. Within the Great Miami Valley, above the sand and gravel deposits, the degrees slope is usually between 0-6° which yield DRASTIC values of 10 or 9. On the hillsides surrounding the Great Miami Valley, the degrees slope varies between 2-18° yielding DRASTIC values of 9, 5, or 3.

Impact of the Vadose Zone: Information on the vadose zone material was collected from published well logs obtained from the ODNR, Division of Water. The vadose zone materials in the glaciofluvial deposits in the buried valley are sand and gravel with small lenses of silt and clay. In the bedrock surrounding the Great Miami Valley, the vadose zone materials are interbedded shale and limestone.

Where the sand and gravel deposits contain no clay lenses, the DRASTIC value assigned was 40, where there was significant clay and/or silt the value was 35. For the bedrock shale and limestone deposits, a value of 20 was assigned since they are bedded sedimentary rock, but there are no sandstone beds.

Hydraulic Conductivity: Based on the study by Ward et. al (1987), the hydraulic conductivity value is 2,608 gpd/ft² for the sand and gravel deposits in the Great Miami Valley which cover the downtown area. This high aquifer conductivity value of 2,608 gpd/ft² results in a DRASTIC value of 30. For shale and limestone bedrock aquifers, the hydraulic conductivity was assumed to be approximately 1 gpd/ft² as per the charts published by Freeze and Cherry (1979).

DRASTIC Hydrogeologic Settings:

The shale and bedrock area are classified in the DRASTIC Hydrogeological Settings as 7Aa - Glacial Till Over Bedded Sedimentary Rock. The typical DRASTIC score given in DRASTIC for Glacial Till Over Bedded Sedimentary Rock areas is 103.

The Great Miami Valley sand and gravel deposits are classified in the DRASTIC Hydrogeological Settings as 7D - Buried Valley. The typical DRASTIC score given in DRASTIC for Buried Valley areas is 156.

G.2.b.3 DRASTIC Scores For Hamilton, Ohio:

Score	D	R	A	S	T	I	C	SETTING
74	15	4	15	8	9	20	3	7Aa
72	15	4	15	6	9	20	3	7Aa1
70	15	4	15	8	5	20	3	7Aa2
68	15	4	15	8	3	20	3	7Aa3
66	15	4	15	8	1	20	3	7Aa4
78	15	4	15	12	9	20	3	7Aa5
161	25	24	24	8	10	40	30	7D
165	25	24	24	12	10	40	30	7D1
171	25	24	24	18	10	40	30	7D2
173	35	24	24	10	10	40	30	7D3
175	35	24	24	12	10	40	30	7D4
181	35	24	24	18	10	40	30	7D5

The DRASTIC map produced for the downtown Hamilton area is shown in Figure 3 in Appendix B.

G.2.b.4 Conclusion:

The potential for ground water pollution potential is relatively high along the Great Miami River as evidenced by the DRASTIC scores ranging from 161-181. This is a result of the permeable vadose zone and aquifer media sand and gravels. Both of the two former gas plant sites in Hamilton are located in the high ground water pollution potential areas. It should be noted that the Chem-Dyne hazardous waste site is located in the same high ground water pollution potential area as the former gas plant sites. The Chem-Dyne site has already caused documented ground water pollution (Ward, 1987).

There is a relatively small risk of ground water pollution potential on the surrounding hillsides due to both the glacial till soils, and the fairly impermeable vadose zone and aquifer shale and limestones.

G.2.b.5 Distance To Water Supplies:

Each of the former Hamilton gas plant sites are located near the Great Miami River. The former Hamilton City Gas Works plant site is located right beside the mouth of the Ford Hydraulic Canal where it empties into the Great Miami River. The former Hamilton Gas Light and Coke Company plant site is located approximately 0.5 miles due east of the Great Miami River.

The former Hamilton Gas Light and Coke Company plant site is located directly above the Great Miami aquifer system which provides water for local businesses and for towns and cities both upstream and downstream of Hamilton. The nearest surface water is the Great Miami River which is located several hundred yards downgradient to the west.

The former Hamilton City Gas Works plant site is located directly above the Great Miami aquifer system which provides water for local businesses and for towns and cities both upstream and downstream of Hamilton. The nearest surface waters are the Ford Hydraulic Canal and the Great Miami River which are located several yards downgradient to the north and west, respectively.

6.2.c Middletown Site

6.2.c.1 Location and Geology:

Middletown, with a population of 58,000, is located in Butler County on the terraced flood plain of the Great Miami River. The major hydrogeologic system in the area consists of a thick sequence of glaciofluvial material deposited in a buried valley system through which the Great Miami River follows today. The downtown part of Middletown covers buried valley deposits.

The Great Miami Valley in Middletown is 2-4 miles wide and contains up to 250 feet of sand and gravel deposits. Clay lenses are present but do not appear to be continuous over the area (Bernhagen, 1947). In Middletown, ground water is used by both industry and the town for drinking water. The aquifer in the sand and gravel deposits appears as a single water bearing formation.

Middletown is located on the terraced flood plain of the Great Miami River. Both the Illinoian and Wisconsin ice sheets passed over the area leaving thick fill in the valley and thin fill on the surrounding uplands. In the valley, the glacial outwash of sand, gravel, and silt is 180 feet deep, while on the uplands, the fill averages 25 feet deep (Stout, 1943).

Water Supplies: The underlying bedrock are the dense shales and hard limestone of the Maysville Formation which offer very little, if any, water supplies. The town gets its water from wells drilled in the glacial outwash. These wells are located just south of the Hook Field Airport. The former gas plant site is approximately 0.5 miles to the southeast of the Middletown waterworks.

6.2.c.2 DRASTIC Parameters

Depth to Ground Water: Information on the depth to ground water was collected from published well logs obtained from the ODNR, Division of Water. The depth to ground water in the glaciofluvial deposits in the flood plain of valley floor is typically 20-50 feet deep yielding a DRASTIC value of 35 or 25. In the surrounding hillside the depth is typically 60-100 feet deep yielding a DRASTIC value of 15.

Net Recharge: The net recharge value of approximately 6 inches per year which Ward (1987) used in his study in the sand and gravel glaciofluvial deposits in the Great Miami Valley in Hamilton was used as the net recharge value. This value is reconfirmed by Fidler (1975) who found the net recharge to be 7 inches per year in the sand and gravel deposits in Dayton Ohio. The sand and gravel deposits received a net recharge DRASTIC value of 24.

A net recharge value of 0-2 inches per year was assumed on bedrock hillsides surrounding the city. This low recharge value was chosen due to the nature of the vadose zone materials (impermeable, dense shale and limestone) and the slopes of the hillsides. The shale and limestone bedrock received a net recharge DRASTIC value of 4.

Aquifer Media: The aquifer media in the buried valley glaciofluvial deposits is sand and gravel. In the bedrock surrounding the Great Miami Valley, the aquifer media is shale and/or shale and limestone. The sand and gravel aquifers received a DRASTIC value of 24, while the shale and limestone aquifers received a DRASTIC value of 15.

Soil Media: Information on the soil media was collected from the Soil Survey of Butler County, Ohio published in 1980 by the Ohio Soil Conservation Service. The soils are loams which are defined in areas as either sandy, silty, or clayey loam. The DRASTIC values for the loams range from 6 to 12 depending on the amount or lack of clay and/or silt. A value of 6 means the loam contains significant silt and/or clay and is somewhat to moderately impermeable. A DRASTIC value of 12 means the loam is sandy and relatively permeable. A soil DRASTIC value of 18 represents areas which have been filled in with debris material which is usually highly permeable.

Topography: The degrees slope were calculated using USGS 7.5 Minute Series Topography Maps of Butler County, Ohio. Within the Great Miami Valley, above the sand and gravel deposits, the degrees slope is usually between 0-6° which yield DRASTIC values of 10 or 9. On the hillsides surrounding the Great Miami Valley, the degrees slope varies between 2-18° yielding DRASTIC values of 9, 5, or 3.

Impact of the Vadose Zone: Information on the vadose zone material was collected from published well logs obtained from the Ohio Department of Natural Resources Division of Water. The vadose zone materials in the glaciofluvial deposits in the buried valley are sand and gravel with small lenses of silt and clay. In the bedrock surrounding the Great Miami Valley, the vadose zone materials are interbedded shale and limestone.

Where the sand and gravel deposits contain no clay lenses, the DRASTIC value assigned was 40, where there was significant clay and/or silt the value was 35. For the bedrock shale and limestone deposits, a value of 20 was assigned since they are bedded sedimentary rock, but there are no sandstone beds.

Hydraulic Conductivity: The hydraulic conductivity value of 2,608 gpd/ft² from Ward (1987) was used for the sand and gravel deposits of the Great Miami Valley which cover the downtown area. This high aquifer conductivity value of 2,608 gpd/ft² results in a DRASTIC value of 30. For shale and limestone bedrock aquifers, the hydraulic conductivity was assumed to be approximately 1 gpd/ft² as per the charts published by Freeze and Cherry (1979).

DRASTIC Hydrogeologic Settings:

The shale and bedrock area is classified in the DRASTIC Hydrogeological Settings as 7Aa - Glacial Till Over Bedded Sedimentary Rock. The typical DRASTIC score given in DRASTIC for Glacial Till Over Bedded Sedimentary Rock areas is 103.

The Great Miami Valley sand and gravel deposits are classified in the DRASTIC Hydrogeological Settings as 7D - Buried Valley. The typical DRASTIC score given in DRASTIC for Buried Valley areas is 156.

G.2.c.3 DRASTIC Scores For Middletown, Ohio:

<u>Score</u>	<u>D</u>	<u>R</u>	<u>A</u>	<u>S</u>	<u>T</u>	<u>I</u>	<u>C</u>	<u>SETTING</u>
69	10	4	15	8	9	20	3	7Aa
65	10	4	15	8	5	20	3	7Aa1

DRASTIC Scores For Middletown, Ohio (continued):

Score	D	R	A	S	T	I	C	SETTING
171	35	24	24	8	10	40	30	7D
175	35	24	24	12	10	40	30	7D1
173	35	24	24	10	10	40	30	7D2
165	25	24	24	12	10	40	30	7D3
181	35	24	24	18	10	40	30	7D4
171	25	24	24	18	10	40	30	7D5
161	35	24	24	18	10	40	30	7D5

The DRASTIC map produced for the downtown Middletown area is shown in Figure 4 in Appendix B.

G.2.c.4 Conclusion:

The potential for ground water pollution potential is relatively high along the Great Miami River in Middletown as evidenced by the DRASTIC scores ranging from 161-181. This is a result of the permeable vadose zone and aquifer media sand and gravels. The former gas plant site is located in the high ground water pollution potential area.

Conversely, there is a relatively small risk of ground water pollution potential on the surrounding hillsides due to both the glacial till soils, and the fairly impermeable vadose zone and aquifer shale and limestones.

G.2.c.5 Distance To Water Supplies:

Middletown gets its water from wells located just south of the Hook Field Airport, which is approximately 0.5 miles to the northwest of the former gas plant site. The normal hydraulic gradient probably draw ground water from around the

former gas plant site to the west and southwest and thus away from the town's wells.

The former gas plant site is located directly above the Great Miami aquifer system which provides water for local businesses and for towns and cities both upstream and downstream of Middletown. The nearest surface water is the Great Miami River which is located several hundred yards downgradient to the west/southwest.

6.2.d Hillsboro Site

6.2.d.1 Location and Geology:

Hillsboro Ohio, which has a population of around 6,500, is located in Highland County and lies on the glaciated Lexington peneplain at approximately 1,100 feet above sea level. Several streams head around the downtown area, but none offer any large quantity of water. The area has been glaciated by the Illinoian ice sheet depositing thin glacial drift made up of till and offering only small amounts of water (Stout, 1943).

The underlying bedrock are the Bisher and Lilley members of the Niagara Formation which consists of dolomite with interbedded shales which contain only small supplies of ground water. At 80 feet below the Niagara beds is the 40 foot thick Brassfield limestone. At the base of the Brassfield, there is a porous layer offering some ground water. Under the Brassfield are the beds of the Cincinnati Group which offer little or no ground water supply (Stout, 1943).

Water Supply: Highland County is covered by a thin veneer of glacial drift, except in the northeast part of the county where moraine deposits are up to 100 feet thick and are a good source of ground water. In the western part of the county the dense shale bedrock offers little or no ground water resources; while in the northeastern part of the county the bedrock changes to dolomite which offers a better source of ground water since the dolomite is more permeable (Kaser, 1965). Along the streams in the county, there are usually good ground water supplies.

The principle source of water for the town of Hillsboro is an surface reservoir located about 3 miles due north of the former gas plant site. The town

uses approximately 800,000 gallons per day. The town also has supplementary supplies from a well field in the gravel fill along Clear Creek which is about 2 miles from the former gas plant site. The city collects ground water from gravel deposits in the Clear Creek area north of town at depths of 40-50 feet. Clear Creek and Rocky Fork offer the only good possibilities of ground water supplies in the area. However, small ground water supplies can be obtained from bedrock at shallow depths (Stout, 1943).

6.2.d.2 DRASTIC Parameters

Depth to Ground Water: Information on the depth to ground water was collected from published well logs obtained from the ODNR, Division of Water. The depth to water varied across the Hillsboro area from 15-50 deep, and usually averaged about 30 feet deep yielding a DRASTIC value of 35 or 25. Ground water was found usually in the shale and limestone bedrock which was covered by fairly impermeable glacial till deposits.

Net Recharge: A net recharge value of 0-2 inches per year was assumed due to the nature of the vadose zone materials (impermeable glacial tills comprised primarily of clay material). The shale and limestone bedrock received a net recharge DRASTIC value of 4.

Aquifer Media: Information on the aquifer media was collected from published well logs obtained from the ODNR, Division of Water. In general the aquifers were located in the shale and limestone bedrock under glacial till deposits. The well yields from these bedrock aquifers is usually very low. The bedrock aquifers were given a DRASTIC aquifer media value of 15.

Soil Media: Information on the soil media was collected from the Soil Survey of Butler County, Ohio published in 1980 by the Ohio Soil Conservation Service. The soils in the Hillsboro area are loams which are defined in areas as either sandy, silty, or clayey loams. The DRASTIC soil media values given for the loams ranged from 6 to 10 depending on the amount or lack of clay and/or silt. A value of 6 means the loam contains significant silt and/or clay and is somewhat to moderately impermeable, while a DRASTIC value of 10 means the loam contains less clay and is more permeable.

Topography: The degrees slope were calculated using USGS 7.5 Minute Series Topography Maps of Highland County, Ohio. Within the Great Miami Valley, above the sand and gravel deposits, the degrees slope is usually between 2-6° which yield DRASTIC values of 10 or 9. On the hillsides surrounding the Great Miami Valley, the degrees slope varies between 2-18° yielding DRASTIC values of 9, 5, or 3.

