DAMES AND MOORE

FINAL REPORT

ASHLAND LAKE FRONT/NORTHERN STATES POWER PROJECT

ASHLAND, WISCONSIN

MARCH 17, 1995

DAMES & MOORE

Dames & Moore Job #05644-065

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March 17, 1995

Mr. James Musso
Northern States Power Company
100 N. Barstow St.
P.O. Box 8
Eau Claire, WI 54702

Dear Mr. Musso:

Attached is our final report of the Ashland Lake Front site. This report has been prepared in accordance with the scope of work described in our proposal of January 17, 1995.

Copies have been forwarded to the individuals listed below.

If you need additional copies, please call.

Very truly yours,

DAMES & MOORE

David P. Trainor
Managing Principal

cc: John Wilson, NSP
Tony Murphy, City of Ashland
Jamie Dunn, WDNR - Northwest District
Cy Ingraham, SEH
Charles Sweeney, Michael Best & Friedrich

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1.0 INTRODUCTION

This report has been prepared in response to a number of issues dealing with potential coal tar and creosote contamination measured at the Ashland, Wisconsin Lake Front area. The specific subject area occupies approximately 10 acres at the site of the existing Ashland waste water treatment plant (WWTP), constructed on fill as part of the reclaimed shoreline of Lake Superior. This WWTP site is adjacent to property directly south which is currently owned by Northern States Power Company (NSP) (see Figure 1). The NSP site is the former site of a manufactured gas plant (MGP) facility, which operated from the late 1800's until 1947, under a variety of ownerships.

This report was authorized by NSP to evaluate the potential for coal tar residue produced from the MGP operations causing contamination at the WWTP site. The scope of this report included the following:

- Summarize information on the uses of coal tar for wood preservation (coal tar creosote), as well as other uses of coal tar as a product;

- Review existing information provided by NSP to calculate approximate quantities of coal tar produced during historic operations at the MGP;

- Evaluate the possibility of other potential contaminant sources at the WWTP site; and

- Review, compare and comment on environmental reports prepared by Northern Environmental Technologies, Inc. (NET) prepared in 1989 on the WWTP site, and subsequent reports prepared in 1994 and 1995 by Short Elliott and Hendrickson (SEH) on the same property. The Northern report was authorized by the City of Ashland to evaluate conditions on the property in preparation for expansion of the WWTP. (Because of the contamination encountered by

Northern, the expansion project was halted.) The SEH reports were authorized by the WDNR to further evaluate potential contaminant sources at the property.

This information is the subject of this report.

2.0 HISTORICAL BACKGROUND

The MGP began operations at the current NSP site in about 1885. It was first owned by the Ashland Light Power and Street Railway Company, and operated under that name until 1922, when it was acquired by a new utility called Lake Superior District Power (LSDP). During its period of operation, the facility produced manufactured gas through both carbonization and, beginning in 1920, gasification. Carbonization consisted of a heat treatment process on coal that produced a methane/hydrogen gas called coal gas. Gasification involved passing steam through hot coal or coke which produced a hydrogen and carbon monoxide mixture called water gas. Both products were commercially sold for fuel. By-products of each process included tar, coke and ammonia, although in lesser amounts during gasification. The tar by-product itself was often sold as a fuel source.

During the time of the MGP operations, the WWTP property was the site of a large lumber operation. This particular lumber operation was one of many along that portion of the Chequamegon Bay shoreline. Until 1901, the facility operated under the name of R.C. Pope & Company. At that time, it was acquired by the John Schroeder Lumber Company, and operated until 1936. Wood preservation through treatment of wood products with compounds such as creosote was a large part of the Schroeder Company's business.

3.0 COAL TAR AND COAL TAR CREOSOTE

Records provided by NSP indicate that for some years the majority of the coal tar generated by the MGP was sold (see Section 4.0). It was likely this material was sold to the local lumber operations, which used the material in wood preservation. (Coal tar belongs to a major class of wood preservative called preservative oil.) The mills used the coal tar to create coal tar creosote, the coal tar by-product used in wood preservation. The coal tar creosote was used particularly for the preservation of railroad ties, which were produced in large quantities by Schroeder. Eye witness accounts as well as other information developed as part of this report indicate an open coal tar creosote pit located south of the present WWTP was used to treat lumber on the property.

Mr. Lee Gjovick, formerly with the U.S. Forest Products Laboratory and a recognized expert in the field of coal tar and coal tar creosote was interviewed by Dames & Moore. He confirmed the coal tar generated from the MGP was likely used by local lumber companies in the wood preservation process. Although the MGP records are incomplete, data indicates that for similar MGP sites, the majority of the coal tar generated during the life of the MGP was sold. Because of the readily available market, the purchasers were likely the nearby lumber companies.

Standards for creosote solutions set forth by The American Wood Preservers' Association include the following:

> **"The material shall be a pure coal tar product derived from tar produced by the carbonization of bituminous coal. It may either be a coal tar distillate or a solution of coal tar in coal tar distillate."**

Furthermore, the United States Department of Agriculture indicates,

> **"Coal tar is extensively employed in solution with coal tar creosote for the treatment of ties and to some extent other classes of timber. Mixtures of coal tar and creosote commonly contain about 20 to 50 percent of tar by volume."**

Mr. Gjovick wrote a paper on the chemical composition of raw creosote, and how it compares to the creosote composition found in treated wood. There are more than 200 compounds in creosote. These compounds are primarily polycyclic aromatic hydrocarbons. Table 1, which is taken directly from Mr. Gjovick's paper, lists the major components in creosote while Table 2 summarizes the analysis of treated wood and creosote. The creosote composition found in the treated wood is almost identical to the raw creosote composition. Additionally, Mr. Gjovick stated that creosote will not readily leach from the wood. In most cases, it must intentionally be removed from the wood by a physical process. Therefore contamination most likely occurs during the wood treating process from indiscrete creosote handling and operational procedures.

Additional uses of coal tar include tank and pipeline coatings. Coal tar is one of the oldest and most reliable tank coatings. As stated in the Petroleum Engineering Handbook,

> **"...coal tar has extremely low permeability, protects the surface by the mechanical exclusion of moisture and air, is extremely water resistant, and resists weak mineral acids, alkalis, salts, brine solutions, and other aggressive chemicals well."**

Carbon steel pipe can be protected internally using a coal tar epoxy coating. Because this internal coating should be about 3/32" thick, the use is limited to large diameter pipe lines.

In the past, coal tar was used to manufacture high intensity carbon arc lamps (i.e. search lights or light house lights). Coal tar pitch was used on a carbon probe to generate a carbon arc. Coal tar was also used as a direct heat source when burned as fuel (in boilers or similar mechanisms).

The compound concentration varies between coal tar and coal tar creosote.

> **As stated in the U.S.D.A. Bulletin No. 1036 titled "Coal-Tar and Water-Gas Tar Creosotes: Their Properties and Methods of Testing" by Ernest Bateman in 1922, "...the concentration of toxic elements in coal tar is only about one-fourth of that in coal-tar creosote, because coal-tar creosote is only about one-fourth of the volume of the coal-tar from which it is distilled and contains practically all the toxic principals. It has also been shown by this bulletin that coal tar does not retard the evaporation of creosote mixed with it."**

Consequently, the lighter elements in creosote (BTEX compounds) will evaporate over time.

Large quantities of creosotes were used at the turn of the century. Between 1909 and 1918 it is estimated that 758,676,587 gallons of creosote were used by wood treatment plants in the United States. Approximately 352,425,886 gallons were produced domestically and the rest was imported. These numbers indicate that all available coal tar creosote was probably used in the wood treatment process.

4.0 THE MANUFACTURED GAS PLANT

The predominant by-product generated by the MGP was tar. To a lesser extent, the following compounds were also known MGP by-products and in some cases had some commercial value:

- coke
- ammonia
- naphthalene
- crude light oil and derivatives
- light oil derivatives
- coal screenings and residue
- spent iron oxide
- spent lime

Gas production information on the MGP provided by NSP was available from 1900 to 1947. From this data, coal tar production was estimated. Residual coal tar volumes were calculated by estimating the amount of coal tar sold. A report on tar waste disposal of manufactured gas plants prepared for the USEPA estimated that approximately 74% of the tar waste generated by MGPs was sold, and the remaining 24% was reused by the plant, sold without documentation, or discarded. When generating the numbers used to calculate residual tar volumes for the MGP plant in Ashland, it was assumed 70% of the tar produced was sold or reused and the remaining 30% was used for undocumented purposes. The assumptions used were based on known figures regarding tar sold (6 years worth of data supplied by NSP), and information contained in the report prepared for USEPA. In addition, NSP records indicate that 2800 gallons of coal tar were used annually as boiler fuel at the MGP. Furthermore, there is evidence the coal tar was used as roofing material.

A total volume of 178,451 gallons of tar was calculated for the years 1900 to 1947. This represents the volume not sold as a commercial product. This information is summarized in

Table 3 (however this volume does not account for material used as fuel or roofing material).

The former MGP was located on a bluff overlooking Lake Superior on Chequamegon Bay in Ashland. Adjacent to the facility, a north south trending ravine drained toward the Bay. Witnesses have indicated the ravine was filled with debris and other waste materials. Sometime between 1909 and 1923, the ravine was filled. The exact year is unknown. Based upon a series of Flood Insurance Maps, the ravine was completely filled in by 1923.