Impact of the Vadose Zone: Information on the vadose zone material was collected from published well logs obtained from the Ohio Department of Natural Resources Division of Water. The vadose zone materials are glacial till deposits of Illinoian and Wisconsin age consisting primarily of clay materials with local lenses of sand and gravel. The glacial tills were given a DRASTIC impact of vadose zone value of 20.

Hydraulic Conductivity: Using published well logs, the hydraulic conductivity was estimated using the program TGUESS developed by K.R. Bradbury and E.R. Rothschild in 1986 at the Wisconsin Geological and Natural History Survey. The program estimates transmissivity from specific capacity data. Several assumptions were made to use the program. The storage coefficient of the aquifers in the area were all given a value of 0.01 for use in the programs calculations.

All the well log data showed hydraulic conductivity values between 1-10 gallons per day per square foot (gpd/ft²) when used in the TGUESS program; resulting in a DRASTIC hydraulic conductivity value of 3 given across the Hillsboro area. Although no wells were drilled in the sand and gravel deposits along the Little Fork Creek, the hydraulic conductivity in that area may be slightly higher than 100 gpd/ft².

Hydrogeological Settings

The Hillsboro area is classified by DRASTIC in the DRASTIC Hydrogeological Settings as 7Aa - Glacial Till Over Bedded Sedimentary Rock. The typical DRASTIC score given in DRASTIC for Glacial Till Over Bedded Sedimentary Rock areas is 103; however, in the Hillsboro area the scores were slightly lower due to the presence of the glacial till.

G.2.d.3 DRASTIC Scores For Hillsboro, Ohio:

Score	D	R	A	S	T	I	C	SETTING
95	35	5	15	8	9	20	3	7Aa
93	35	5	15	6	9	20	3	7Aa1
91	35	5	15	8	5	20	3	7Aa2
89	35	5	15	6	3	20	3	7Aa3
85	25	5	15	8	9	20	3	7Aa4
81	25	5	15	6	5	20	3	7Aa5

The DRASTIC map produced for the Hillsboro area is shown in Figure 5 in Appendix B.

G.2.d.4 Conclusion:

The potential for ground water pollution potential is relatively low in the Hillsboro Ohio area as result of the impermeable vadose zone and the shale and limestone aquifer. Also, the towns sources of water are located several miles from the former gas plant site.

G.2.d.5 Distance To Water Supplies

The principle source of water for the town of Hillsboro is an upground reservoir located about 3 miles due north of the former gas plant site. The town uses approximately 800,000 gallons per day. The town also has supplementary supplies from a well field in the gravel fill along Clear Creek which is about 2 miles from the former gas plant site. The city collects ground water from gravel deposits in the Clear Creek area north of town at depths of 40-50 feet.

G.2.e Wilmington Site

G.2.e.1 Location and Geology:

Wilmington Ohio, with a population of 10,500, is located in Clinton County which lies within the Till Plains section of the Central Lowland physiographic province. Wilmington lies at the headwaters of the Lytle Creek. Clinton County is covered with glacial drift deposits ranging in thickness up to 300 feet deep covering a limestone and dolomite bedrock. The limestone and dolomite bedrock offer little or no ground water in the western part of the county and only small amounts in the eastern half of the county. Where there are buried valley deposits there are adequate ground water supplies.

In Wilmington, the bedrock consists of limestone and interbedded shale layers covered by glacial till. Both the Illinoian and Wisconsin ice sheets passed over the area leaving a thin drift 10-30 feet deep, except in Wilmington where the drift thickens to 50-80 feet deep. There is some evidence of an old buried valley near the fair grounds where the drift is 150 feet deep (Stout, 1943).

Surrounding Wilmington the aquifers used for ground water supplies are the shale and limestone bedrock strata which are confined by 20-80 feet of glacial till. The glacial till is comprised mainly of clay material. Locally, there are sand and gravel lenses which contain ground water and are also covered by the impermeable glacial till.

The underlying bedrock is unimportant for ground water supplies except for the dense, hard low porosity limestone of the Brassfield Formation. At the base of the Brassfield Formation is a layer of broken porous rock about 3 feet in depth. The ground water is confined to about 80 feet in depth (Stout, 1943).

Water Supplies: The principle sources of water for the town of Wilmington, in 1965, was a surface reservoir. In 1965, the town pumped 6,000 gallons of ground water and 678,000 of reservoir water per day (Water Inventory Report, 1965). In 1988, the town still has two reservoirs, but primarily uses water pumped from the Cowlan Creek taken in Burtonville which is 2.5 miles due south from the former gas plant site. The town uses 1.6×10^6 gallons per day. The most likely source for future ground water development is the glacial fill to the southwest of town (Stout, 1943).

G.2.e.2 DRASTIC Parameters

Depth to Ground Water: Since the aquifers were assumed to be confined by glacial till deposits, the depth to water was taken as the depth to the top of the aquifer bed. The DRASTIC values were either 35, 25, 15, or 5.

Net Recharge: A net recharge value of 0-2 inches per year was assumed due to the nature of the vadose zone materials (impermeable glacial tills comprised primarily of clay material). This corresponds to a DRASTIC net recharge value of 4.

Aquifer Media: Information on the aquifer media was collected from published well logs obtained from the Ohio Department of Natural Resources Division of Water. In general the aquifers were located in the shale and limestone bedrock under glacial till deposits. The well yields from these bedrock aquifers is usually very low. The bedrock aquifers were given a DRASTIC aquifer media value of 15.

There are local lenses of sand and gravel which contain ground water, and in the Lytle Creek bed there are sand and gravel deposits containing water. The sand and gravel aquifers were given a DRASTIC aquifer media value of 24.

Soil Media: Information on the soil media was collected from the Soil Survey of Butler County, Ohio published in 1980 by the Ohio Soil Conservation Service. The downtown area of Wilmington was not surveyed by the Soil and Conservation Service. However, since all the soil coverage surrounding the town is silty loam it is assumed that the soil coverage over Wilmington likewise is silty loam. The silty loam soils were given a DRASTIC soil media value of 8.

Topography: The degrees slope were calculated using USGS 7.5 Minute Series Topography Maps of Clinton County, Ohio. The area was given DRASTIC values for degrees slope of 5, 9, or 10.

Impact of the Vadose Zone: Information on the vadose zone material was collected from published well logs obtained from the Ohio Department of Natural Resources Division of Water. The vadose zone materials are glacial till deposits of Illinoian and Wisconsin age consisting primarily of clay materials with local

lenses of sand and gravel. Areas which had confining layers of glacial till were given a impact of vadose zone materials DRASTIC value of 5.

Hydraulic Conductivity: Using published well logs, the hydraulic conductivity was estimated using the program TGUESS (Bradbury and Rothschild, 1986). The storage coefficient of the aquifers in the area were all given a value of 0.02 for use in the programs calculations.

Nearly all the well log data showed hydraulic conductivity values between 1-100 gallons per day per square foot (gpd/ft²) when used in the TGUESS program; resulting in a DRASTIC hydraulic conductivity value of 3 given across the Wilmington area. Although no wells were drilled in the sand and gravel deposits along the Lytle Creek, the hydraulic conductivity in that area may be slightly higher than 100 gpd/ft².

DRASTIC Hydrogeologic Settings:

The shale and bedrock area is classified in the DRASTIC Hydrogeological Settings as 7Aa - Glacial Till Over Bedded Sedimentary Rock. The typical DRASTIC score given in DRASTIC for Glacial Till Over Bedded Sedimentary Rock areas is 103.

6.2.e.3 DRASTIC Scores For Wilmington, Ohio:

<u>Score</u>	<u>D</u>	<u>R</u>	<u>A</u>	<u>S</u>	<u>T</u>	<u>I</u>	<u>C</u>	<u>SETTING</u>
50	5	4	15	8	10	5	3	7Aa
55	15	4	15	8	5	5	3	7Aa1
59	15	4	15	8	9	5	3	7Aa2
60	15	4	15	8	10	5	3	7Aa3
68	25	4	15	8	9	4	3	7Aa4
74	25	4	24	8	5	5	3	7Aa5

DRASTIC Scores For Wilmington, Ohio:

<u>Score</u>	<u>D</u>	<u>R</u>	<u>A</u>	<u>S</u>	<u>T</u>	<u>I</u>	<u>C</u>	<u>SETTING</u>
84	35	4	24	8	5	5	3	7Aa6

The DRASTIC map produced for the Wilmington area is shown in Figure 6 in Appendix B.

G.2.e.4 Conclusion:

The potential for ground water pollution potential is relatively low in the Wilmington Ohio area as result of the impermeable vadose zone and aquifer shale and limestones.

G.2.e.5 Distance To Water Supplies

The former gas plant site is several hundred yards from the Lyttle Creek and 2.5 miles from the Cowlan Creek from which Wilmington pumps most of it's drinking water.

G.2.f Ripley Site

G.2.f.1 Location and Geology:

Ripley Ohio, which has a population of about 5,000 people is located in Brown County right at the edge of the glaciated area of Ohio. Ripley is located alongside the Ohio River. The western edge of the city was glaciated, while the eastern edge was not glaciated. The town of Ripley is located over buried valley strata. Brown County, in its glaciated areas, has a bedrock made up of thin limestone and shale beds covered by a thin veneer of glacial drift up to depths of 30 feet. Along the Ohio River, there are sand and gravel deposits which contain aquifers which yield 500-1,000 gallons per minute. The well yields depend on the amount of water infiltration from the river into the sand and gravel aquifers. Elsewhere in the county, ground water occurs in bedrock and in local lenses of sand and gravel.

Ripley is located on the terminal moraine of the Illinoian ice sheet which crosses the Ohio River at the town. The Ohio River Valley and local stream beds are deeply filled with glacial outwash consisting of sand, gravel, and silt (Stout, 1943). The Ohio River fronts Ripley on the southwest, Cornick Run on the west, Redoak Creek cuts across the eastern part of the town, and Eagle Creek enters the Ohio approximately one mile east of Ripley.

Water Supplies: In Ripley, locals wells are drilled into sand and gravel with depths to water being 75-100 feet deep. In 1988, Ripley pumps around 400,000 gallons per day from local sand and gravel aquifers along the Ohio River on Waterworks Road. This site is located approximately 1 mile upstream from the former coal gas plant site.

6.2.f.2 DRASTIC Parameters

Depth to Ground Water: The depth to water along the river was between 30-50 feet deep yielding a DRASTIC value of 25. On the immediate surrounding hillsides, the depth to water is between 15-30 feet yielding a DRASTIC value of 35.

Net Recharge: The net recharge value was assumed to be about 6 inches per year. (Ward et. al, 1987, uses 6.1 inches per year in his study on the sand and gravel glaciofluvial deposits in the Great Miami Valley in Hamilton). The sand and gravel deposits received a net recharge DRASTIC value of 24.

A net recharge value of 0-2 inches per year was assumed on bedrock hillsides surrounding the city. This low recharge value was chosen due to the nature of the vadose zone materials (impermeable, dense shale and limestone) and the slopes of the hillsides. The shale and limestone bedrock received a net recharge DRASTIC value of 4.

Aquifer Media: Information on the aquifer media was collected from published well logs obtained from the ODNR, Division of Water. In general the aquifers were located in the shale and limestone bedrock under glacial till deposits. The well yields from these bedrock aquifers is usually very low. The bedrock aquifers were given a DRASTIC aquifer media value of 15. The sand and gravel aquifer along the Ohio River was given a DRASTIC aquifer media value of 24.

Soil Media: Information on the soil media was collected from the Soil Survey of Brown County, Ohio published in 1988 by the Ohio Soil Conservation Service. The soils in the Ripley area are loams formed in loess and/or glacial outwash and are well drained. The DRASTIC value for soil media was given as 10.

Topography: The degrees slope were calculated using USGS 7.5 Minute Series Topography Maps of Brown County, Ohio. The area along the Ohio River has a slope of 0-2 degrees and a DRASTIC value of 10. The immediate hillsides have slopes between 12-18 degrees and were given a DRASTIC value of 3.

Impact of the Vadose Zone: Information on the vadose zone material was collected from published well logs obtained from the Ohio Department of Natural Resources Division of Water. The vadose zone materials are glacial till deposits of Illinoian and Wisconsin age consisting primarily of clay materials with local lenses of sand and gravel. The glacial tills were given a DRASTIC impact of vadose zone value of 20.

Hydraulic Conductivity: Using published well logs, the hydraulic conductivity was estimated using the program TGUESS (K.R. Bradbury and Rothschild, 1986). The storage coefficient of the aquifers in the area were all given a value of 0.02 for use in the programs calculations.

Using the well log data for well along the Ohio River in the sand and gravel deposits showed hydraulic conductivity values between 700-1,000 gallons per day per square foot (gpd/ft²) when used in the TGUESS program; resulting in a DRASTIC hydraulic conductivity value of 18 given across the Wilmington area. The well log data in the surrounding area showed hydraulic conductivity values between 0-100 gallons per day per square foot (gpd/ft²) when used in the TGUESS program; resulting in a DRASTIC hydraulic conductivity value of 3.

DRASTIC Hydrogeologic Settings:

The shale and bedrock area is classified in the DRASTIC Hydrogeological Settings as 7Aa - Glacial Till Over Bedded Sedimentary Rock. The typical DRASTIC score given in DRASTIC for Glacial Till Over Bedded Sedimentary Rock areas is 103.

The sand and gravel deposits along the Ohio River are classified in the DRASTIC Hydrogeological Settings as 7D - Buried Valley. The typical DRASTIC score given in DRASTIC for Buried Valley areas is 156.

G.2.f.3 DRASTIC Scores For Ripley, Ohio:

Score	D	R	A	S	T	I	C	SETTING
90	35	4	15	10	3	20	3	7Aa
131	25	24	24	10	10	20	18	7D

The DRASTIC map produced for the Ripley area is shown in Figure 7 in Appendix B.

G.2.f.4 Conclusion:

The potential for ground water pollution potential is relatively high in the sand and gravel deposits along the Ohio River where the former gas plant site is located.

G.2.f.5 Distance To Water Supplies:

The former gas plant site is located downstream of Ripley's waterworks; however, the plant site is located less than 100 yards from the Ohio River. The site is located on the edge of downtown Ripley and overlies extensive ground water supplies of the Ohio River Valley aquifer.

G.2.g Lebanon Site

G.2.g.1 Location and Geology:

Lebanon Ohio, which has a population of around 10,000, is located in Warren County in the southwest corner of the state. The Turtle Creek flows through buried valley sediments just to the south of the town. Both the Illinoian and

Wisconsin ice sheets passed over the area leaving glacial tills covering the bedrock. A result of the glaciation is the buried valley which runs northeast to southwest past Lebanon through which Turtle Creek flows today. The buried valley deposits contains glacial outwash sands and gravels up to 250 feet deep (Stout, 1943).

The underlying bedrock are the hard limestone and dense shales of the top of the Maysville Formation which offer little or no ground water supplies (Stout, 1943).

Warren County contains covered glacial drift deposits ranging in thickness of 25-120 feet deep covering a shale and limestone bedrock similar to the bedrock in Hamilton and Butler counties. The shale and limestone bedrock are too dense and offer little or no ground water resources; however, where there are buried valley deposits, there are adequate ground water supplies. The Little Miami River which flows through the county is located above buried valley deposits and contains aquifers supplying ground water.

Water Supplies: The town of Lebanon draws 1.3×10^6 gallons per day of ground water from wells in the Turtle Creek area about 0.5 miles due west from the former gas plant site.

6.2.g.2 DRASTIC Parameters

Depth to Ground Water: Information on the depth to ground water was collected from published well logs obtained from the Ohio Department of Natural Resources (ODNR), Division of Water. The depth to ground water ranges from 15-30 and 30-50 feet deep yielding DRASTIC values of 35 or 25, respectively.

Net Recharge: The net recharge was assumed to be approximately 6 inches per year in the sand and gravel deposits. Ward (1987) used a net recharge value of 6.1 inches per year for the sand and gravel deposits in Hamilton, Ohio. It is assumed that the net recharge in Hamilton is similar to the sand and gravel deposits in the Turtle Creek area. The sand and gravel deposits received a net recharge DRASTIC value of 24.

A net recharge value of 0-2 inches per year was assumed in limestone and shale deposits surrounding the Turtle Creek area. This low recharge value was chosen due to the nature of the vadose zone materials (impermeable, dense shale and limestone) and the slopes of the hillsides. The shale and limestone bedrock received a net recharge DRASTIC value of 4.

Aquifer Media: Information on the aquifer media was collected from published well logs obtained from the ODNR, Division of Water. The aquifer media in the buried valley glaciofluvial deposits are sand and gravel. In the bedrock surrounding the Turtle Creek area, the aquifer media is shale and/or shale and limestone. The sand and gravel aquifers received a DRASTIC value of 24, while the shale and limestone aquifers received a DRASTIC value of 15.

Soil Media: Information on the soil media was collected from the Soil Survey of Warren County, Ohio published in 1980 by the Ohio Soil Conservation Service. The soils are loams which are defined in areas as either sandy, silty, or clayey loam. The DRASTIC values for the loams range from 6 to 12 depending on the amount or lack of clay and/or silt. A value of 6 means the loam contains significant silt and/or clay and is somewhat to moderately impermeable. A DRASTIC value of 12 means the loam is sandy and relatively permeable.

Topography: The degrees slope were calculated using USGS 7.5 Minute Series Topography Maps of Warren County, Ohio. Generally in the Lebanon area the degrees slope is between 2-6° yielding a DRASTIC value of 9. On the hillsides the degrees slope varies between 6-18° yielding DRASTIC values of 5 or 3.

Impact of the Vadose Zone: Information on the vadose zone material was collected from published well logs obtained from the ODNR, Division of Water. In the Lebanon area the vadose zone materials are predominately glacial tills consisting of silt and clay material yielding a DRASTIC value of 20.

Hydraulic Conductivity: Using published well logs, the hydraulic conductivity was estimated using the program TGUESS (Bradbury and Rothschild, 1986). The storage coefficient of the aquifers in the area were all given a value of 0.02 for use in the programs calculations.

In the buried valley sediments, using the well log data showed hydraulic conductivity values greater than 2000 gallons per day per square foot (gpd/ft²)

when used in the TGUSS program; resulting in a DRASTIC hydraulic conductivity value of 30. The well log data in the surrounding area showed hydraulic conductivity values between 0-100 gallons per day per square foot (gpd/ft²) when used in the TGUSS program; resulting in a DRASTIC hydraulic conductivity value of 3.

DRASTIC Hydrogeologic Settings:

The shale and bedrock area is classified in the DRASTIC Hydrogeological Settings as 7Aa - Glacial Till Over Bedded Sedimentary Rock. The typical DRASTIC score given in DRASTIC for Glacial Till Over Bedded Sedimentary Rock areas is 103.

The sand and gravel deposits in the Turtle Creek area are classified in the DRASTIC Hydrogeological Settings as 7D - Buried Valley. The typical DRASTIC score given in DRASTIC for Buried Valley areas is 156.

6.2.g.3 DRASTIC Scores For Lebanon, Ohio:

Score	D	R	A	S	T	I	C	SETTING
78	25	4	15	8	3	20	3	7Aa
80	25	4	15	8	5	20	3	7Aa1
84	25	4	15	8	9	20	3	7Aa2
94	35	4	15	8	9	20	3	7Aa3
98	35	4	15	12	9	20	3	7Aa4
130	15	24	24	8	9	20	30	7D
146	35	24	24	8	5	20	30	7D1

DRASTIC Scores For Lebanon, Ohio (continued):

<u>Score</u>	<u>D</u>	<u>R</u>	<u>A</u>	<u>S</u>	<u>T</u>	<u>I</u>	<u>C</u>	<u>SETTING</u>
150	35	24	24	8	9	20	30	7D2
151	35	24	24	8	10	20	30	7D3
152	35	24	24	10	9	20	30	7D4
154	35	24	24	12	9	20	30	7D5

The DRASTIC map produced for the Lebanon area is shown in Figure 8 in Appendix B.

G.2.g.4 Conclusion:

The potential for ground water pollution potential is relatively high in the Turtle Creek area around Lebanon due to the vadose zone and aquifer media sand and gravel deposits. The aquifer in the Turtle Creek area is an important source of water for the town of Lebanon.

Due to the former gas plant's proximity to the Lebanon wellfields and the common aquifer, the potential for any contamination from former plant wastes is a genuine concern.

G.2.g.5 Distance To Water Supplies

The town of Lebanon draws 1.3×10^6 gallons per day of ground water from wells in the Turtle Creek area about 0.5 miles due west and downstream from the former gas plant site.

G.2.h Xenia Site

G.2.h.1 Location and Geology:

Xenia Ohio with a population of around 40,000 people is located in Greene County. The town lies on the glaciated Lexington peneplain. Both the Illinoian and Wisconsin ice sheets passed over the area, leaving glacial drift deposits ranging from 25-100 feet deep in the area. Small buried valleys are known in the area (Stout, 1943). The Little Miami River flowing south passes just to the west of Xenia. At the western edge of Xenia are buried valley sediments through which the Little Miami flows.

The underlying bedrock in and around Xenia are the top beds of the Richmond Formation which consists of hard limestone and dense shales which contain little or no ground water (Stout, 1943). Greene County in general, is covered by a thin veneer of glacial drift which ranges in thickness from a few feet to 200 feet thick. Buried valley sediments of sand and gravel follow the Little Miami River which flows just to the west of Xenia. The buried valley sediments offer good ground water resources (Kaser, 1965).

The western part of Greene County, including all but the northeast corner of Xenia, is underlaid by the Richmond and Maysville Groups which are comprised of interbedded plastic shales and thin limestone layers. These formations offer little or no ground water resources; usually less than 5 gallons per minute (gpm). The eastern part of Greene County, including the northeast edge of Xenia, is underlaid by the Niagara and Clinton Groups consisting of interbedded limestones and dolomites. These sediments offer better sources of ground water with wells usually yielding 5-15 gpm and some wells up to 150 gpm.

The soils covering the town of Xenia include the Fox-Ockley-Thackery Soil Series on the western side of the town. The Sleeth-Westland-Thackery Soil Series cover the northeast corner of the town, while the Miami-Celina-Fox Soil Series covers the eastern side of the town. (Water Inventory Report, 1964).

Water Supplies: In 1964 the town of Xenia received the majority of its water supply from ground water, drawing 1,540,000 gallons per day of ground water and 1,000 gallons of surface water. (Water Inventory, 1964) Wells were drilled to the southwest of the town through clay to a depth of 28-40 feet into

gravel. The glacial drift in the area offers the only source of ground water (Stout, 1943).

In 1988, the Xenia Waterworks draws approximately 3.5×10^6 gallons per day of ground water from the buried valley aquifer below the Little Miami River. The Waterworks is located due north of the Xenia along Route 68 about 3.5 miles from the former coal gas plant.

In general, the well yields around Xenia are 5-25 gallons per minute wherever sand and gravel deposits occur in stream beds or as lenses within the glacial drift deposits. There is little or no ground water from the bedrock. In Xenia, at the western edge of the city where the Shawnee Creek flows away from the town, there are sand and gravel deposits as one approaches the Little Miami River. It appears that well yields of 100-500 gallon per minute could be expected (Water Inventory Report, 1964).

6.2.h.2 DRASTIC Parameters

Depth to Ground Water: Information on the depth to ground water was collected from published well logs obtained from the Ohio Department of Natural Resources Division of Water. The depth to ground water ranges from 15 to over 100 feet deep. In general, the depth to water in the western part of Xenia is over 70 feet deep yielding a DRASTIC score of 15. In other parts of the town, the depth to water varies between 15-30 and 30-50 feet deep yielding DRASTIC values of 35 or 25, respectively.

Net Recharge: The value for net recharge was assumed to be between 4-6 inches per year in the buried valley sediments (primarily sand and gravels) which are just to the west of Xenia. These sand and gravel deposits received a net recharge DRASTIC value of 24. For the rest of the Xenia area, where there are glacial till deposits over sedimentary rock (limestones and shales), the net recharge was assumed to be between 0-2 inches per year yielding a DRASTIC value of 4. This low recharge value was chosen due to the nature of the vadose zone materials (glacial till over impermeable shale and limestone).

Aquifer Media: Information on the aquifer media was collected from published well logs obtained from the ODNR, Division of Water. The aquifer media

in the buried valley glaciofluvial deposits is sand and gravel. The sand and gravel aquifers received a DRASTIC value of 24. For the rest of the area, the aquifer media are the shales and limestone bedrock which received a DRASTIC value of 15.

Soil Media: Information on the soil media was collected from the Soil Survey of Greene County, Ohio published in 1978 by the Ohio Soil Conservation Service. The soils are loams which are defined in areas as either sandy, silty, or clayey loam; however, in the Xenia area the soils are predominately silty loams. The DRASTIC value for the silty loam is 8.

Topography: The degrees slope were calculated using USGS 7.5 Minute Series Topography Maps of Warren County, Ohio. Generally in the Xenia area the degrees slope is between 2-6° yielding a DRASTIC value of 9. On the hillsides the degrees slope varies between 6-12° yielding DRASTIC values of 5.

Impact of the Vadose Zone: Information on the vadose zone material was collected from published well logs obtained from the ODNR, Division of Water. In the Xenia area the vadose zone materials are predominately glacial tills consisting of silt and clay materials yielding a DRASTIC value of 20. Note that several of the well logs located in the northeast part of Xenia appear to show that the glacial till acts as a confining layer. This could not be verified and was not used in the DRASTIC model.

Hydraulic Conductivity: Using published well logs, the hydraulic conductivity was estimated using the program TGUESS (Bradbury and Rothschild, 1986). One assumption was made to use the program; the storage coefficient of the aquifers in the area were all given a value of 0.02 for use in the programs calculations.

In the buried valley sediments, using the well log data showed hydraulic conductivity values greater than 300-700 gallons per day per square foot (gpd/ft²) when used in the TGUESS program; resulting in a DRASTIC hydraulic conductivity value of 12.

The well log data in the rest of the Xenia area showed that the bedrock aquifer had hydraulic conductivity values between 0-100 gallons per day per square foot (gpd/ft²) when used in the TGUESS program; resulting in a DRASTIC hydraulic conductivity value of 3.

DRASTIC Hydrogeologic Settings:

The shale and bedrock area is classified in the DRASTIC Hydrogeological Settings as 7Aa - Glacial Till Over Bedded Sedimentary Rock. The typical DRASTIC score given in DRASTIC for Glacial Till Over Bedded Sedimentary Rock areas is 103.

The sand and gravel deposits in the Turtle Creek area are classified in the DRASTIC Hydrogeological Settings as 7D - Buried Valley. The typical DRASTIC score given in DRASTIC for Buried Valley areas is 156.

G.2.h.3 DRASTIC Scores For Xenia, Ohio:

Score	D	R	A	S	T	I	C	SETTING
70	15	4	15	8	5	20	3	7Aa
74	15	4	15	8	9	20	3	7Aa1
80	25	4	15	8	5	20	3	7Aa2
84	25	4	15	8	9	20	3	7Aa3
94	35	4	15	8	9	20	3	7Aa4
108	15	24	24	8	5	20	12	7D
112	15	24	24	8	9	20	12	7D1
113	15	24	24	8	10	20	12	7D2

The DRASTIC map produced for the Xenia area is shown in Figure 9 in Appendix B.

G.2.h.4 Conclusion:

The potential for ground water pollution potential is relatively high in the Xenia only in the area of the Little Miami River Valley where there are buried

valley sediments. The buried valley aquifer in the Little Miami River area is an important source of water for the town of Xenia. The potential for ground water pollution potential at the former gas plant site in Xenia is relatively moderate as compared to the other sites mapped with the DRASTIC model.

6.2.h.5 Distance To Water Supplies:

The Xenia Waterworks is located about 3.5 miles due north of the former coal gas plant along Route 68. The Shawnee Creek which flows right past the former plant site empties into the Little Miami River downstream of where the Xenia Waterworks is located.

6.3 Comparison of Ground Water Contamination Potential of Former Gas Plant Sites in Southwestern Ohio

6.3.a High Ground Water Pollution Potential Areas

The sites in Cincinnati (two sites), Hamilton (two sites), Middletown, Lebanon, and Ripley are all located in areas (buried valley sediments) where the relative ground water pollution potential is high. These sites overlie extensive aquifer systems which are a source of water for home and businesses. Please refer to Table 4.

The DRASTIC scores for the Hamilton area (161-181) includes the location of the Chem-Dyne hazardous waste area. The two Hamilton gas plant sites would have the same potential for ground water pollution as the Chem-Dyne site as determined by the DRASTIC model. The Middletown gas plant site is in an area with scores (171-181), higher than those at the Chem-Dyne site. The downtown Cincinnati site (140-160), the East Cincinnati site on Eastern Avenue (160), the Lebanon site (130-154), and the Ripley site (130) all have DRASTIC scores are just slightly lower than the Chem-Dyne area.

6.3.b. Low Ground Water Pollution Potential Areas

The sites in Xenia, Hillsboro, and Wilmington gas plant sites are located in areas (Glacial Till Over Sedimentary Rock) where the potential for ground water pollution is relatively low. The scores for each of these sites are lower than the

scores for the Chem-Dyne hazardous waste site. These sites overlie strata which have small ground water supplies. Please refer to Table 4.