The area down slope from the ravine adjacent to the shore of the Bay (the site of the present WWTP) was also filled during historic times. The depth of this fill averages about 14 feet. Much of this area contains known contamination consisting of miscellaneous debris discarded by different entities over several years. It is in this area where the reported creosote treatment pit was located. Attempts to obtain an aerial photograph of this area prior to 1923 were not successful. The earliest aerial photograph of the area that is available was taken between 1937 and 1939 by the Department of Transportation.

Because of the lack of data, the volume of the ravine is unknown. However, an attempt to calculate the volume of the ravine on the NSP property was performed. By using the City of Ashland Flood Insurance Maps, a partial physical description of the area prior to the filling of the ravine, and information obtained from site soil boring data taken from a recent subsurface investigation on the NSP property by the Cedar Corporation, the following dimensions of the ravine were developed:

Ravine volume estimation:

Average width	= 20 ft
Average length	= 300 ft
Average depth	= 20 ft
Volume of ravine	= 120,000 cf

Assuming a worst case condition, that none of the unaccounted for coal tar was burned, but was disposed of in the ravine, a computation of the ravine filling was performed. Using the data on the residual tar volume developed for the years 1900 to 1923 (the latest year the ravine may have been filled), a value for the volume of the ravine that may have been occupied by coal tar was computed as follows (note the exact volume of the ravine is unknown):

Residual tar volume (from Table 3A)	= 55,609 gallons
	= 7,434 cf
Ravine volume - Residual tar volume	= 120,000 cf - 7,434 cf
	= 112,566 cf

It appears that only about 6% of the ravine may have been filled with residual coal tar before the ravine was filled. Although the above figures are based on incomplete information, and no data is available for the years before 1900, they give some indication of what the maximum tar volume was that filled the ravine. When the coal tar is removed from the ravine, the exact volume will be known.

According to subsurface data developed on the site and the surrounding area, the ravine contamination appears to be confined by an impervious clay layer. Coal tar is highly viscous. It's resistance to flow makes it highly unlikely that contamination throughout the Lake Front Site is from the migration of coal tar from the ravine. It is probable the coal tar was placed in the ravine for convenience, since regulations for waste disposal of this material did not exist at the time. The SEH report states,

> **"A former ravine appears to have previously discharged in the immediate vicinity of the seep and TW-9".**

Evidence to support this statement has not been uncovered. The ravine is orientated in the direction of the seep and TW-9, but there is no documentation that material was physically discharged from the filled ravine. In addition, no observations have been made of this material extruding from this area of the ravine (between the bluff and the railroad).

The MGP records indicate the plant began manufacturing water gas in 1920. The U.S.D.A reports,

> **"Water-gas tar is obtained from petroleum oil as a by-product in the manufacture of water gas. Water-gas-tar creosote is produced by distillation from water-gas tar... While water-gas tar and the creosote produced from it are not considered so generally effective as coal-tar creosote, service-test records indicate that they have good preservative properties."**

Because large quantities of creosote had to be imported for wood treatment plants, and due to the MGPs proximity to the saw mill, it would seem reasonable to assume the lumber company used coal tar creosote and/or water gas tar creosote for wood preservation. Economically and logistically, the incentive to use the MGP coal tar product in the wood preservation process existed.

5.0 OTHER POTENTIAL CONTAMINATION SOURCES

The Lake Front Area had been used as a general fill site since commercially developed by the lumber operations in the nineteenth century. It was subsequently used as a general disposal site for the City and County of Ashland for decades in the twentieth century. Mr Dave Wosepka, an employee of the City of Ashland Waste Water Treatment Department, indicated the site was filled over a period of several years with sawdust, fly ash, and various other unknown materials. The waste water treatment plant was built on the site in 1951. The structure was built on concrete and creosote treated wood pilings due to the unstable ground. Mr. Wosepka indicated in a telephone interview that all the waste associated with the operation of the plant was treated and hauled to a licensed landfill. Accordingly, Mr. Wosepka indicated there should be no contamination caused by the operation of the waste water treatment plant. However, in 1923 the site contained an open trench which was identified as an open sewer. This open sewer was in the western section of the site, and crossed filled ground. According to information contained in the 1994 SEH report, it was still present in 1946.

In a construction drawing prepared by Greeley & Hanson in 1951 for the WWTP, there is an area in the south west corner designated a "Coal Tar Dump". In a memo dated April 19, 1991, Karen Vermillion of the WDNR stated,

> **"A portion of the 10 acre site was used for the disposal of wood, wood preservatives, and electrical power transformers with PCB's. ...Prior to 1920's site occupied by Schrader (sic) Sawmill. It manufactured RR ties and timbers for docks-treated them with creosote in a creosote pit located to south of site."**

No additional information about this potential disposal site has been developed. SEH excavated a test pit (TP-4) in this location and reportedly found a "tarry" substance, but did not conclude the site was a coal tar dump.

The SEH report indicates a vertical steel pipe encountered in the northeast portion of the WWTP property could possibly be an old well casing. This open well could provide a contamination source for groundwater.

Elevated lead concentrations were found in soils analyzed by SEH throughout the WWTP site. The concentrations varied and were not consistent, but likely reflect a source from the materials placed in the area over decades of filling.

6.0 TECHNICAL REVIEW OF EXISTING REPORTS

Four technical reports on the subject area were reviewed for similarities and differences in field data analysis and general site information. An Environmental Assessment prepared for the City of Ashland by Northern Environmental Technologies Inc. in 1989, a Remedial Investigation Interim Report prepared by Short Elliott Hendrickson Inc. in 1994, an Existing Conditions Report prepared by Short Elliott Hendrickson Inc. in February of 1995, and a Soil Analysis prepared by the Cedar Corporation in January of 1995 were examined. The Cedar Corporation report contained soil boring and analysis data on collected soil samples from six soil borings in the area of the former MGP (refer to Figure 8). The other reports (from 1989, 1994, and 1995) included historical data, geological history, magnetic field surveys, and groundwater and soil analysis data on the WWTP area (and in the case of the 1995 SEH report, the former ravine area south of the NSP property).

As earlier described, the NET report was prepared as an environmental assessment for the proposed expansion of the WWTP. A reconnaissance level magnetometer survey was performed over the area to assess the presence of buried metallic objects. The results of this work showed no significant anomalies, other than small near-surface objects and some buried objects in soil piles near the south central portion of the site. The report also addressed three soil borings converted into monitoring wells for the purpose of evaluating groundwater conditions in the shallow aquifer in the fill perched above the natural clay soils. In addition, a composite sample of soil from other soil borings advanced on the property at that time (borings advanced for geotechnical evaluation of the proposed WWTP expansion) was analyzed for constituent properties. The results of the analysis and the conclusions of the report show that the predominant contaminant source on the property is coal tar creosote. The composite soil data compared to the dissolved constituents in groundwater confirm this conclusion. The relative concentrations of VOC and PAH compounds approximate those measured in pure coal tar. (See Table 4) Naphthalene, a major PAH compound in coal tar, is 10 to 100 times the volume of the light weight VOC (BTEX) compounds.

In 1994, SEH performed an interim investigation of the WWTP site by conducting an electromagnetic and magnetometer survey of the WWTP (a higher level of geophysical effort than NET performed in 1989), as well as a resampling of the three existing wells installed by NET. SEH found anomalous low conductivity values on the south-southeast and north-northwest portions of the property as a result of their geophysics efforts. As a result of these efforts, SEH proposed further investigations on the property.

In the 1994 report, SEH compared the 1989 groundwater data developed by NET with their data developed in 1994. This data is markedly different comparing several compounds. This data is graphically displayed in Figures 2 through 7 and can be reviewed in tabular form in Tables 5 and 5A (Tables 5 and 5A are taken directly from the SEH report). The compounds that were analyzed in both investigations were plotted. In 1989 the concentration of benzene in groundwater samples from MW-1 was 190 ppb (parts per billion) while in 1994 this figure increased to 4,240 ppb. Field data from both studies indicate the groundwater level remained unchanged between 1989 and 1994. Differences in sampling procedures and laboratory analysis may explain the differences in the results. However, additional testing of these wells would be necessary to establish consistent lab results.

The Cedar report contained analytical results on soil samples from six borings advanced on the NSP property near the former MGP. This data was used to determine the extent of the ravine that was filled in sometime between 1909 and 1923. The boring logs showed a pattern of coal tar contamination consistent with a physical description of where the center of the ravine was located. The coal tar waste appears to be about 20' below the surface. Soil borings taken outside the former ravine area do not indicate coal tar contamination. VOC analyses on soil samples from the coal tar waste showed the presence of benzene, toluene, ethylbenzene, and xylene; PAH analyses on these same samples indicated the presence of acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene, and pyrene. The relative concentrations of these compounds are consistent with other coal tar wastes. The analytical results are summarized in Table 6 and 6A (taken directly from the Cedar report).

Although the data is limited, the Cedar report (and later substantiated by SEH) shows the area of coal tar contamination to be concentrated in the center of the ravine.

The 1994 SEH report provided a work plan for further site investigation. This work was subsequently performed later in 1994, and discussed in the 1995 Existing Conditions Report. This work consisted of a series of nine test pits to evaluate anomalies identified by the geophysics, as well as an area where debris or solid waste was disposed, and where earlier maps had indicated a "coal tar dump." The effort also involved the installation of 13 temporary monitoring wells to evaluate soil and groundwater conditions. One of these wells, TW-13, was advanced south of the NSP property within the area of the former ravine. Selected soil samples from each of the well borings were subjected to analyses for VOCs and PAHs. Similarly, two rounds of groundwater data were collected from the wells and analyzed for the same parameters (only one round was collected from TW-13).