G.4 Environmental Contamination Potential of Former Gas Plant Sites in Southwestern Ohio

At the former gas plant sites in southwestern Ohio, any wastes still present are likely to be primarily below ground level. Several of the sites are now covered by new buildings. Soils at former gas plants can be assumed to be contaminated with plant wastes (e.g. tars) due to the methods of waste handling, storage, and disposal that were likely used.

G.5 Personal Contamination Potential of Former Gas Plant Sites in Southwestern Ohio

In general, the gas plant sites in southwestern Ohio appear to offer only moderate worker health and safety risks in relation to other inactive waste sites. However, it can be assumed that workers performing excavation or construction at former gas plant sites will be exposed to tars and/or other plant wastes either by direct contact or through inhalation. During the excavation of a former gas plant site in central Illinois, the potential for inhalation exposures were said to have occurred for both workers and area residents (Martin, 1988).

The potential pathways for tar exposure are: (1) ingestion; (2) skin contact; (3) inhalation; and (4) water contamination. Tars can cause chemical burns upon prolonged dermal contact.

H. CONCLUSIONS

H.1 Information of Potential Use by Environmental Health Authorities

This study collected the following types of information that may be of use to environmental agencies at the local, state, and national level:

- (1) The location and historical operations of the gas plants which operated in southwestern Ohio.
- (2) The present day usage of the sites.
- (3) The relative ground water pollution potential around each former gas plant site.
- (4) The location and usage of ground water and surface water supplies around the former gas plant sites.
- (5) Recommendations for personal hygiene protection during excavation or construction work.

H.2 Recommendations for Future Investigative Work

The following sections offer criteria for each former gas plant site which environmental health officials should review when considering which sites are to be investigated. Important considerations are the DRASTIC ground water pollution potential scores, the amounts of wastes the plant generated, the years of plant operations (the earlier the years of operation the less concern was given to waste management), the condition of the former plant site today, and the distance to well sites and surface water.

It should be remembered that at all the former gas plant sites there is the potential for buried wastes to still be present on plant property even if the former buildings are gone. This is due to the fact that often the tar wells and waste holding ponds were not excavated when the plant buildings were demolished.

Some of the former plants are less likely to pose potential problems for several reasons:

- (1) The plant site is located in a low DRASTIC ground water pollution potential area.

(2) The plant site is located either in (a) an area where there is little ground water and/or (b) there is little use of the ground water.

(3) The plant site is located away from a city's source of water; e.g. either a surface source or ground water well sites.

(4) The plant site today is covered by new buildings. This would not preclude sampling techniques; however, it could hinder any site assessment and/or removal of wastes.

For the plants which are chosen for investigation, the following are suggested:

(1) An additional historical search be conducted to locate where the company might have disposed of it's wastes. This would involve searching for old plant records that may not have been found during the work for this thesis.

(2) Interview any persons who might be related to old owners or operators of the plant.

(3) If the site is cleared of former plant buildings, check for demolition records to see if any wastes were encountered and/or removed.

Tables 5 and 6 present for each former gas plant site a summary of the historical data and ground water pollution data.

TABLE 5
Historical Investigation Results

<u>Plant</u>	<u>Years Of Operation</u>	<u>Present Day Use Of Site</u>
Cincinnati (Downtown Site)	1843-1909	Partially covered by CG&E Plant. Old buildings and foundations present. Old atlas maps show location of tar wells.
Cincinnati (Eastern Ave. Site)	1882-1909	Partially covered by CG&E buildings. Old foundations present. Old atlas maps show location of tar wells.
Hamilton (City Gas Works)	1890-1910's	Covered by electrical generating station. Old atlas map shows location of plant.
Hamilton (H Gas Light & Coke Co.)	1856-1910's	Vacant lot. Old foundations present. Oily/tarry soils visible on surface. Old atlas map shows location of plant.
Middletown	1873-1905	Partially covered by electrical substation. No old buildings present. Old atlas map shows location of plant.
Hillsboro	1874-1949	Town garage. No old buildings present.
Wilmington	1873-1927	Vacant lot. No old buildings present.
Ripley	1860-1910's	Automobile repair/parts store. No old buildings present. Old atlas map shows location of plant.
Lebanon	1879-1940's	Occupied by small electric station.
Xenia	1860-1910's	Car parts rebuilding company. Two original buildings being used. A lot of oils on the ground from parts stripping. Old atlas map shows location of plant.

TABLE 6
DRASTIC Mapping Results

<u>Plant</u>	<u>Priority of Investigation</u>	<u>Amount of Tars Generated, gallons¹</u>	<u>DRASTIC Index Score²</u>	<u>Distance To Water Supplies</u>
Cincinnati West (Downtown Site)	High	1901. 2.8×10^6	140-160	Adj. to Ohio River. Located over Mill Creek and Ohio River Valley aquifer.
Cincinnati East (Eastern Ave. Site)	High	1901. 2.8×10^6	160	Adj. to Ohio River. Located over Ohio River Valley aquifer. 3 miles downstream from city intake of Ohio Riv. water
Hamilton (City Gas Works)	High	1901. 4.3×10^4	161-181	Adj. to Great Miami River. Located over Great Miami River Valley aquifer.
Hamilton (H. Gas Light & Coke Co.)	High	1901. 3.6×10^4	161-181	Adj. to Great Miami River. Located over Great Miami River Valley aquifer.
Middletown	High	1901. 1.1×10^4	165-181	Adj. to Great Miami River. Located over Great Miami River Valley aquifer. 0.5 miles from city wells.
Hillsboro	Low	3 to 9×10^3	81-95	3 miles from town reservoir. 2 miles from town wells in Clear Creek. No major aquifer system nearby.
Wilmington	Low	1905. 7.3×10^3	68	2.5 miles from town water supplies at Cowlan Creek. No major aquifer system nearby.

1. Estimated value using 730 gallons of tar yielded per 1×10^6 ft³ of gas produced (Eng, 1985).
2. DRASTIC ground water pollution potential values as compared to Chem-Dyne hazardous waste Superfund site (Hamilton, Ohio) value of 161. Scores are for areas immediately surrounding former gas plants.

TABLE 6
DRASTIC Mapping Results, continued . . .

<u>Plant</u>	<u>Priority of Investigation</u>	<u>Amount of Tars Generated, gallons¹</u>	<u>DRASTIC Index Score²</u>	<u>Distance To Water Supplies</u>
Ripley	Moderate	1.4×10^3 /year	131	Downstream from town water supplies. Adj. to Ohio River and over Ohio River Valley aquifer system.
Lebanon	High	1927.3×10^3	130-154	0.5 miles upstream from town wells. Beside Turtle Creek and over major aquifer system.
Xenia	Moderate	7.3×10^3 /year	70-94	3.5 miles from town wells. Beside Shawnee Creek. Near major aquifer system.

1. Estimated value using 730 gallons of tar yielded per 1×10^6 ft³ of gas produced (Eng, 1985).

2. DRASTIC ground water pollution potential values as compared to Chem-Dyne hazardous waste Superfund site (Hamilton, Ohio) value of 161. Scores are for areas immediately surrounding former gas plants.

H.2.a West End Station Plant Site - Downtown Cincinnati

For the following reasons, it is important to investigate whether there are any buried wastes at the former gas plant site in downtown Cincinnati:

(1) The gas plant which operated at this site was one of the first to open in Ohio and the plant operated for most of its history when coal tars were discarded rather than sold.

(2) The amount of wastes created at this plant were quite large due to the volume of coal gas generated. In 1854 the West Station gas plant produced an estimated 17,000 gallons of coal tar. In 1901 the two Cincinnati gas plants together produced an estimated 2.6×10^6 gallons of coal tar.

(3) The former plant site is located in an important downtown area, is located right beside the Ohio River, and finally is directly over the Mill Creek/Ohio River Valley aquifer system.

(4) The former gas plant site is in a moderately high ground water pollution potential area as determined using the DRASTIC model. The downtown area around the former gas plant site received DRASTIC scores of 150-165. The Chem-Dyne hazardous waste area in Hamilton Ohio which has documented ground water pollution received a score of 161.

Today the former plant site is occupied by the former West End Electric Power Plant and a substation operated by the Cincinnati Gas and Electric Company (CG&E). Several buildings are apparently still in use and the foundation of one or more can be seen on the site. Upon visiting the boundary of the plant site, workers were seen using a bulldozer to dig on part of the old plant property. It is hoped that no wastes are discovered accidentally while routine construction occurs.

There are several old atlas maps of the City of Cincinnati which show both the exact location of the old plant and the exact location of the tar wells where coal tars were kept until later disposal. By knowing the exact location of the tar wells in relation to the former buildings, one can accurately determine where best to sample for contaminants.

H.2.b East End Station Plant Site - Eastern Avenue

For the following reasons, it is important to investigate whether there are any buried wastes at the former gas plant site on Eastern Avenue in Cincinnati:

(1) The amount of wastes created at this plant were quite large due to the volume of coal gas generated. In 1901 the two Cincinnati gas plants together produced an estimated 2.6×10^6 gallons of coal tar. The East End Station could have produced over one million gallons of coal tars annually.

(2) The former plant site is located right beside the Ohio River and is located directly over the important Ohio River Valley aquifer system.

(3) The former gas plant site is in a high ground water pollution potential area as determined using the DRASTIC model. The area around the former gas plant site received DRASTIC scores of 160. The Chem-Dyne hazardous waste area in Hamilton Ohio which has documented ground water pollution received a score of 161.

There are several old atlas maps of the city of Cincinnati which show both the exact location of the old plant and the exact location of the tar wells where coal tars were kept until later disposal.

H.2.c Hamilton Sites

H.2.c.1 Public Plant Site (Hamilton City Gas Works)

For the following reasons, it is important to investigate whether there are any buried wastes at the former Hamilton City Gas Works plant site in downtown Hamilton:

(1) The gas plant operated for most of its history when coal tars were discarded rather than sold.

(2) The amount of wastes created at this plant were quite large due to the volume of coal gas generated. In 1900, the plant produced an estimated 44,000 gallons of coal tars.

(3) The former plant site is located in an important downtown area right beside the Great Miami River

(4) The plant is located directly over the very important Great Miami Valley aquifer system.

(5) The former gas plant site is in a high ground water pollution potential area as determined using the DRASTIC model. The area around the former gas plant site (which includes the Chem-Dyne hazardous waste site) received a DRASTIC score of 161. The Chem-Dyne hazardous waste area located adjacent to the former plant site has documented ground water pollution.

H.2.c.2 Private Plant Site (The Hamilton Gas Light and Coke Company)

For the following reasons, it is important to investigate whether there are any buried wastes at the former Hamilton Gas Light and Coke Company plant site in downtown Hamilton:

(1) The gas plant operated for most of its history when coal tars were discarded rather than sold.

(2) The amount of wastes created at this plant were quite large due to the volume of coal gas generated. In 1901 The Hamilton Gas Light and Coke Company produced an estimated 36,500 gallons of coal tars.

(3) The former plant site is located in an important downtown area and less than 0.5 miles from the Great Miami River.

(4) The plant is located directly over the very important Great Miami Valley aquifer system.

(5) The former gas plant site is now a vacant lot which appears to have been leveled, perhaps in preparation of future building or construction.

(6) The former gas plant site is in a high ground water pollution potential area as determined using the DRASTIC model. The area around the former gas plant site (which includes the Chem-Dyne hazardous waste site) received a DRASTIC score of 161. The Chem-Dyne hazardous waste area (which is approximately 1 mile north of the former gas plant site on High Street) has documented ground water pollution.

Today the plant site is a cleared lot on High Street and former building foundations can be seen. If testing of the soils were to be conducted, there are oily/tarry soils which are on the edge of the property which appear to have been scraped off to the side. This site in particular has no buildings on it and there would be easy access to test for buried wastes.

H.2.d Middletown Plant Site

For the following reasons, it is important to investigate whether there are any buried wastes at the former gas plant site in downtown Middletown:

(1) The gas plant operated for most of it's history when coal tars were discarded rather than sold.

(2) The amount of wastes created at this plant were moderate. The gas plant in Middletown produced an estimated 7,000 gallons of coal tars annually.

(3) The former plant site is located in an important downtown area and less than 0.5 miles from the Great Miami River.

(4) The plant is located directly over the very important Great Miami Valley aquifer system.

(5) The former gas plant site is in a high ground water pollution potential area as determined using the DRASTIC model. The area around the former gas plant site received a DRASTIC score of 171, which is higher than the DRASTIC score of 161 for the Chem-Dyne hazardous waste area which has documented ground water pollution.

H.2.e Hillsboro Plant Site

Due to the following factors, it is felt that any potential wastes buried at the former gas plant site in Hillsboro pose only minimal risk:

(1) The amount of wastes created at this plant were moderate. The gas plant in Hillsboro produced an estimated 7,500 gallons of coal tars per year.

(2) The former plant site is located in an area where there is little ground water and no major aquifer system.

(3) The former gas plant site is several miles from Hillsboro's source of drinking water.

(4) The former gas plant site is in a relatively low ground water pollution potential area as determined using the DRASTIC model. The area around the former gas plant site received a DRASTIC score of 93. The DRASTIC score for the Chem-Dyne hazardous waste area in Hamilton which has documented ground water pollution was 161.

However, the playground located across the street and 20 feet lower in elevation from the former plant site should be periodically investigated for any evidence of the migration of plant wastes.

H.2.f Wilmington Plant Site

Due to the following factors, it is felt that any potential wastes buried at the former gas plant site in Wilmington pose only minimal risk:

- (1) The amount of wastes created at this plant were moderate. In 1905 the gas plant in Wilmington produced an estimated 7,000 gallons coal tars.
- (2) The former plant site is located in an area where there is little ground water and no major aquifer system.
- (3) The former gas plant site is several miles from Wilmington's source of drinking water.
- (4) The former gas plant site is in a low ground water pollution potential area as determined using the DRASTIC model. The area around the former gas plant site received a DRASTIC score of 68. The DRASTIC score for the Chem-Dyne hazardous waste area in Hamilton which has documented ground water pollution was 161.

H.2.g Ripley Plant Site

For the following reasons, it is important to investigate whether there are any buried wastes at the former plant site in Ripley:

- (1) The gas plant operated for most of it's history when coal tars were discarded rather than sold.
- (2) The former plant site is located beside the Ohio River.
- (3) The plant is located directly over the very important Ohio River Valley aquifer system.
- (4) The former gas plant site is in a moderately high ground water pollution potential area as determined using the DRASTIC model. The area around the former gas plant site received a DRASTIC score of 130. The DRASTIC score for the Chem-Dyne hazardous waste area in Hamilton which has documented ground water pollution was 161.