The results of the test pit investigation were inconclusive. Groundwater filled the test pits when excavated making proper lithologic characterization impossible. As a result, the attempts to characterize geophysical anomalies, as well as the "coal tar dump", were unsuccessful.

The results of the soil and groundwater analysis resulted in the conclusion stated in the report that "it appears on-site contamination may have originated from past contamination of the former ravine." This conclusion is based on the fact that the highest level of PAH and VOC contaminants were measured in soil and groundwater samples collected from TW-13 installed at the head of the former ravine, TW-9, installed at the mouth of the former ravine (north of the railroad), and two seep samples collected at the bluff face roughly corresponding to where the former ravine opened to the former shoreline bottom lands. The data from this report is reproduced in Tables 7, 7A, and 8. The latest SEH data indicates several conditions.

- The groundwater data collected from wells MW-1, 2 and 3 are all similar to the earlier round collected by SEH in 1994; these data do not appear similar to the NET samples collected from these wells in 1989;

- There is agreement between sampling events for most compounds, indicating the data is generally reliable;

- The highest concentrations are found in TW-9 and TW-13. The highest BTEX values are found in TW-13 (TW-13 was sampled only once).

- The soil data collected from these well borings (TW-9 and TW-13) and subject analyses yields values consistent with other samples of coal tar and coal tar residue; naphthalene to BTEX ratios consistently fall between 10 and 100 to 1.

In general, the methods utilized to develop the data in the latest SEH report are sound. However, from a strictly technical evaluation, the conclusion that the MGP site is the source of contamination for the rest of the WWTP site is flawed, for the understated fact that much of the WWTP property is already contaminated with coal tar creosote and other waste.

It is not realistic to assume that the VOC and PAH contamination (and metals contamination indicated in the 1994 SEH report) measured in soil and groundwater at the WWTP site occurred as a result of the migration of an approximate quantity of 7,500 cubic feet of coal tar (see Section 4.0) onto this property. (Note that this value is a worst case number, since much of this material was likely utilized in unaccounted methods as a product.) This material is highly viscous, and cannot easily migrate. Additionally, the filling of the ravine prior to 1923 would indicate the material would necessarily migrate as a pore fluid through fill, which would make this migration potential that much less.

The migration rate (i.e. potential flow rate through fill and unconsolidated, silty sand) of the coal tar is assumed to be zero. This is based on evidence suggesting the viscosity of coal tar dictates its inability to flow horizontally. The kinematic viscosity of coal tar was obtained by extrapolating a curve from a correlation relating kinematic viscosity to specific gravity for several oils, and from this value, the dynamic viscosity was calculated. The coal tar viscosity increases with increasing specific gravity and lower temperatures. The estimated dynamic

viscosity of coal tar is 5,660 cp (assuming a specific gravity of 1.12 @ 100° F). The actual viscosity is likely to be higher because the ground temperature in Northern Wisconsin is rarely above 55°F. Therefore, it will act more like a solid than a liquid at this temperature. For comparison sake, the viscosity of water at 100°F is 0.6783 cp, and 1.202 cp at 55°F. The ability for coal tar to "flow" linearly at a ground temperature of 55°F is essentially non existent. It should be noted the value for the viscosity of coal tar is a rough estimate and was extrapolated from a curve comparing a large number of oils (i.e. paraffinic, asphaltic, and combination based). Although the margin for error is substantial, it can be concluded that coal tar is essentially immobile in its pure form.

The increase in BTEX concentrations in the MW-1 and MW-2 wells from 1989 to 1994 indicates that much of this VOC contamination may be the result of other petroleum derived materials. Similarly, the high toluene concentration in the TW-13 sample, and the occurrence of 1,2,4-trimethylbenzene in groundwater at other site locations indicates this potential condition. Neither of these compounds are characteristic at these concentrations in coal tar. Additionally, toluene has only been measured in low concentrations, especially in the latest SEH study, in two other samples from the well network. (It is recognized that the measurement of toluene in the sample from TW-13 cannot be considered characteristic from that location until additional data is developed.)

The existence of VOC contamination on the WWTP property caused by petroleum or other sources unrelated to the ravine can also be observed with other data in the latest SEH report. High levels of BTEX, other potentially fuel oil derived VOCs (butylbenzenes, trimethylbenzene), as well as naphthalene, were measured in TW-6, a well several hundred feet west of the ravine mouth at the base of the bluff. Additionally, although the increases in VOCs in the Northern wells since 1989 were earlier noted, the spatial relationship of the VOC concentrations measured in MW-1 and MW-2 is not consistent with groundwater flow if the ravine is considered the source. TW-13, located at the head of the ravine, yielded the highest values. Slightly lower values were measured at TW-9, at the mouth of the ravine, downgradient from TW-13. MW-2, about 150 feet north and downgradient from TW-9, yielded still lower values. However, MW-

1, located approximately 150 feet north (down gradient) from MW-2, yielded significant increases above the levels in MW-2. As a result of these factors, the data strongly suggests other contaminant sources on the WWTP property in addition to the ravine.

The SEH final report also attempts to implicate the MGP site as the source of contamination at the WWTP area through speculation and anecdotal information. Included in the Remedial Investigation Interim Report was a statement made by a local city employee. Quoted directly from the SEH report, "Mr. Larry Wisner, City of Ashland Museum curator, stated that he had heard that contamination on the subject property was related to the historic manufactured gas plant (MGP) located on St. Claire Street, south of the site." The SEH report goes on to say, "This belief was also stated by Mr. John Walters, a local historian and former dock worker at the Consolidated Paper Company located west of the subject property on the 'Commercial Dock'". A personal interview was conducted with both of the above named gentlemen in January, 1995 by Veritas Associates, Inc. The interview with Mr. Wisner can be summarized by saying he had no recollection of creosoting operations going on at Schroeder Lumber Company. In addition he recalled visiting the MGP site in the 1950s and was under the impression it was still in operation (in fact, the MGP stopped producing gas in 1947). He offered additional sources of potential information regarding lumber operations. Mr. John Walters indicated during his interview that a coal tar pond was located south of the WWTP. He estimated the pond volume to be about 700 cf. Mr. Walters went on to discuss the railroad cars which regularly dumped tar material in the area. In addition, he stated the site was used as a general land fill for the City of Ashland.

Other interviews conducted by Veritas Associates, Inc. with various people associated with the area confirmed the use of the area as a land fill, and the regular dumping of some kind of waste by railroad cars. The presence of a coal tar creosote pit was described by Mr. Robert Wright, a former employee of the Reiss Coal Company, as being about 16 ft by 6 ft and located near the lumber company.

The SEH Interim Report goes on to implicate the MGP plant based on the presence of metals such as aluminum, copper, zinc, iron and others. The presence of these metals can be a result of many different sources. Wood preservation operations (which used metals in addition to tars) and unknown waste disposed at the site over a period of about 35 years are more viable source candidates.

Information regarding wood preservation methods was also included in the 1995 SEH document. The report stated, "The period of time when wood treatment could have occurred corresponds to the time frame when creosote formulas were undefined, therefore a standard chemical composition of creosote was not available." The 1922 publication earlier referenced in this report contradicts this claim. Additionally, the creosote process has been used for wood preservation since the late 1800's according to "The Wisconsin Lumberman"; the November, 1874 issue contained an article entitled "Preservation of Timber by the 'Bethel Creosoting (sic) Method'". The Handbook on Wood Preservation, published in 1916 by the American Wood Preservers' Association, defines the composition of creosote and coal tar creosote, and can be found in Appendix A.

In the latest report, SEH used a document titled "Management of Manufactured Gas Plant Sites-Vol.1" to identify chemicals of concern at MGP sites. While this document contains useful information, it is based on a survey of 33 MGP sites. Historically there were over 1500 MGP sites, all with different capacities and operational processes. It is unlikely that many of the 33 sites referred to in the study were adjacent to a rail road tie treatment operation. Therefore it should be used as a guide, but not as a source of information to identify what should have been left behind at the Lake Front Site. Many other waste materials (particularly petroleum products) could have generated the contaminated material found. The SEH findings go on to alleviate the lumber operations of responsibility because, "... no treatment pits or buildings were noted historically or physically observed during the site investigation." The NET report included documentation of the existence of a creosote pit located south of the current waste water treatment plant. This particular reference was excluded from both of the SEH reports. Furthermore, SEH's attempt to confirm a creosote pit identified from earlier maps through their

test pit investigation was inconclusive because of unforeseen site conditions; no further discussion of this feature, and it's possibility as a contaminant source is discussed. Instead, the focus of contaminant sources in the SEH study is the ravine, and through implication the MGP site.

7.0 SUMMARY

The contamination at the Ashland Lake Front Site was likely caused by wood preservation operations that occurred on the property, dissolved constituents in groundwater migrating onto the property from off site (coal tars and other materials in the ravine) and waste associated with the disposal of unknown materials that occurred for several decades on the WWTP property. The latest SEH report marks the MGP waste as the predominant source. The report indicates coal tar, an extremely viscous compound disposed in the former ravine, migrated across the Lake Front area, causing contamination of the WWTP site. It is more likely this contamination occurred during indiscreet creosote handling and operational procedures associated with the wood treatment process and other site specific activities, and the unauthorized disposal of other wastes on site. Because specific information regarding daily lumber operations and MGP operations is incomplete, and because unknown waste disposed by the railroad and the City and County of Ashland occurred over a period of several years, it is difficult to conclude that existing contamination may have resulted from any one predominant source.

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Creosote.

The creosote suitable for preserving wood is derived from the tar obtained in the destructive distillation of wood, coal, petroleum, etc. Creosote oil, in the scientific sense; may be defined as any and all distillate oils boiling between 200° and 400° Centigrade, which are obtained by distillation from tars consisting principally of compounds belonging to the aromatic series and containing well-defined amounts of phenoloids.

Creosote is the most important wood preservative, and has been in use for this purpose for a great many years. The consumption of creosote oil in the United States in the five years from 1909 to 1913 more than doubled, and in the seven years from 1909 to 1915 was as follows:

CREOSOTE USED IN THE UNITED STATES.

Year	Total Creosote Used.	Domestic Creosote.	Per Cent of Total	Imported Creosote.	Per Cent of Total
	Gallons.	Gallons.		Gallons.	
1909	51,426,212	13,862,171	27	37,569,041	73
1910	63,266,271	18,184,355	29	45,081,916	71
1911	73,027,335	21,510,629	29	51,516,706	71
1912	83,666,490	31,135,195	37	52,531,295	63
1913	108,373,359	41,700,167	38	66,673,192	62
1914	79,334,606	28,026,870	35	51,307,736	65
1915	80,859,442	43,358,435*	54	37,501,007	46

*41,333,890 gals. coal-tar and 2,024,545 gals. water-gas-tar.

The domestic production of creosote oil has grown steadily, especially since the European war interfered with exports to the United States. In 1914 the production of creosote oil in the United States amounted to 28,026,870 gallons, and a year later had nearly doubled to 43,358,435 gallons. Domestic manufacturers furnished 35% of the total amount of creosote oil used in 1914, and in 1915 they supplied 54%. The imports in 1914 amounted to 65% of the total consumption of creosote oil in the United States, and in 1915 the foreign supply fell to 46%.

Specifications for coal-tar creosote oil, calculated on the basis of the dry oil when distilled by the common method (using an 8-oz. retort, asbestos covered, with standard thermometer, bulb ½ in. above the surface of the oil), prepared by the American Railway Engineering Association, are as follows:

Distillation	Grade 1.	Grade 2.	Grade 3.
Below 210° C.	5%	5%	10%
" 235° C. Not over	25%	35%	40%
Residue above 355° C. Over	5%—soft	5%—soft	5%—soft
Water Not over	3%	3%	3%
Specific gravity at 38° C.	1.03	1.03	1.025

Grade 1 oil shall be a pure product obtained from coal-gas-tar or coke-oven-tar, and shall be free from any tar, including coal-gas-tar and coke-oven-tar, oil or residue obtained from petroleum or any other source; it shall be completely liquid at 38° C., and shall be free from suspended matter. Oils 2 and 3 shall be the best-obtainable grades of coal-tar creosote.

The specifications for creosote oil prepared in behalf of the American Society of Municipal Improvements in October, 1916, by that association's Committee on Standard Specifications for Creosoted Wood Block Paving, are as follows:

"A" Coal-Tar Paving Oil: A coal-tar product at least 65% a distillate of coal-gas tar or coke-oven tar; the remainder refined or filtered coal-gas tar or coke-oven tar.

"B" Coal-Tar Distillate Oil: A distillate of coal-gas tar or coke-oven tar.

	"A"	"B"
Water	Not more than 3%	Not more than 3%
Matter insoluble in benzol	Not more than 3%	Not more than 0.5%
Specific gravity at 38° C.	Between 1.07 and 1.12	Not less than 1.06
Distillates		
Up to 210° C.	Not over 5%	Not over 5%
Up to 235° C.	Not over 25%	Not over 15%.
Residue above 355° C.	If over 35% shall have float test of not over 80 sec. at 70° C.	If over 10% shall have float test of not over 50 sec. at 70° C.
Specific gravity of fraction between 235° C and 315° C.	Not less than 1.02 at 38°/15.5° C.	Not less than 1.02 at 38°/15.5° C.
Specific gravity of fraction between 315° C and 355° C.	Not less than 1.09 at 38°/15.5° C.	Not less than 1.09 at 38°/15.5° C.
Coke residue	Not more than 10%	Not more than 2%

Zinc Chloride.

The principal water-soluble salt which is used as an antiseptic for

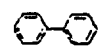
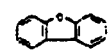
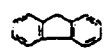
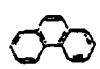
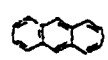
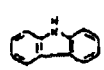
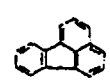
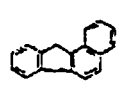
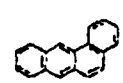
TABLE 1

AMERICAN WOOD-PRESERVERS' ASSOCIATION

Chemical Composition of Creosote

The general chemical composition of creosote has long been known because of work on coal tar (9, 14, 20, 28). Most of the 200 or more compounds in creosote are polycyclic aromatic hydrocarbons. Only a limited number of them—less than 20—are present in amounts greater than one percent. The major polycyclic aromatic hydrocarbons in creosote listed in Table 1 generally comprise at least 75 percent of the creosote. Stasse (23) used fractional distillation to separate and identify some of these major components. Sweeney, *et. al.* (25) used infrared analyses to characterize creosote, and found the major components accounted for the major features of the infrared spectrum of whole creosote. McNeil and Vaughan (16) and Vaughan and Grant (26) used gas chromatography to identify the major components. Becker and Petrowitz (2) used programmed temperature gas chromatography to examine the composition of three different creosotes; of 19 observable peaks, they identified 17. Most of the work on applying gas chromatography to investigate the chemical composition of creosote has been summarized in a 1967 AWPA committee report (3). Thin-layer chromatography and column chromatography, as well as gas chromatography, have been used in related

Table 1.—Major Components in Creosote

Peak No.	Component	Whole Creosote	Boiling Point[1]	Melting Point[1]	Structural Formula	Molecular Weight
		Approx. Pct. ±0.7%	°C. 760	°C.		
1	Naphthalene	3.0	218	80.55		128.2
2	2-Methylnaphthalene	1.2	241.05	24.58		142.2
3	1-Methylnaphthalene	.9	244.64	-22		142.2
4	Biphenyl	.8	255.9	71		154.2
5	Dimethylnaphthalenes	2.0	268	7.66, 105		156.2
6	Acenaphthene	9.0	279	96.2		156.2
7	Dibenzofuran	5.0	287	86-87		168.2
8	Fluorene	10.0	293-295	116-117		166.2
9	Methylfluorenes	3.0	318	46-47		180.2
10	Phenanthrene	21.0	340	101		178.2
11	Anthracene	2.0	340	216.2-.4		178.2
12	Carbazole	2.0	355	247-248		167.2
13	Methylphenanthrenes	3.0	354-355	65-123		192.2
14	Methylanthracenes	4.0	360	81.5-209.5		192.2
15	Fluoranthene	10.0	382	111		202.3
16	Pyrene	8.5	393	156		202.3
17	Benzofluorenes	2.0	413	189-190		216.3
18	Chrysene	3.0	448	255-256		228.3

[1] Values from Handbook of Chemistry and Physics, 1971-72, 52nd ed., Chemical Rubber Publishing Co., Cleveland, Ohio.

TABLE 2

AMERICAN WOOD-PRESERVERS' ASSOCIATION

Table 3.—Analysis of Creosote and Treated Southern Pine Wood by Gas Chromatography

Peak No.[1]	Original Creosote	Percent of Total Area Under Peaks in Sample			
		Unexposed		Exposed to Sea 9.5 Years	
		Creosote-Treated Wood	Creosote Extracted With Toluene from Treated Wood	Wood Sample in Vicinity of Marine-Borer Attack	Wood Sample Not in Vicinity of Marine-Borer Attack
	Pct. ±0.7				
1	3.0	0.8	2.7	2.2	0.8
2	1.2	1.2	1.2	.9	.8
3	.9	.8	.9	.9	.5
4	.8	.9	.7	1.0	.8
5	2.0	1.9	2.3	1.4	1.0
6	9.0	8.1	5.9	5.9	5.0
7	5.0	5.4	4.4	4.0	3.7
8	10.0	7.7	5.8	7.6	7.8
9	3.0	2.8	5.9	1.6	1.6
10	21.0	19.3	19.3	20.4	21.2
11	22.0[2]	--	--	--	--
12	2.0	1.3	.4	.7	.8
13	3.0	1.4	3.6	2.9	3.0
14	4.0	3.2	5.1	3.2	3.8
15	10.0	8.8	8.9	10.0	10.6
16	8.5	8.1	7.5	8.7	9.7
17	2.0	1.4	1.1	3.0	3.2
18	3.0	4.1	3.3	4.1	4.1
Total[3]	84.4	77.2	79.0	78.5	76.4

[1] Numbers correspond to numbers in Table 1.

[2] Values of anthracene are included in values for phenanthrene because they are not completely separated in the analysis.

[3] Total percentage of major peaks in sample.

aromatic hydrocarbons in the creosoted wood had decreased as had the retention of the whole creosote, but the relative amounts of the major components remained unchanged. Perhaps the total concentration of the six or seven major aromatic hydrocarbons in creosote is the important factor in the effectiveness of creosote as a wood preservative.