H.2.h Lebanon Plant Site

For the following reasons, it is important to investigate whether there are any buried wastes at the former gas plant site in downtown Lebanon:

(1) The gas plant operated for a portion of it's history when coal tars were discarded rather than sold.

(2) The amount of wastes created at this plant were moderate. The gas plant in Lebanon produced oil gas until the 1940's at around $4 \times 10^6 \text{ ft}^3$ per year. Using the conversion factor of 730 gallons of tars produced per $1 \times 10^6 \text{ ft}^3$ of gas, the plant produced an estimated 3,000 gallons of tar.

(3) The former plant site is located in an important downtown area and on a small tributary of Turtle Creek .

(4) The plant is located directly over the important Turtle Creek aquifer system which supplies ground water for the city of Lebanon.

(5) The plant is only approximately 0.5 miles upstream from the town's wells.

(6) The former gas plant site is in a high ground water pollution potential area as determined using the DRASTIC model. The area around the former gas plant site received DRASTIC scores between 150-156. The DRASTIC score for the Chem-Dyne hazardous waste area in Hamilton which has documented ground water pollution was 161.

H.2.i Xenia Plant Site

For the following reasons, it is important to investigate the fate of the plant wastes at the former gas plant site in downtown Xenia:

(1) The gas plant in Xenia produced an estimated 7,000 gallons of coal tars per year.

(2) The former plant site is located near the Little Miami River where there are extensive buried valley deposits containing large deposits of ground water.

(3) The former gas plant site is located in an important downtown area beside the Shawnee Creek which feeds into the Little Miami River.

(4) The former gas plant site is in a low ground water pollution potential area as determined using the DRASTIC model. The area around the former gas plant

site received DRASTIC scores of 74-84; however, it is adjacent to the buried valley deposits near the Little Miami River which have DRASTIC scores of 108-113. The DRASTIC score for the Chem-Dyne hazardous waste area in Hamilton which has documented ground water pollution was 161.

H.3 Methods to Verify Contamination

The greatest concern with the plant sites in southwestern Ohio is the prevention of the release of underground pools of wastes by future excavation or construction. If any investigative and/or remedial work is performed at these sites adequate safety precautions for the workers is needed to prevent human exposures.

To thoroughly document whether there is contamination at a former gas plant site, the following strategy is proposed:

- (1) Take quantitative measurements of the soils, ground water, surface water, and the air from each site, and on any wastes present.
- (2) Use non-invasive techniques such as ground penetrating radar or other geophysical methods to help locate any buried wastes or structures.

Samples from a site can be analyzed for ignitability, corrosivity, reactivity, and extract toxicity under RCRA procedures to determine if the samples meet federal definitions for being hazardous wastes (EEI, 1984). Samples may also be analyzed for PAH, phenolics, ammonia, sulfides, and cyanide. Other qualitative measurements would be analysis for TOC and extractable hydrocarbons (EEI, 1984).

If former plant wastes are found at a site, pumping tests should be conducted to define the aquifer properties at the site.

H.4 Industrial Hygiene and Worker Safety

During investigative or construction work at former gas plant sites, the following hygiene practices are needed:

(1) Personal Protective Equipment (PPE) is needed where any possible personal contact is suspected. PPE includes:

- (a) Respirators: Organic vapor cartridge respirators to prevent inhalation of tar volatiles (e.g. benzene)
- (b) Dermal Protection: Impervious gloves, coveralls (Tyvek for possible liquid exposures, cotton for soil or dust exposures), rubber boots, and safety glasses with shields.

(2) Use of hygiene and decontamination areas where contaminated materials can be discarded (as work clothes) or cleaned (as equipment) before leaving the site.

(3) Additional Safe Work Practices include:

- (a) Diking liquid and solid wastes
- (b) Restriction of site access
- (c) Soil and dust control
- (d) Proper testing and labeling of wastes
- (e) Proper worker training covering working with possible hazardous wastes
- (f) Proper medical monitoring of workers
- (g) Worker breathing zone and perimeter air monitoring

To date the health and safety risks to workers at these sites have not been adequately characterized; therefore, when investigative and remedial work is performed at these sites adequate precautions are needed to ensure that the health and safety of personnel is being protected.

H.5 Federal Legislation Pertinent to Former Gas Plant Sites

Due to the toxicity of the wastes potentially present at all former gas plant sites, the plants should all be treated as potential hazardous waste sites. Preparation and careful planning are needed when investigative or construction work is to be performed at these sites to prevent both personal and environmental contamination.

The legal issues concerning former gas plant sites are covered under several federal laws, but are governed primarily under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA or Superfund), and the Superfund Amendments and Reauthorization Act (SARA) of 1986, and the Resource Conservation and Recovery Act (RCRA) of 1976 (RCRA) (EEI, 1984).

CERCLA imposes strict liability for inactive waste sites (the category under which nearly all former gas plant sites are covered) on the current site owners, past owners, and waste generators. RCRA regulations would not pertain to gas plant sites unless under Superfund a remedial action was required which involved the movement of wastes from the former plant sites to an off-site location. Then the RCRA regulations for transportation, storage, and disposal of hazardous wastes would be implemented. It is assumed that the wastes at former gas plant sites would be labeled as "hazardous wastes" under the RCRA guidelines.

Health and safety regulations at hazardous waste sites are under the jurisdiction of the Occupational Safety and Health Administration (OSHA). Both the EPA and OSHA require airborne monitoring of worker exposure both initially before work is performed at a hazardous waste site and then for each new procedure or area encountered. The OSHA standard CFR 1910 would require hazard communication training and medical monitoring of hazardous waste site workers.

I. REFERENCES

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DRASTIC LEGEND

<u>Color Code</u>	<u>DRASTIC Range</u>	<u>Degree of Ground Water Pollution Potential</u>
Red	200+	Highest
Orange	180-199	
Yellow	160-179	
Light Green	140-159	
Dark Green	120-139	
Light Blue	100-119	
Purple	80-99	
Violet	0-79	Lowest

Symbols:

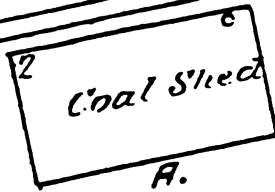
7D	Defines Hydrogeologic Setting (see DRASTIC manual)
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101	DRASTIC Index Score

w: Refers to bodies of water

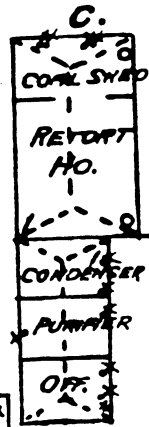
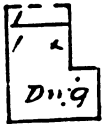
Note: Each DRASTIC map has been photographically superimposed on a United States Geological Service (USGS) topographic map.

N O E X P O S U R E

C. W. & B. R. R.



HILLSBORO OHIO
1887 MAP

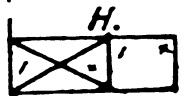
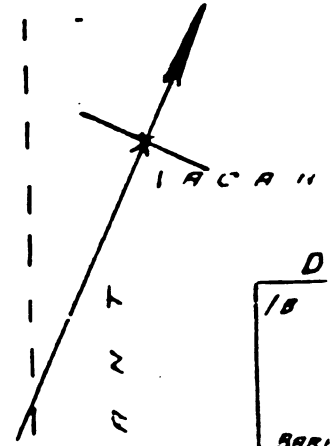


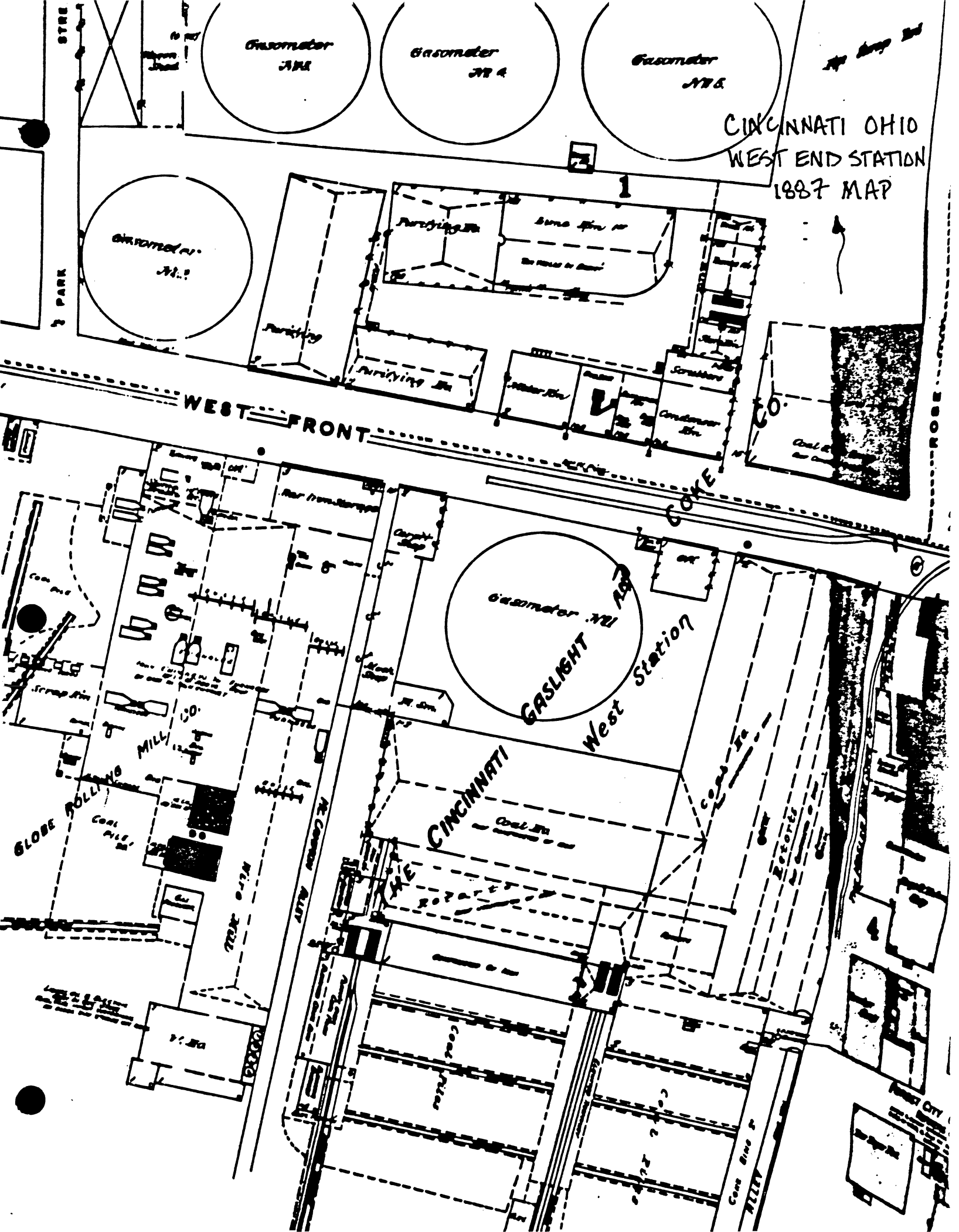
W. NORTH ST.

ALLEY

60'

30'





CINCINNATI OHIO
WEST END STATION
1887 MAP

Gasometer
No. 1

Gasometer
No. 2

Gasometer
No. 3

Gasometer
No. 4

WEST FRONT

Gasometer
No. 5
GASLIGHT
West Station

CINCINNATI

GLOBE ROLLING

MILL

COAL

WIRE MILL

RECOVERED ALLEY

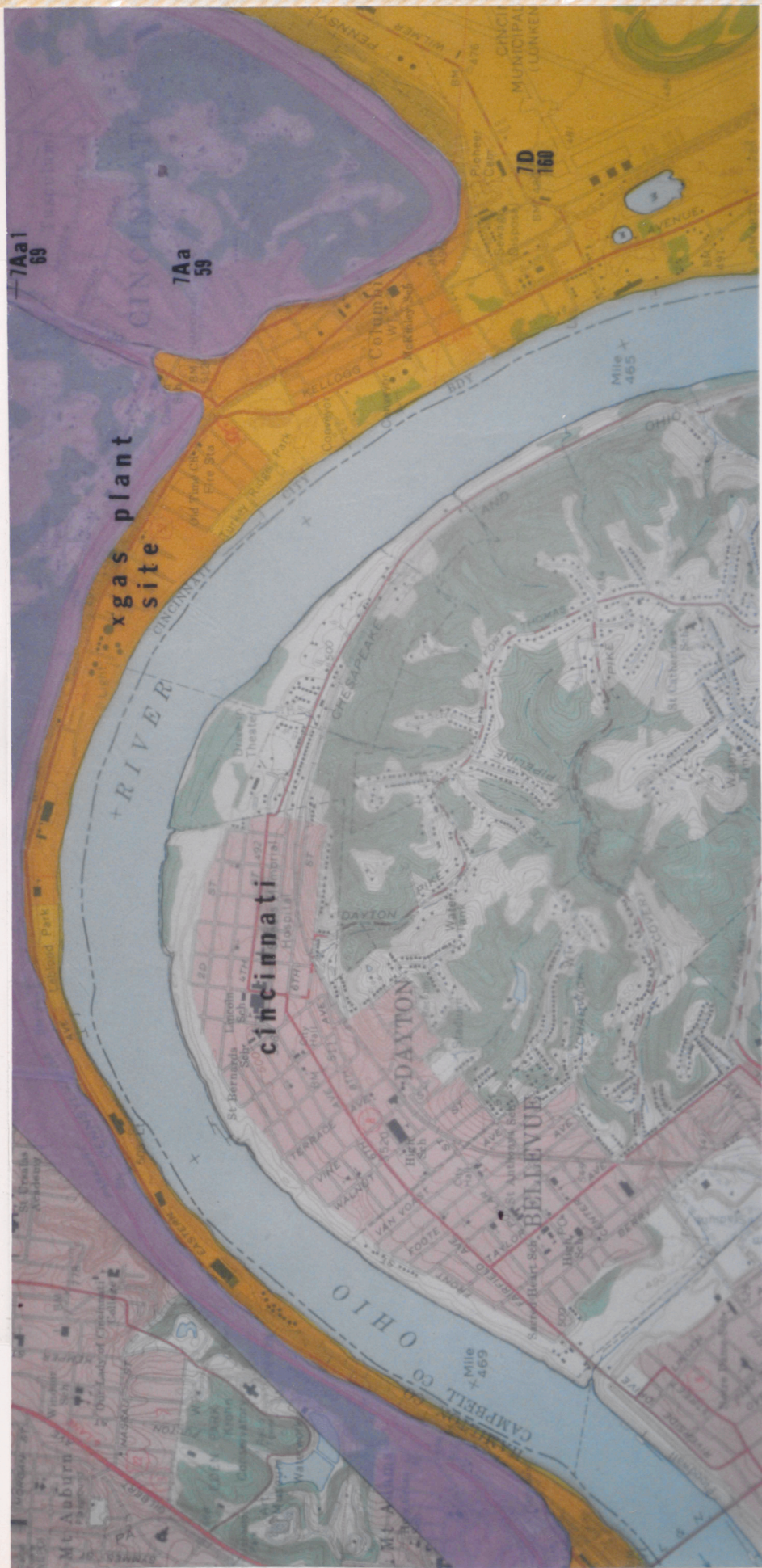
COAL

COAL

COAL

FIGURE 1

DRASTIC MAP OF CINCINNATI (EAST) OHIO



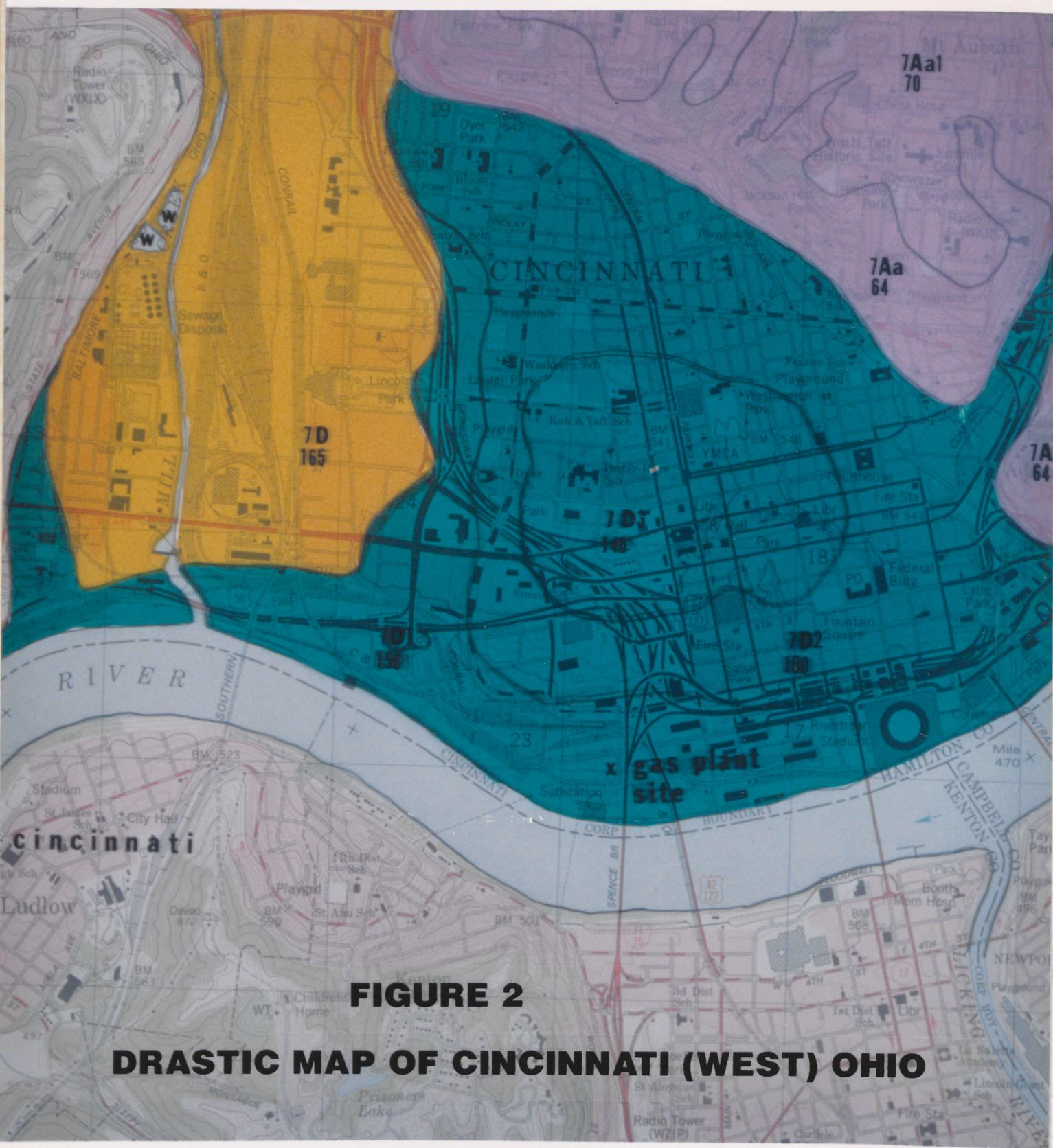
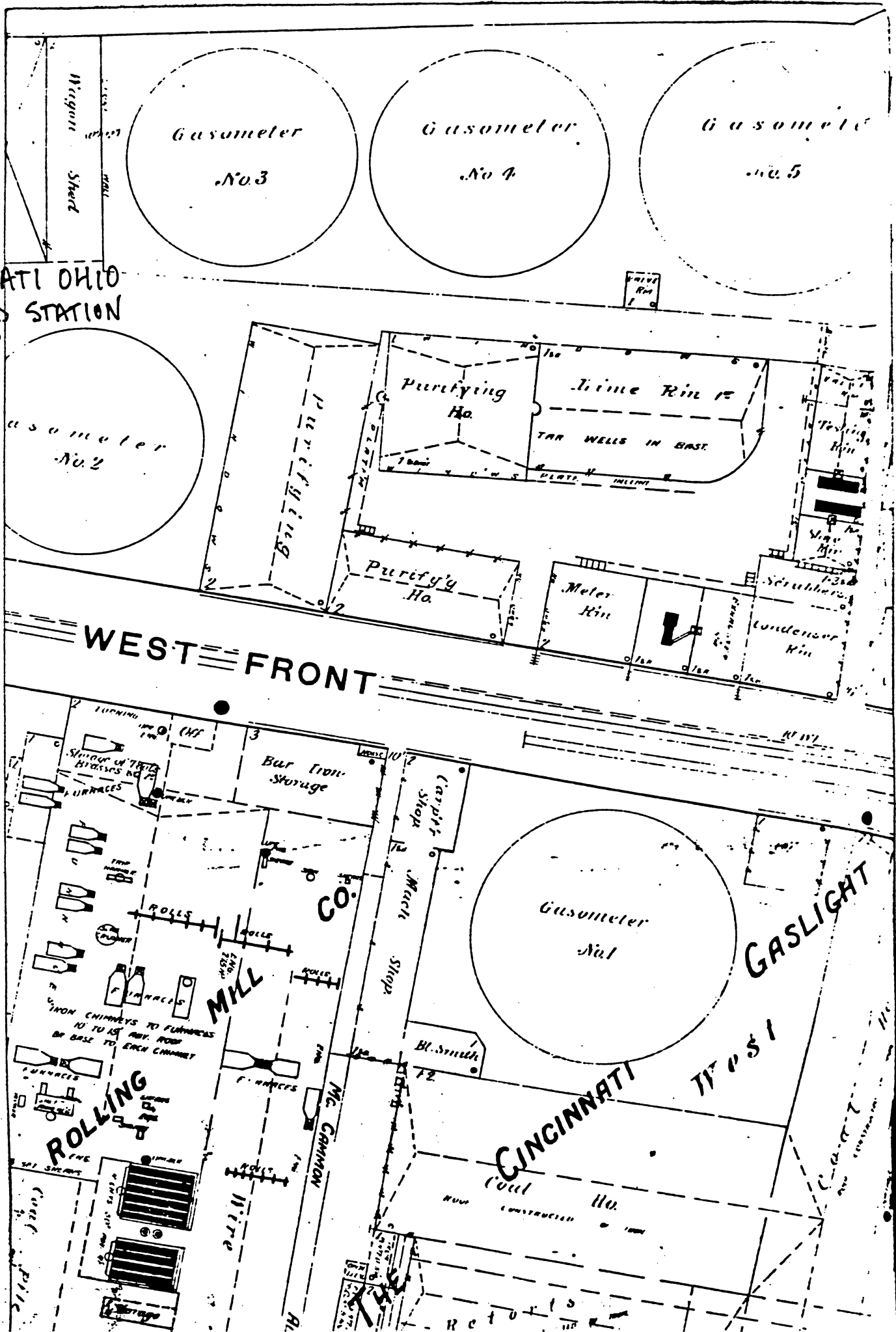
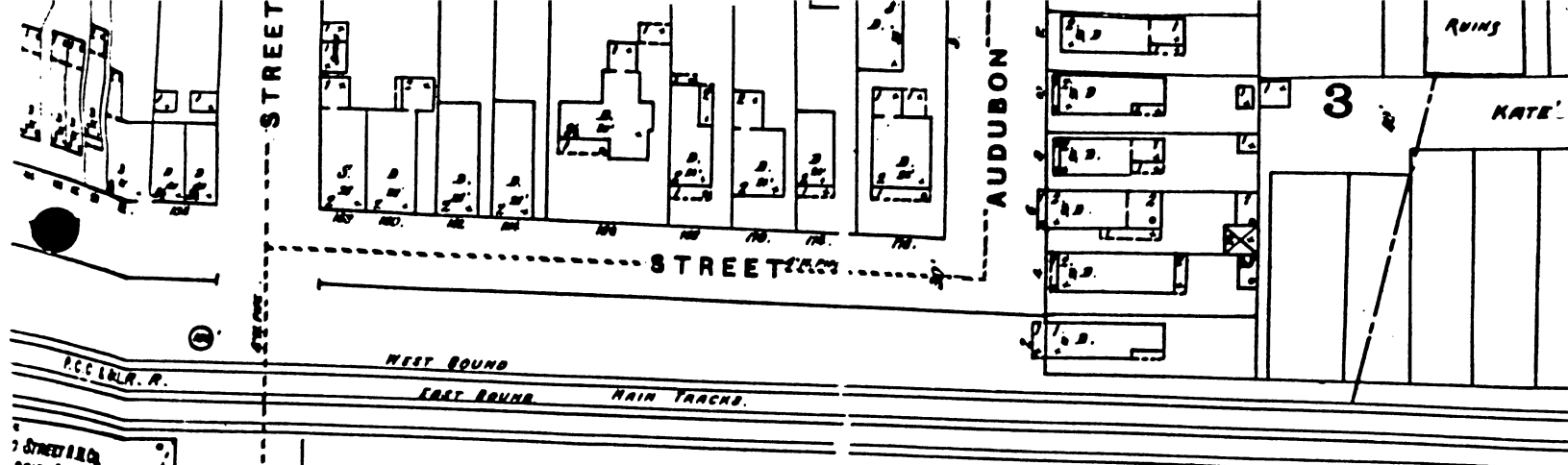


FIGURE 2

DRASTIC MAP OF CINCINNATI (WEST) OHIO

CINCINNATI OHIO
WEST END STATION
1887 MAP



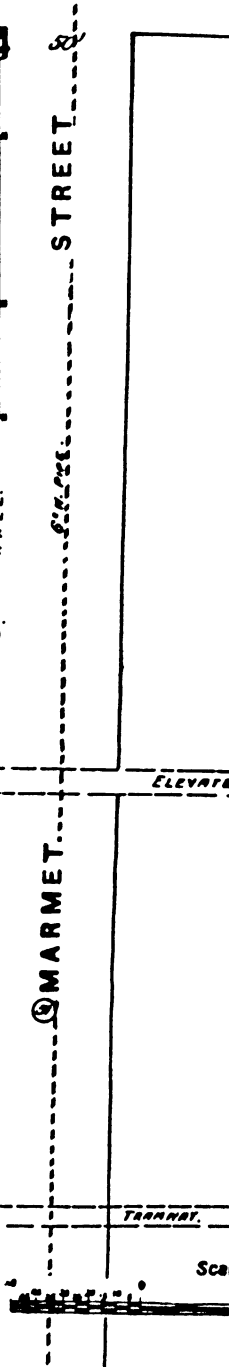
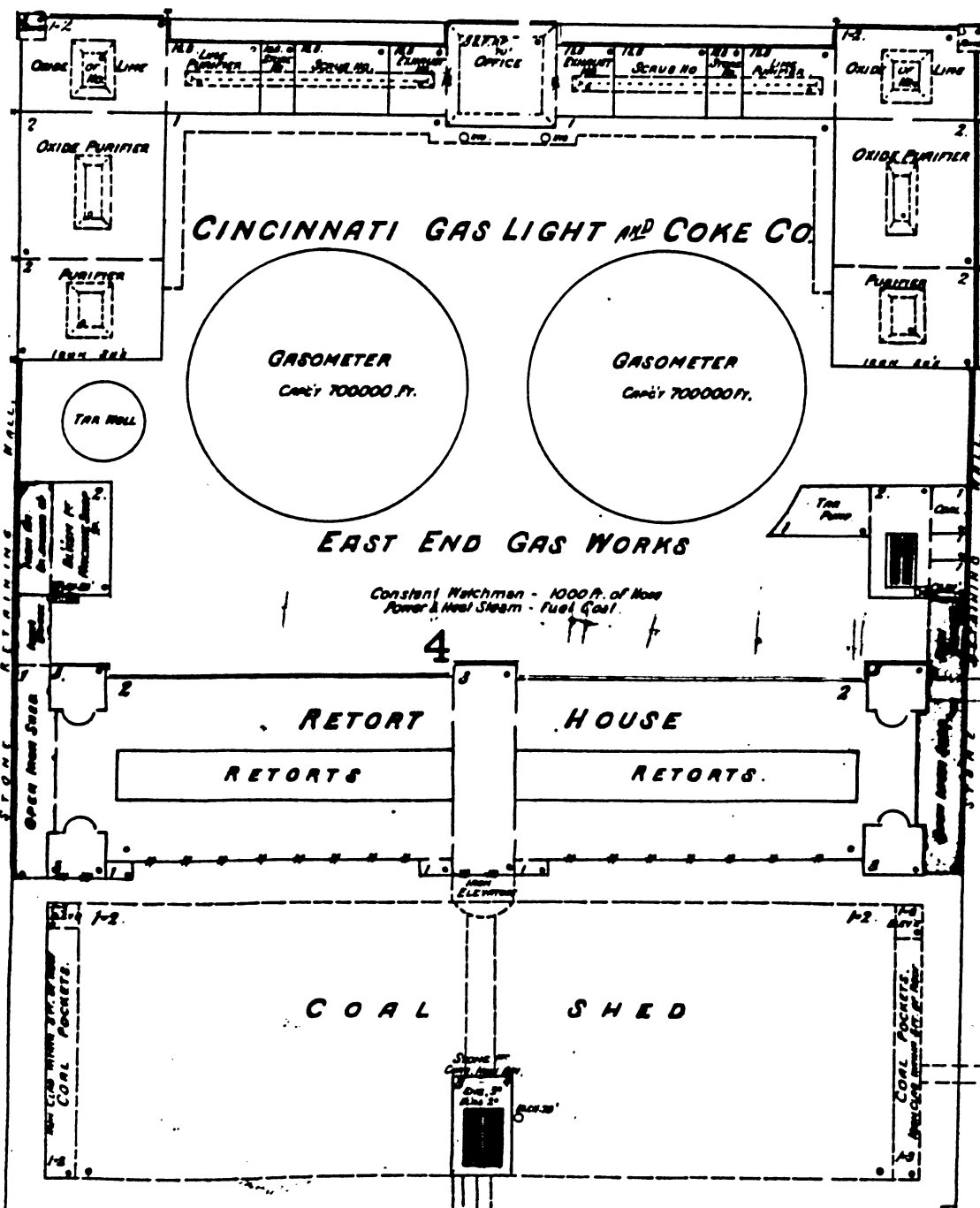


CINCINNATI COMMON'S ST. R. & C. CO
The Old BUNNY SHED

10 CINCINNATI OHIO

EAST END STATION 1887 MAP

AVENUE



CINCINNATI OHIO

EAST END STATION
1887 MAP

0

36

51

MARMET

6' N. P.C.