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TABLE 3

ASHLAND PROJECT
NSP/LSDP MGP ANNUAL GAS AND TAR PRODUCTION 1900 - 1947

YEAR	GAS PROD (MCF)	TAR PROD (GAL)	TAR SOLD (GAL)	UNAC TAR (GAL)	GAL TAR/ MCF GAS	MX GS PRD (MCF/DAY)	PLNT CAP MCF/YR	CAP FACTOR
1947	44,311	20,826	16,183	4,643	0.47	432	157,680	0.28
1946	43,679	20,529	14,348	6,181	0.47	260	91,250	0.48
1945	39,534	18,581	13,007	5,574	0.47	260	91,250	0.43
1944	39,264	17,814	17,814	0	0.45	250	91,250	0.43
1943	34,746	16,331	2,792	13,539	0.47	260	91,260	0.38
1942	36,775	17,284	12,901	4,383	0.47	250	91,250	0.40
1941	41,720	16,600	10,000	6,600	0.40	260	91,260	0.46
1940	39,662	18,641	13,049	5,592	0.47	260	91,250	0.43
1939	45,926	26,000	19,034	6,966	0.57	250	91,250	0.60
1938	45,909	21,577	15,104	6,473	0.47	260	91,250	0.50
1937	38,680	18,180	12,726	5,454	0.47	250	91,250	0.42
1936	36,409	17,112	11,979	5,134	0.47	260	91,260	0.40
1935	32,176	15,123	10,586	4,537	0.47	250	91,250	0.35
1934	29,190	13,719	9,603	4,116	0.47	260	91,260	0.32
1933	33,989	15,975	11,182	4,792	0.47	260	91,250	0.37
1932	36,220	17,023	11,916	5,107	0.47	250	91,260	0.40
1931	37,614	17,679	12,375	5,304	0.47	260	91,250	0.41
1930	39,534	18,581	13,007	5,574	0.47		0	
1929	28,329	13,315	9,320	3,994	0.47		0	
1928	32,009	15,044	10,531	4,513	0.47		0	
1927	30,498	14,334	10,034	4,300	0.47		0	
1926	27,979	13,150	9,205	3,945	0.47		0	
1925	21,699	10,198	7,139	3,059	0.47		0	
1924	21,699	10,198	7,139	3,059	0.47		0	
1923	21,699	10,198	7,139	3,059	0.47		0	
1922	13,281	6,242	4,369	1,873	0.47	90	32,850	0.40
1921	21,862	10,275	7,193	3,083	0.47	90	32,850	0.87
1920	19,196	9,022	6,316	2,707	0.47	90	32,850	0.58
1919	17,228	8,097	5,668	2,429	0.47	90	32,850	0.52
1918	18,795	8,833	6,183	2,650	0.47	90	32,850	0.57
1917	18,922	8,893	6,225	2,668	0.47	80	29,200	0.65
1916	17,461	8,207	5,745	2,462	0.47		0	
1915	16,000	7,520	5,264	2,256	0.47	100	38,500	0.44
1914	16,637	7,819	5,474	2,346	0.47	100	36,500	0.46
1913	18,535	8,711	6,098	2,613	0.47	100	36,500	0.45
1912	15,527	7,298	5,109	2,189	0.47	100	36,500	0.43
1911	19,082	8,968	6,278	2,691	0.47			
1910	18,978	8,920	6,244	2,676	0.47			
1909	20,189	9,489	6,642	2,847	0.47	125	46,625	0.44
1908	19,000	8,930	6,251	2,679	0.47		0	
1907	15,000	7,050	4,935	2,115	0.47			
1906	14,000	6,580	4,606	1,974	0.47			
1905	13,000	6,110	4,277	1,833	0.47			
1904	12,000	5,640	3,948	1,692	0.47			
1903	11,000	5,170	3,619	1,551	0.47			
1902	10,000	4,700	3,290	1,410	0.47			
1901	9,000	4,230	2,961	1,269	0.47			
1900	18,000	8,460	5,922	2,538	0.47			
TOTALS:	1,251,942	589,179	410,728	178,451	0.47 (average)	199.54 (average)	52,784 (average)	0.46 (average)

*UNAC TAR = UNACCOUNTED FOR TAR (I.E. IT MAY HAVE BEEN REUSED)

TABLE 3A

ASHLAND PROJECT
NSP/LSDP MGP ANNUAL GAS AND TAR PRODUCTION 1900 - 1923

YEAR	GAS PROD (MCF)	TAR PROD (GAL)	TAR SOLD (GAL)	UNAC TAR (GAL)	GAL TAR/ MCF GAS	MX GS PRD (MCF/DAY)	PLNT CAP MCF/YR	CAP FACTOR
1923	21,699	10,198	7,139	3,059	0.47		0	
1922	13,281	6,242	4,369	1,873	0.47	90	32,850	0.40
1921	21,862	10,275	7,193	3,083	0.47	90	32,850	0.87
1920	19,196	9,022	6,316	2,707	0.47	90	32,850	0.58
1919	17,228	8,097	5,668	2,429	0.47	90	32,850	0.52
1918	18,795	8,833	6,183	2,650	0.47	90	32,850	0.57
1917	18,922	8,893	6,225	2,668	0.47	80	29,200	0.65
1916	17,461	8,207	5,745	2,462	0.47		0	
1915	16,000	7,520	5,264	2,256	0.47	100	38,500	0.44
1914	16,637	7,819	5,474	2,346	0.47	100	36,500	0.46
1913	18,535	8,711	6,098	2,613	0.47	100	36,500	0.45
1912	15,527	7,298	5,109	2,189	0.47	100	36,500	0.43
1911	19,082	8,968	6,278	2,691	0.47			
1910	18,978	8,920	6,244	2,676	0.47			
1909	20,189	9,489	6,642	2,847	0.47	125	46,625	0.44
1908	19,000	8,930	6,251	2,679	0.47		0	
1907	15,000	7,050	4,935	2,115	0.47			
1906	14,000	6,580	4,606	1,974	0.47			
1905	13,000	6,110	4,277	1,833	0.47			
1904	12,000	5,640	3,948	1,692	0.47			
1903	11,000	5,170	3,619	1,551	0.47			
1902	10,000	4,700	3,290	1,410	0.47			
1901	9,000	4,230	2,961	1,269	0.47			
1900	18,000	8,460	5,922	2,538	0.47			
TOTALS:	394,391	185,364	129,755	55,609	0.47 (avg)	95.91 (avg)	27,720 (avg)	0.53 (avg)

UNACCOUNTED FOR TAR: 55,609 GAL
7,434 CF
1,324 BBL

*UNAC TAR = UNACCOUNTED FOR TAR (I.E. IT MAY HAVE BEEN REUSED)

TABLE 4

MAJOR CONSTITUENTS OF COAL TAR PER FISHER (1938) [a,b]
(PERCENTAGES BASED ON THE ORIGINAL TAR)

Coal tar			
Light oil, up to 200°C (392°C)	5.0		
Benzene	....	0.1	
Toluene	....	0.2	
Xylene	....	1.0	
Heavy solvent naphtha	....	1.5	
Middle oil, 200-250°C (392-482°F)	17.0		
Tar acids	....	2.5	
Phenol	....	....	0.7
Cresols	....	....	1.1
Xylenols	....	....	0.2
Higher tar acids	....	....	0.5
Tar bases	....	2.0	
Pyridine	....	....	0.1
Heavy bases	....	....	1.9
Naphthalene	....	10.9	
Unidentified	....	1.7	
Heavy oil, 250-300°C (482-572°F)	7.0		
Methylnaphthalenes	....	2.5	
Dimethylnaphthalenes	....	2.4	
Acenaphthene	....	1.4	
Unidentified	....	1.0	
Anthracene oil, 300-350°C (572-662°F)	9.0		
Fluorene	....	1.6	
Phenanthrene	....	4.0	
Anthracene	....	1.1	
Carbazole	....	1.1	
Unidentified	....	1.2	
Pitch	62.0		
Gas	....	2.0	
Heavy oil	....	21.8	
Red wax	....	7.0	
Carbon	....	32.0	

(a) Reproduced from Wilson & Wells, (1950, p. 374) and referenced from R.N. Shreve, "The Chemical Process Industries," p. 91, McGraw-Hill Book Company, Inc., New York, 1945.

(b) Also reported in Gas Engineers Handbook (1966, p. 3/17) and referenced as being obtained from C.H. Fisher, "Composition of Coal Tar and Light Oil", Bur. of Mines Bull. 412, Washington, D.C. 1938.

TABLE 5

Summary of Groundwater Analytical Results – Ashland Lakefront Property

Parameter	Concentrations in micrograms per liter (µg/l)											
	MW-1 1/25/89	MW-1 6/20/94	MW-2 1/25/89	MW-2 6/20/94	MW-3 1/25/89	MW-3 6/20/94	MW-3 Duplicate 6/20/94	AW-1 1/25/89	AW-1 6/20/94	TP-2 8/20/91	PAL	ES
VOCs												
Benzene	190	4,240	390	1,090	51.4	0.8	0.8	N/D	N/D	2,000	0.5	5
Ethylbenzene	N/D	413	190	113	N/D	N/D	N/D	N/D	N/D	240	140	700
Naphthalene	N/A	1,490	N/A	607	N/A	N/D	N/D	N/A	N/D	150	8	40
Toluene	27.1	651	31.7	N/D	N/D	N/D	N/D	N/D	N/D	N/D	68.6	343
1,2,4-Trimethylbenzene	N/A	107	N/A	N/D	N/A	N/D	N/D	N/A	N/D	170	--	--
Xylenes	223.8	449	350	N/D	N/D	N/D	N/D	N/D	N/D	290	124	620
PAHs												
Acenaphthene	330	253	300	42.8	88	11.9	N/A	N/D	N/D	N/A	--	--
Acenaphthylene	38	465	33	98.5	N/D	N/D	N/A	N/D	N/D	N/A	--	--
Anthracene	110	9.35	320	1.60	100	39.0	N/A	N/D	N/D	N/A	--	--
Benzo(a)Anthracene	59	0.473	93	0.522	180	56.4	N/A	N/D	N/D	N/A	--	--
Benzo(a)Pyrene	51	0.539	79	0.691	170	69.3	N/A	N/D	N/D	N/A	0.0003	0.003
Benzo(b)Fluoranthene	53	N/D	77	0.387	150	28.1	N/A	N/D	N/D	N/A	--	--
Benzo(ghi) Perylene	27	N/D	45	N/D	110	N/D	N/A	N/D	N/D	N/A	--	--
Benzo(k)Fluoranthene	N/D	N/D	N/D	N/D	N/D	19.8	N/A	N/D	N/D	N/A	--	--
bis(2-Ethylhexyl)Phthalate	18	N/A	28	N/A	58	N/A	N/A	N/D	N/A	N/A	--	--
Chrysene	60	N/D	92	N/D	180	N/D	N/A	N/D	N/D	N/A	--	--
Dibenzo(a,h)Anthracene	N/D	N/D	14	N/D	26	N/D	N/A	N/D	N/D	N/A	--	--
Di-n-Butylphthalate	N/D	N/A	N/D	N/A	N/D	N/A	N/A	4	N/A	N/A	--	--
Fluoranthene	110	N/D	140	N/D	260	210	N/A	N/D	N/D	N/A	--	--

N/D = Analyte not detected above laboratory quantitation limit
N/A = Sample not analyzed for indicated parameter
BOD = Biological Oxygen Demand
COD = Chemical Oxygen Demand
TOC = Total Organic Carbon
PAL = Preventive Action Limit (ch. NR 140, Wis. Adm. Code)
ES = Enforcement Standard (ch. NR 140, Wis. Adm. Code)

TABLE 5A

Summary of Groundwater Analytical Results – Ashland Lakefront Property (Continued)

Parameter	Concentrations in micrograms per liter (µg/l)											
	MW-1 1/25/89	MW-1 6/28/94	MW-2 1/25/89	MW-2 6/28/94	MW-3 1/25/89	MW-3 6/28/94	MW-3 Duplicate 6/28/94	AW-1 1/25/89	AW-1 6/28/94	TP-2 8/28/91	PAL	ES
Fluorene	180	51.3	150	4.05	83	6.29	N/A	N/D	N/D	N/A	--	--
Indeno(1,2,3-cd)Pyrene	22	N/D	33	N/D	80	N/D	N/A	N/D	N/D	N/A	--	--
1-Methyl Naphthalene	N/A	575	N/A	59.2	N/A	N/D	N/A	N/A	N/D	N/A	--	--
2-Methyl Naphthalene	N/A	344	N/A	20.1	N/A	N/D	N/A	N/A	N/D	N/A	--	--
Naphthalene	150	702	1,800	90.1	16	N/D	N/A	N/D	N/D	N/A	8	40
Phenanthrene	370	53.2	300	N/D	170	19.2	N/A	N/D	N/D	N/A	--	--
Phenol	N/D	N/A	14	N/A	N/D	N/A	N/A	N/D	N/A	N/A	1,200	6,000
Pyrene	230	N/D	370	N/D	790	317	N/A	N/D	N/D	N/A	--	--
Metals												
Aluminum	N/A	66	N/A	66	N/A	37	N/A	N/A	61	N/A	--	--
Arsenic	N/D	N/D	N/D	1.4	N/D	N/D	N/A	N/D	2.1	N/A	5	50
Chromium	N/D	N/A	N/D	N/A	N/D	N/A	N/A	N/D	N/A	N/A	10	100
Copper	23	N/A	N/D	N/A	N/D	N/A	N/A	N/D	N/A	N/A	130	1,300
Iron	N/A	1,210	N/A	3,650	N/A	959	N/A	N/A	N/D	N/A	150	300
Zinc	12	N/A	4	N/A	16	N/A	N/A	8	N/A	N/A	2,500	5,000
Indicators												
BOD (mg/l)	14	N/A	14	N/A	42	N/A	N/A	N/A	N/A	N/A	--	--
Chloride (mg/l)	54.8	N/A	64.6	N/A	64.1	N/A	N/A	N/A	N/A	N/A	125	250
COD (mg/l)	330	N/A	224	N/A	1,870	N/A	N/A	N/A	N/A	1,200	--	--
Sulfate (mg/l)	3.6	N/A	5.5	N/A	4.6	N/A	N/A	N/A	N/A	N/A	--	--
TOC (mg/l)	29.0	8.28	25.2	10.2	27.1	12.3	N/A	N/A	N/D	N/A	--	--

N/D = Analyte not detected above laboratory quantitation limit
N/A = Sample not analyzed for indicated parameter
BOD = Biological Oxygen Demand
COD = Chemical Oxygen Demand
TOC = Total Organic Carbon
PAL = Preventive Action Limit (ch. NR 140, Wis. Adm. Code)
ES = Enforcement Standard (ch. NR 140, Wis. Adm. Code)

TABLE 6

Table 1. VOC Analysis of Soil Samples and Water Sample From Seep
NSP - Ashland Lakefront Ravine Project
Ashland, WI

Compound	Units of Measure	Location Laboratory ID Sample date Sample Depth	SB-1-23' 100310905 12/21/94 23 feet	SB-2-20' 100310913 12/21/94 20 feet	SB-3-12' 100310921 12/21/94 12 feet	SB-4-20' 100310930 12/21/94 20 feet	SB-5-9' 100310948 12/21/94 9 feet	SB-6-19' 100310956 12/21/94 19 feet	SEEP 100310964 12/21/94
VOC									
CHLOROMETHANE	ug/kg		ND	ND	ND	ND	ND	ND	ND
BROMOMETHANE	ug/kg		ND	ND	ND	ND	ND	ND	ND
VINYL CHLORIDE	ug/kg		ND	ND	ND	ND	ND	ND	ND
CHLOROETHANE	ug/kg		ND	ND	ND	ND	ND	ND	ND
METHYLENE CHLORIDE	ug/kg		ND	4	3	ND	5	5	ND
ACETONE	ug/kg		ND	18	6	260	14	14	ND
CARBON DISULFIDE	ug/kg		ND	ND	ND	ND	ND	ND	ND
1,1 - DICHLOROETHENE	ug/kg		ND	ND	ND	ND	ND	ND	ND
TRANS - 1, 2 - DICHLOROETHENE	ug/kg		ND	ND	ND	ND	ND	ND	ND
CHLOROFORM	ug/kg		ND	ND	ND	ND	ND	ND	ND
1, 2 - DICHLOROETHANE	ug/kg		ND	ND	ND	ND	ND	ND	ND
2-BUTANONE	ug/kg		ND	ND	ND	ND	ND	ND	ND
1, 1, 1 - TRICHLOROETHANE	ug/kg		ND	ND	ND	ND	ND	ND	ND
CARBON TETRACHLORIDE	ug/kg		ND	ND	ND	ND	ND	ND	ND
VINYL ACETATE	ug/kg		ND	ND	ND	ND	ND	ND	ND
BROMODICHLOROMETHANE	ug/kg		ND	ND	ND	ND	ND	ND	ND
1, 1, 1 - TETRACHLOROETHANE	ug/kg		ND	ND	ND	ND	ND	ND	ND
1, 2 - DICHLOROPROPANE	ug/kg		ND	ND	ND	ND	ND	ND	ND
TRANS - 1, 3 - DICHLOROPROPENE	ug/kg		ND	ND	ND	ND	ND	ND	ND
TRICHLOROETHENE	ug/kg		ND	ND	ND	ND	ND	ND	ND
DIBROMOCHLOROMETHANE	ug/kg		ND	ND	ND	ND	ND	ND	ND
1, 1, 2 - TRICHLOROETHANE	ug/kg		ND	ND	ND	ND	ND	ND	ND
BENZENE	ug/kg		410	ND	ND	1300	ND	290	2000
CIS - 1, 3 - DICHLOROPROPENE	ug/kg		ND	ND	ND	ND	ND	ND	ND
2 - CHLOROETHYL VINYL ETHER	ug/kg		ND	ND	ND	ND	ND	ND	ND
BROMOFORM	ug/kg		ND	ND	ND	ND	ND	ND	ND
2 - HEXANONE	ug/kg		ND	ND	ND	ND	ND	ND	ND
4 - METHYL - 2 - PENTANONE	ug/kg		ND	ND	ND	ND	ND	ND	ND
TETRACHLOROETHENE	ug/kg		ND	ND	ND	ND	ND	ND	ND
TOLUENE	ug/kg		810	ND	ND	6900	ND	3900	260
CHLOROBENZENE	ug/kg		ND	ND	ND	ND	ND	ND	ND
ETHYLBENZENE	ug/kg		10000	ND	ND	22000	ND	19000	210
STYRENE	ug/kg		ND	ND	ND	ND	ND	ND	ND
XYLENE	ug/kg		9800	ND	ND	25000	ND	20000	570

ug/kg = micrograms per kilogram (ppb - parts per billion) Water sample analytical results are reported in ug/L (ppb - parts per billion)

Note: Detects of methylene chloride and acetone may be the result of laboratory contamination ND = Not detected

TABLE 6A

Table 2. PAH Analysis of Soil Samples
NSP - Ashland Lakefront Ravine Project
Ashland, WI