UPPER BLK
UPPER BLK
UPPER BLK

10' N. P.C.
ONE 25' N. P.C.

THE MARMET COAL CO.

EAST END GAS WORKS

COAL YARD

TRAVELLING TRAMWAY

TRAVELLING TRAMWAY

COAL YARD

COAL
SHED

1

2

CORBIN

60'

ST.

15'

12' 11' 9"
D.

2

2

2

12' 11' 9"
D.

2

STREET

STREET

FIGURE 3
DRASTIC MAP OF HAMILTON OHIO

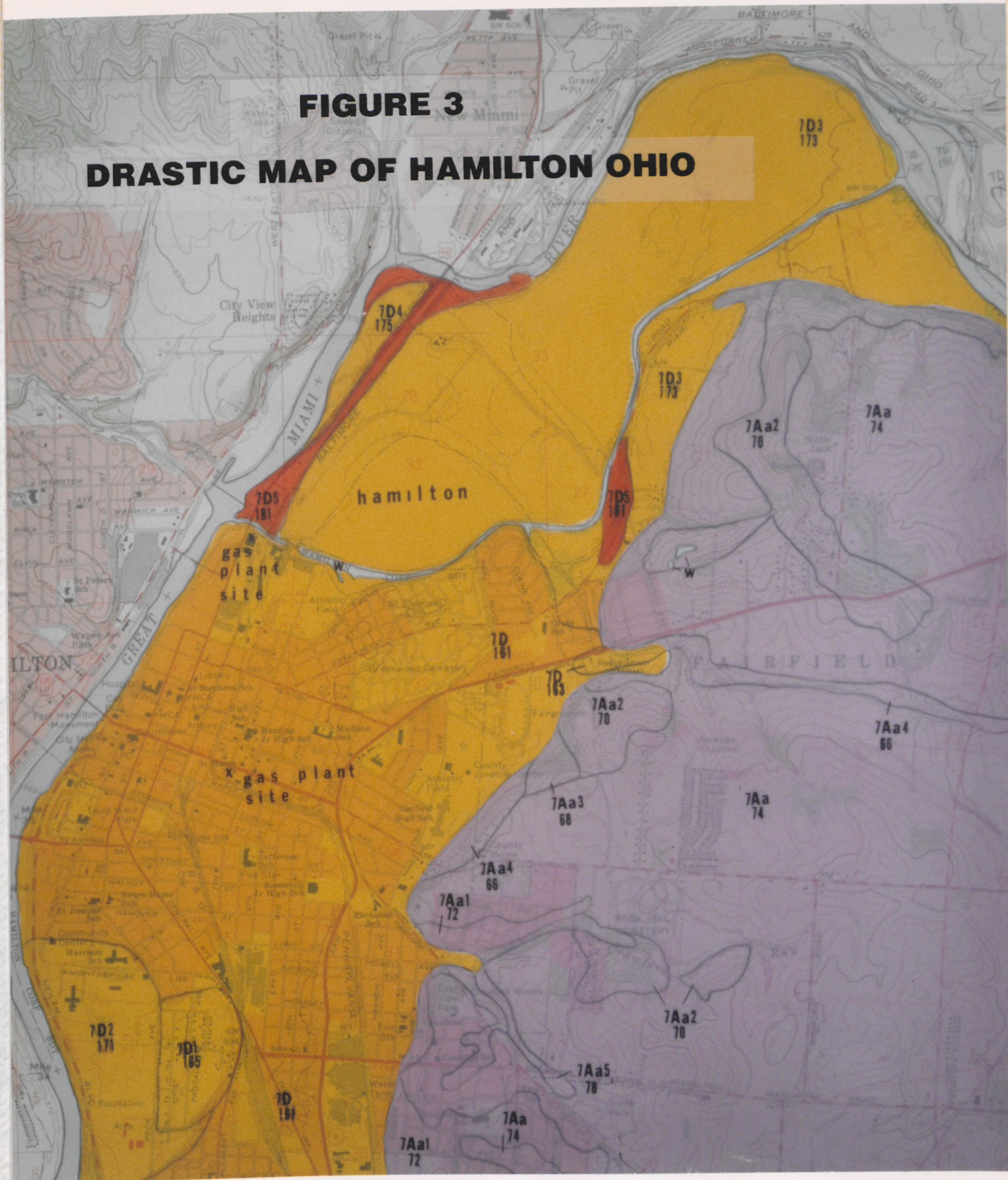
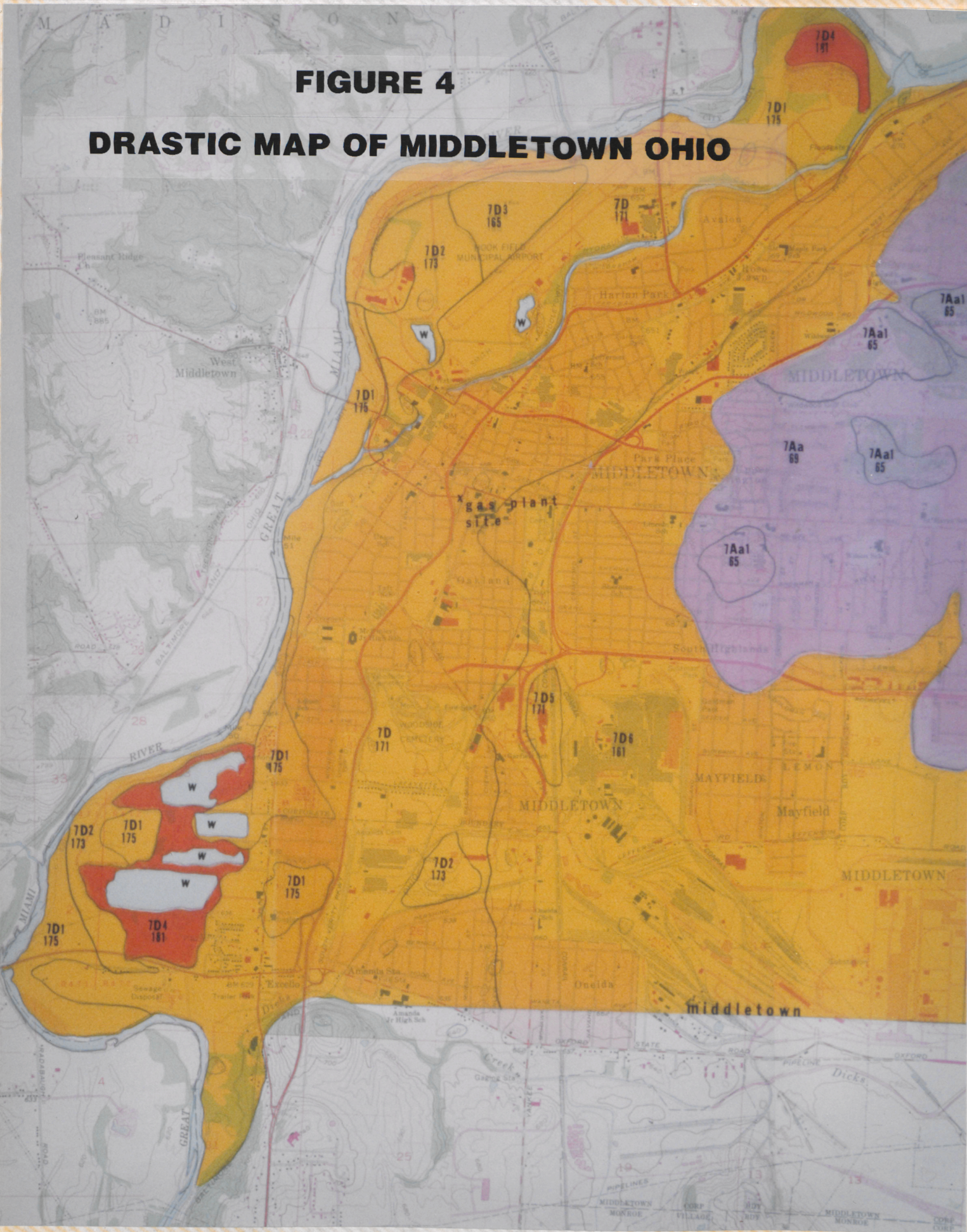


FIGURE 4

DRASTIC MAP OF MIDDLETOWN OHIO

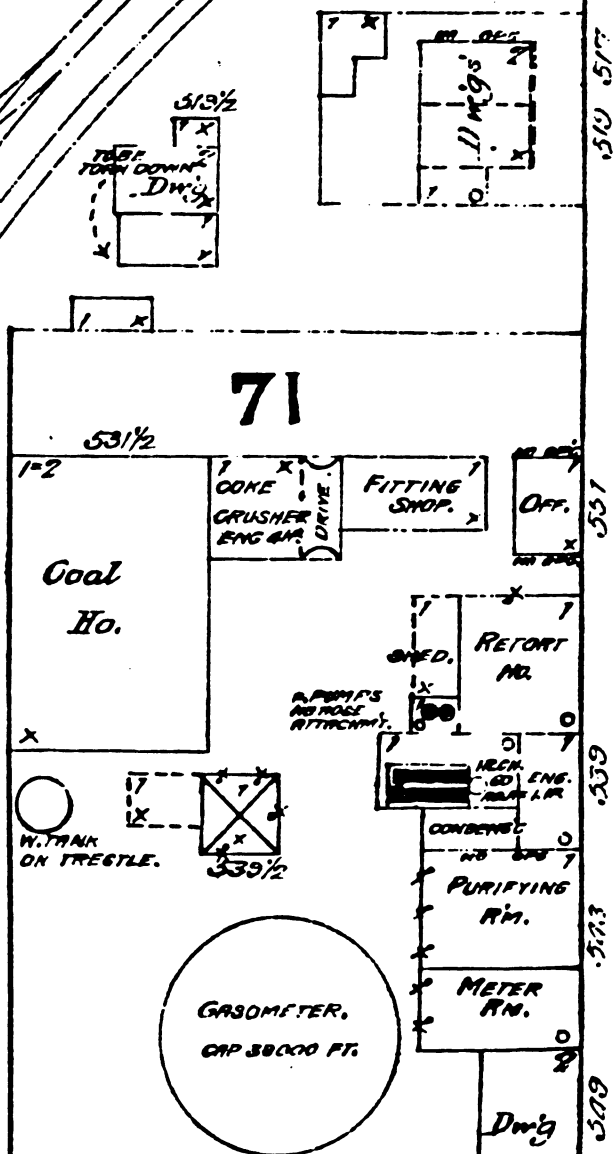


BASIN

HAMILTON OHIO
PRIVATE PLANT SITE
1887 MAP

HIGH

SEE



HAMILTON GAS LIGHT & COKE CO.
CONSTANT WATCHMAN,
100' HOSE LIGHTS: GAS.
FUEL COAL.
OXIDE OF IRON PROCESS.