Compound	Units of Measure	Location Laboratory ID Sample date Sample Depth	SB-1-23' 100310905 12/21/94 23 feet	SB-2-20' 100310913 12/21/94 20 feet	SB-3-12' 100310921 12/21/94 12 feet	SB-4-20' 100310930 12/21/94 20 feet	SB-5-9' 100310948 12/21/94 9 feet	SB-6-19' 100310956 12/21/94 19 feet
PAH's								
ACENAPHTHENE	mg/kg		160	ND	ND	330	ND	570
ACENAPHTHYLENE	mg/kg		80	ND	ND	260	ND	230
ANTHRACENE	mg/kg		85	19	ND	210	ND	280
BENZO (a) ANTHRACENE	mg/kg		24	7.5	0.33	54	0.21	55
BENZO (b) FLUORANTHENE	mg/kg		24	7.1	ND	52	0.34	50
BENZO (k) FLUORANTHENE	mg/kg		12	2.9	0.24	23	0.17	26
BENZO (a) PYRENE	mg/kg		48	15	0.64	110	0.38	100
BENZO (ghI) PERYLENE	mg/kg		33	9.6	0.99	70	0.34	62
CHRYSENE	mg/kg		58	16	0.54	110	0.28	88
DIBENZO (a,h) ANTHRACENE	mg/kg		ND	ND	0.54	ND	0.31	ND
FLUORANTHENE	mg/kg		67	17	0.83	150	0.55	190
FLUORENE	mg/kg		79	4.4	ND	190	ND	250
INDENO (1,2,3-cd) PYRENE	mg/kg		30	8.9	0.43	58	0.27	61
NAPHTHALENE	mg/kg		240	ND	ND	630	ND	720
1-METHYLNAPHTHALENE	mg/kg		310	11	ND	1100	ND	660
2-METHYLNAPHTHALENE	mg/kg		120	ND	ND	320	ND	98
PHENANTHRENE	mg/kg		200	37	0.13	> 610	0.22	> 680
PYRENE	mg/kg		150	43	1.7	> 370	0.79	> 420

mg/kg = milligrams per kilogram (ppm - parts per million)
PAH = Polynuclear Aromatic Hydrocarbons

ND = Not detected

TABLE 7

Summary of Groundwater Analytical Results
Volatile Organic Compounds
Concentrations in micrograms per liter (µg/l)

Well Number	Date Sampled	Parameter											
		Benzene	Ethylbenzene	Xylenes	n-Propylbenzene	Toluene	Isopropylbenzene	Naphthalene	tert-Butylbenzene	n-Butylbenzene	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	p-Isopropyltoluene
MW-1	9/15/94	2440	292	ND	ND	ND	ND	2360	202	652	ND	ND	ND
	10/20/94	3340	353	443	ND	ND	ND	1930	ND	ND	ND	ND	ND
MW-2	9/15/94	236	124	104	ND	ND	ND	1000	66.6	279	ND	ND	ND
	10/20/94	659	178	207.7	ND	ND	ND	1020	ND	ND	ND	ND	ND
MW-3	9/15/94	1.2	ND	ND	ND	ND	ND	1.4	1.0	1.5	ND	ND	ND
	10/20/94	2.55	ND	ND	ND	ND	ND	1.15	ND	ND	ND	ND	ND
TW-1	9/15/94	513	46.6	104.2	ND	ND	ND	455	ND	ND	ND	ND	ND
	10/20/94	450	95.4	99.9	ND	ND	ND	749	ND	ND	ND	ND	38.7
TW-2	9/19/94	379	ND	ND	ND	ND	ND	98.2	ND	ND	ND	ND	ND
	10/20/94	578	71.1	52.4	ND	ND	ND	111	ND	ND	ND	ND	134
TW-3	9/15/94	8.3	11.4	33.7	ND	ND	ND	331	ND	7.2	12.2	ND	18.0
	10/20/94	546	43	52	ND	34.9	ND	701	ND	17.9	33.9	8.17	23.0
TW-4	9/19/94	ND	ND	ND	ND	ND	ND	29.9	ND	ND	ND	ND	ND
	10/20/94	1.29	5	ND	ND	ND	ND	52.2	ND	ND	ND	ND	9.18
TW-5	9/19/94	738	459	366	7.5	35.1	16.3	392	ND	615	67.5	12.2	ND
	10/20/94	601	308	251	ND	ND	ND	3120	ND	ND	67.9	ND	ND
TW-6	9/19/94	3150	1290	1285	ND	ND	ND	3,600	296	ND	ND	ND	ND
	10/20/94	3400	1370	1331	ND	ND	ND	4050	ND	ND	219	ND	ND
TW-7	9/19/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	10/20/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TW-8	9/15/94	1150	56.4	ND	ND	ND	ND	89.8	ND	ND	ND	ND	ND
	10/20/94	1590	82.3	ND	ND	ND	ND	151	ND	ND	ND	ND	ND
TW-9	9/19/94	833	1170	ND	ND	ND	ND	8740	ND	ND	ND	ND	ND
	10/20/94	1590	2300	2430	ND	ND	ND	18600	ND	ND	ND	ND	ND
TW-10	9/19/94	509	78.0	ND	ND	ND	ND	919	73.6	ND	ND	ND	ND
	10/20/94	479	ND	ND	ND	ND	ND	540	ND	ND	ND	ND	ND
TW-10 (Duplicate)	10/20/94	434	ND	ND	ND	ND	ND	529	ND	ND	ND	ND	ND

ND = Not detected above laboratory quantitation limit
Preventive Action Limits (PALs) and Enforcement Standards (ES) Published in ch. NR 140.10, Wis. Admin. Code, March, 1994
-- = ES/PAL Standards have not been developed

TABLE 7A

(Continued)
Summary of Groundwater Analytical Results
Volatile Organic Compounds
Concentrations in micrograms per liter (µg/l)

Well Number	Date Sampled	Parameter											
		Benzene	Ethylbenzene	Xylenes	n-Propylbenzene	Toluene	Isopropylbenzene	Naphthalene	tert-Butylbenzene	n-Butylbenzene	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	p-Isopropyltoluene
TW-11	9/19/94	ND	200	134	ND	ND	ND	2290	127	ND	ND	ND	ND
	10/20/94	ND	ND	ND	ND	ND	ND	1270	ND	ND	ND	ND	ND
TW-11 (Duplicate)	9/19/94	ND	186	125	ND	ND	ND	2210	ND	ND	ND	ND	ND
TW-12	9/19/94	141	53.3	ND	ND	ND	ND	530	ND	ND	ND	ND	73.3
	10/20/94	253	70	ND	ND	ND	ND	634	ND	ND	ND	ND	75.1
TW-13	12/2/94	20500	3180	5180	ND	10000	ND	8760	ND	ND	ND	ND	ND
Seep Sample	9/19/94	1640	ND	ND	ND	ND	ND	1300	ND	ND	ND	ND	ND
	10/20/94	3250	378	483	ND	ND	ND	2590	ND	ND	ND	ND	ND
AW-1	9/19/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	10/20/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
AW-2	9/19/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	10/20/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trip Blank	9/19/94	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	10/20/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Preventive Action Limit		0.5	140	124	-	68.6	-	8	-	-	-	-	-
Enforcement Standard		5	700	620	-	343	-	40	-	-	-	-	-

ND = Not detected above laboratory quantitation limit
Preventive Action Limits (PALs) and Enforcement Standards (ES) Published in ch. NR 140.10, Wis. Admin. Code, March, 1994
- = ES/PAL Standards have not been developed