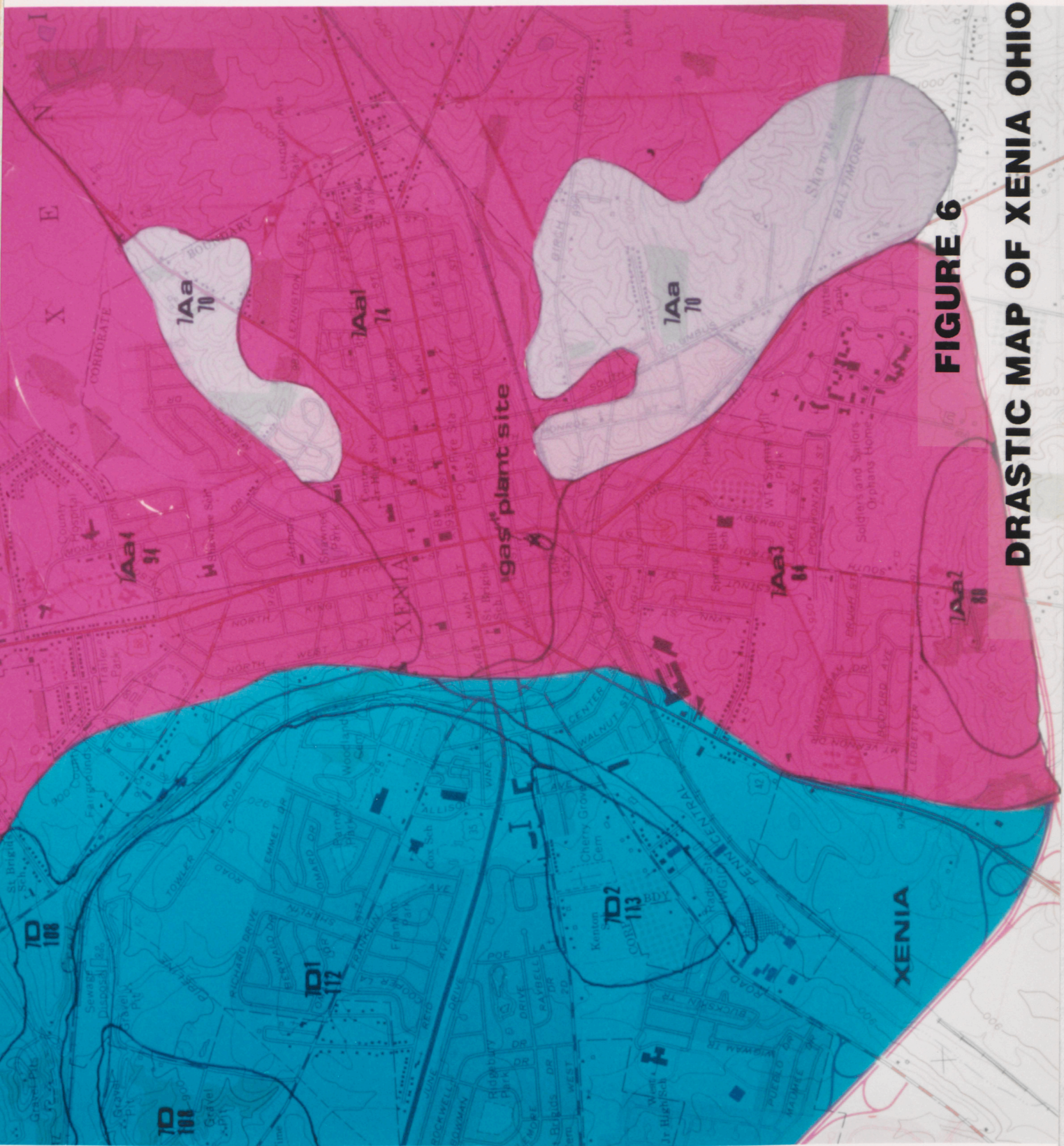
1895 Atlas of Warren County

MIDDLETOWN OHIO
1895 MAP

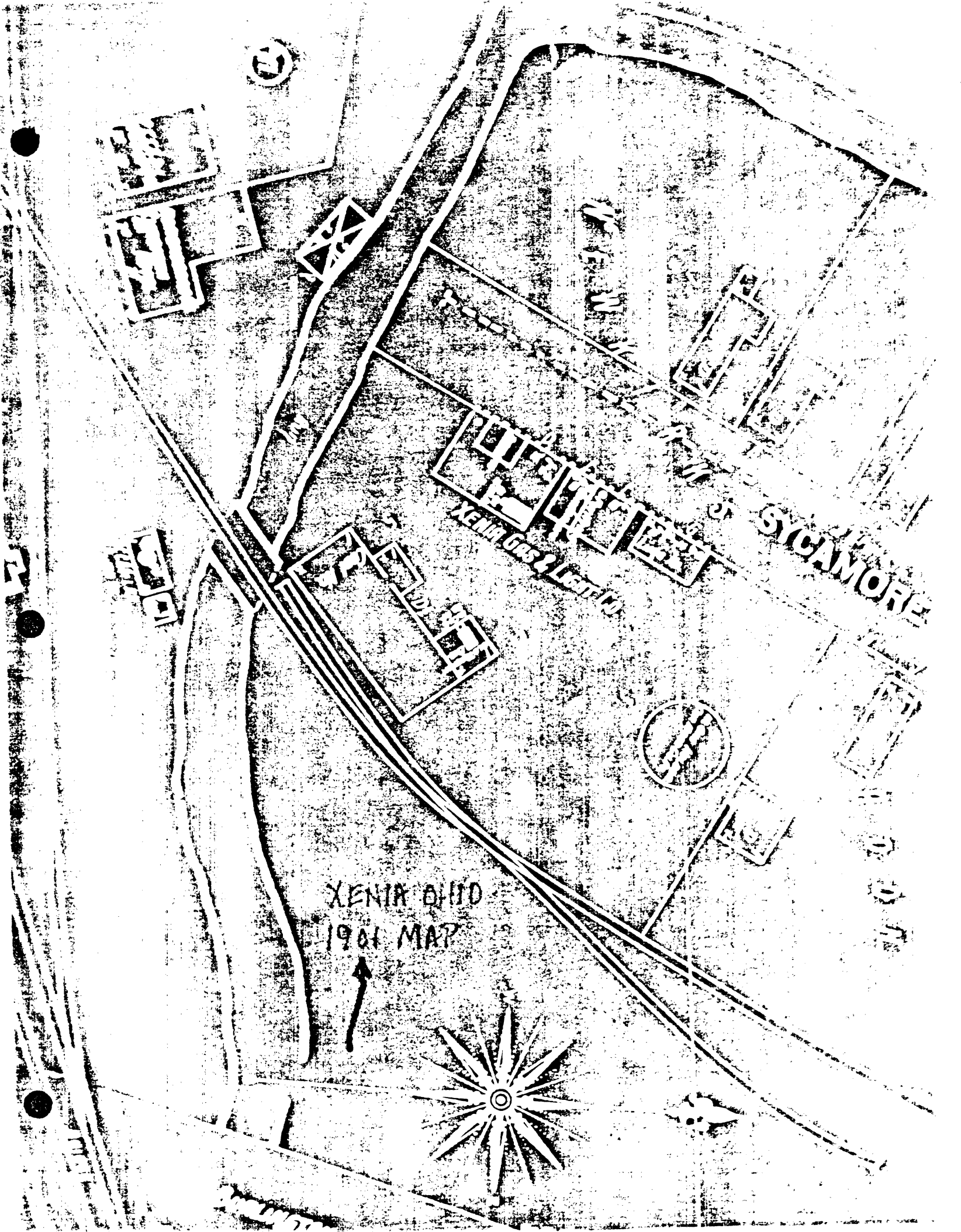
CITY OF MIDDLETOWN

SECTIONS 34, 28 & 22





ALTER COMPOSITE BRONZE SOLID



XENIA OHIO
1901 MAP

SYCAMORE

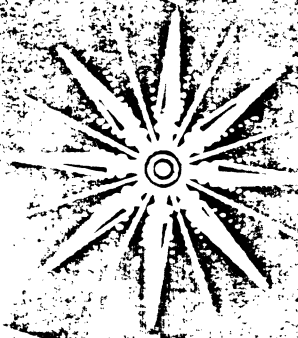


FIGURE 7

DRASTIC MAP OF RIPLEY OHIO

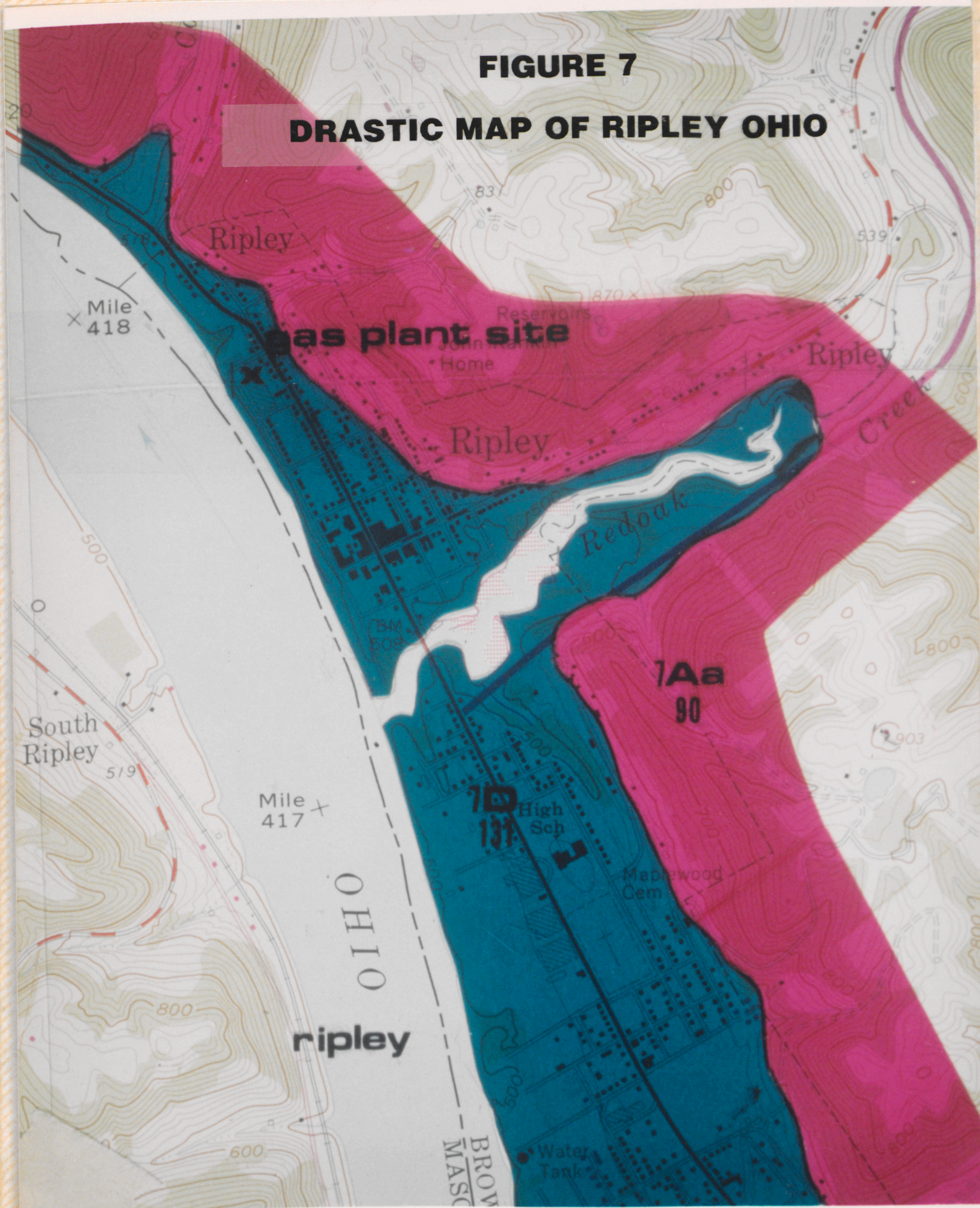
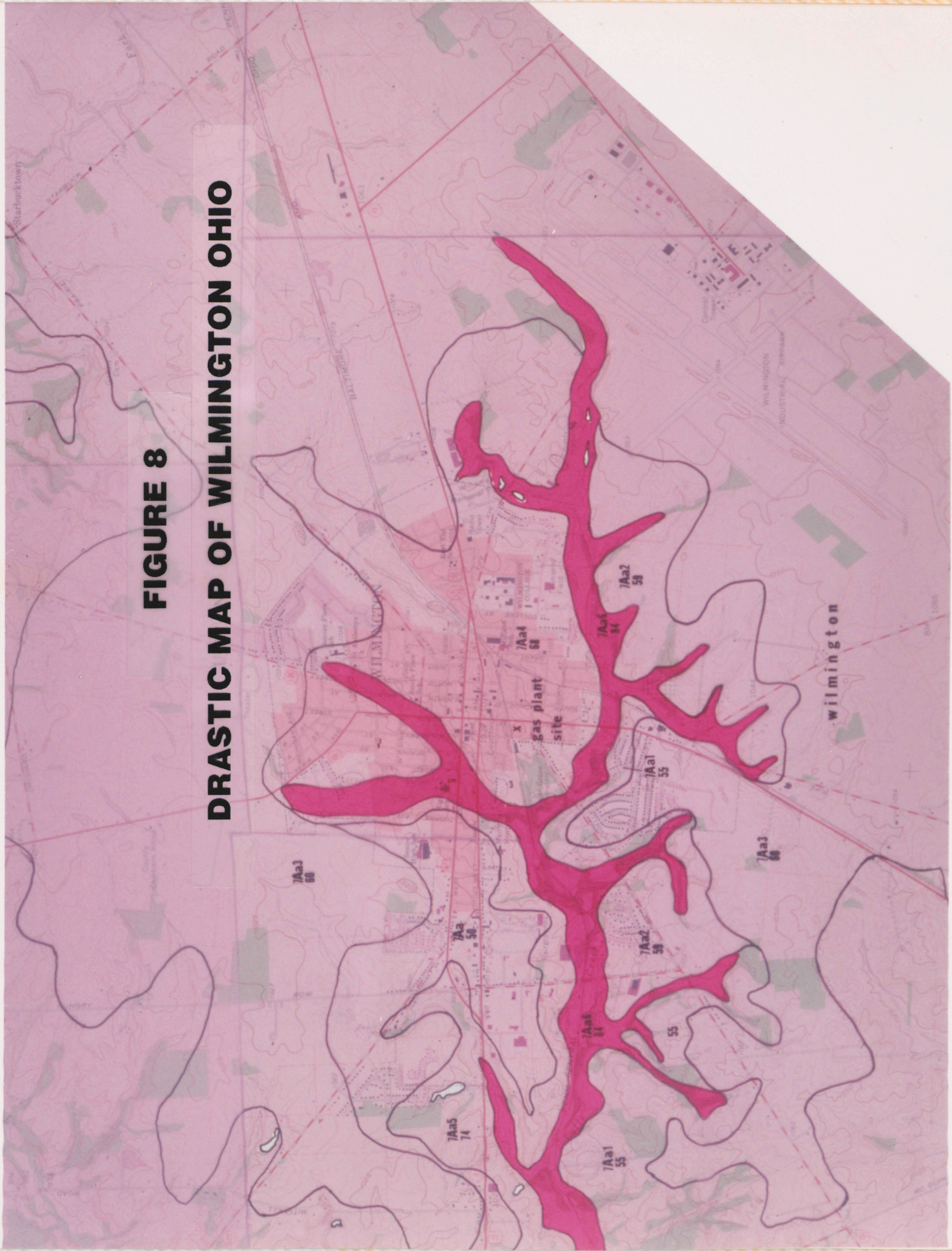


FIGURE 8

DRASTIC MAP OF WILMINGTON OHIO



SYCAMORE

CITY GAS WORKS

RIPLEY OHIO
1884 MAP

J.P. PARKER FOUNDRY.

FUEL-COAL. NO WATCHMAN. NO HOSE
NO LIGHTS.

GREEN LUMBER

THE BOYD M'FG CO.

SAW & PLANING MILL. 412½

SAY MILL.

ENG. CIS. E ENG.
BO N.P. F. P. P.

ON 35' AIR RT.

FUMP 300' 1/2" RUBBER HOSE.

NE V. PINE TO TOP OF J:
WATER BBL & BUCKETS FLOW

HEAT-STEAM. FUEL-SHAKES & CO
LIGHT-OIL IN STATIONARY TIN LARD
NIGHT & DAY WATCHMAN.

7	*				
---	---	--	--	--	--

1

STORAGE. SHINGLE
SHED

1

7 21

410i 410j

OHIO PIANO!

Shed.

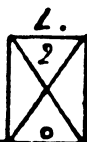
729

66'

12

SPRING ST.

WILMINGTON OHIO
1895 MAP



33'

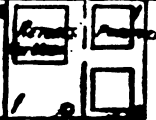
20'

17

N. 14.50.

0

Shed.

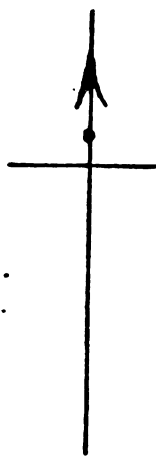


M.



Shed.

WILMINGTON GAS WKS.



50'