TABLE 8

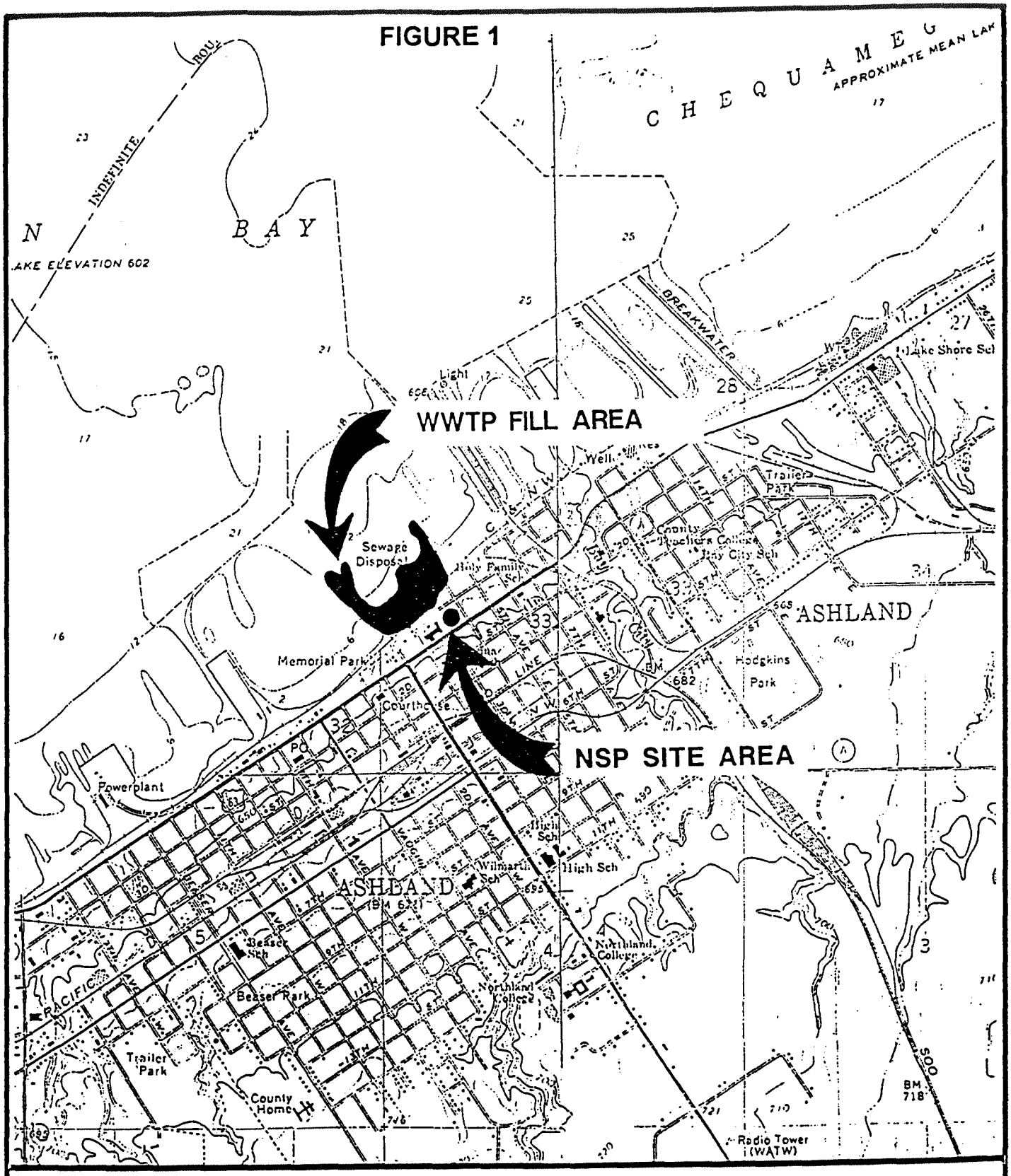
Summary of Groundwater Analytical Results
Polynuclear Aromatic Hydrocarbons
Concentrations in micrograms per liter (µg/l)

Well Number	Date Sampled	Parameter																
		Acenaphthene	Acenaphthylene	Anthracene	Benzo(a)-Anthracene	Benzo(a)Pyrene	Benzo(b)-Fluoranthene	Benzo(k)-Fluoranthene	Benzo(g,h,i)-Perylene	Chrysene	Dibenzo(a,h)-Anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-cd)-Pyrene	2-Methyl Naphthalene	Phenanthrene	Pyrene	Naphthalene
MW-1	9/15/94	185	5.16	8.25	4.37	3.39	2.69	ND	ND	ND	ND	9.39	44.4	ND	268	52.4	14.6	470
	10/20/94	182	7.93	20.4	10.4	10.6	8.50	2.10	4.97	9.03	ND	25.0	59.9	4.84	353	93.9	28.9	228
MW-2	9/15/94	7.85	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.81	1.34	ND	ND	0.812	3.40	0.894
	10/20/94	43.3	3.53	2.92	2.61	4.29	2.92	1.53	3.26	2.89	ND	4.85	9.54	2.75	91.4	11.2	6.79	857
MW-3	9/15/94	24.9	13.2	25.9	142	163	97.4	59.8	63.0	125	ND	169	ND	53.7	ND	33.8	502	ND
	10/20/94	ND	ND	ND	37.5	49.4	31.0	14.9	26.3	39.0	ND	65.7	ND	24.6	ND	ND	127	ND
TW-1	9/15/94	75.2	6.7	21.7	49.8	48.3	37.7	18.0	29.1	48.8	ND	78.9	24.2	24.1	7.56	28.5	188	12.0
	10/20/94	121	13.4	29.0	37.0	45.7	32.1	17.5	29.2	44.0	ND	80.8	38.3	24.2	55.0	53.4	125	58.7
TW-2	9/19/94	23.4	3.08	8.71	31.7	31.8	21.9	12.0	12.1	29.0	ND	51.0	8.50	10.9	ND	7.45	120	20.6
	10/20/94	33.3	3.65	7.03	17.0	17.1	13.6	5.97	7.48	17.8	1.45	37.0	10.8	6.57	ND	6.88	51.5	48.5
TW-3	9/15/94	194	31.5	107	172	206	142	81.5	103	158	ND	215	112	85.9	87.4	298	529	47.8
	10/20/94	164	36.5	83.7	80.4	115	72.9	37.0	67.8	89.1	ND	148	95.3	57.4	151	219	220	75.1
TW-4	9/19/94	38.9	6.34	21.7	41.8	45.2	32.5	10.2	ND	36.9	ND	51.6	16.2	ND	8.13	37.5	146	10.7
	10/20/94	37.2	8.03	19.7	18.9	22.3	15.7	9.53	13.6	20.7	ND	38.1	16.8	12.6	5.67	25.8	59.9	ND
TW-5	9/19/94	1,631	95.6	700	481	386	282	ND	192	427	ND	768	839	165	2,376	2,829	1,362	2,634
	10/20/94	243	17.3	91.6	42.2	46.6	31.3	14.9	26.1	43.7	ND	92.1	110	25.1	372	339	132	678
TW-6	9/19/94	2,301	142	1,131	685	507	375	ND	182	540	ND	1,107	1,005	153	2,693	3,751	2,192	5,907
	10/20/94	1,691	144	866	366	335	236	123	153	377	ND	775	671	136	2,034	2,482	1,152	5,500
TW-7	9/19/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	10/20/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TW-8	9/15/94	32.1	ND	2.02	2.64	ND	ND	ND	ND	1.75	ND	4.22	6.80	ND	3.59	8.84	6.14	62.6
	10/20/94	73.2	ND	6.61	5.22	ND	4.04	ND	ND	4.94	ND	11.4	16.9	ND	ND	22.5	12.4	140
TW-9	9/19/94	14,460	587	4,373	3,465	3,278	2,136	1,272	1,090	2,597	ND	5,615	4,644	1,044	16,465	24,186	13,911	39,749
	10/20/94	6,544	480	2,689	1,344	1,434	921	428	695	1,363	ND	3,215	2,663	571	7,252	8,925	4,241	19,267
TW-10	9/19/94	523	77.4	164	116	104	74.1	43.6	40.1	102	ND	176	223	36.5	977	864	420	1,005
	10/20/94	216	40.6	69.3	30.0	29.2	20.7	11.6	14.9	30.9	ND	70.2	101	13.8	149	229	89.2	23.1
TW-11	9/19/94	447	7.25	60.2	27.1	14.5	12.6	9.36	ND	19.7	ND	47.8	122	ND	732	280	85.5	2,794
	10/20/94	375	17.1	113	36.2	27.5	20.5	14.5	12.4	34.9	ND	88.2	159	11.6	518	282	109	656
TW-12	9/19/94	39.3	2.47	1.09	ND	7.59	5.46	2.33	14.4	ND	ND	2.19	6.11	10.2	5.18	4.42	4.85	459
	10/20/94	68.1	ND	ND	ND	5.37	ND	ND	7.45	ND	ND	ND	11.9	5.76	9.44	6.81	ND	563
TW-13	12/02/94	914	3,570	1,685	921	898	715	339	389	843	ND	1,862	1,879	362	9,780	6,072	3,380	24,769
AW-1	10/20/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
AW-2	9/19/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	10/20/94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Seep Sample	9/19/94	26,429	2,130	8,056	6,764	5,866	4,753	2,201	2,891	5,626	ND	13,235	11,009	2,522	38,120	62,103	39,877	18,776
	10/20/94	19,625	3,823	8,842	6,800	7,754	6,260	3,066	4,022	7,298	624	15,725	11,437	3,578	24,594	38,293	22,136	30,250
PAL	--	--	--	--	--	--	0.0003	--	--	--	--	--	--	--	--	--	--	--	8
ES	--	--	--	--	--	--	0.003	--	--	--	--	--	--	--	--	--	--	--	40

ND = Not detected above laboratory quantitation limit
Preventive Action Limits (PALs) and Enforcement Standards (ES) published in CH NR 140.10, Wis. Admin. Code, March 1994

-- = ES/PAL Standards have not been developed

FIGURE 1



BASE MAP SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC QUADRANGLE, ASHLAND EAST AND ASHLAND WEST, WISCONSIN, DATED 1964, PHOTOREVISED 1975.

QUADRANGLE LOCATION

NORTH

SCALE: 1" = 2000'

NSP ASHLAND LAKEFRONT SITE INVESTIGATION

FIGURE 1
SITE LOCATION MAP

DRWN. BY EAP	PROJ. NO.
DATE JAN., 1995	DAMES & MOORE

KEY TO FIGURES

KEY TO COMPOUNDS PLOTTED IN FIGURES 2 THROUGH 7

COMP ID	COMPOUND NAME
	VOCs
1	BENZENE
2	ETHYLBENZENE
3	TOLUENE
4	XYLENES
	PAHs
5	ACENAPHTHENE
6	ACENAPHTHYLENE
7	ANTHRACENE
8	BENZO(a)ANTHRACENE
9	BENZO(a)PYRENE
10	BENZO(b)FLUORANTHENE
11	BENZO(ghi)PERYLENE
12	BENZO(k)FLUORANTHENE
13	CHRYSENE
14	DIBENZO(A,H)ANTHRACENE
15	FLUORANTHENE
16	FLUORENE
17	INDENO(1,2,3-cd)PYRENE
18	NAPHTHALENE
19	PHENANTHRENE
20	PYRENE

FIGURE 2

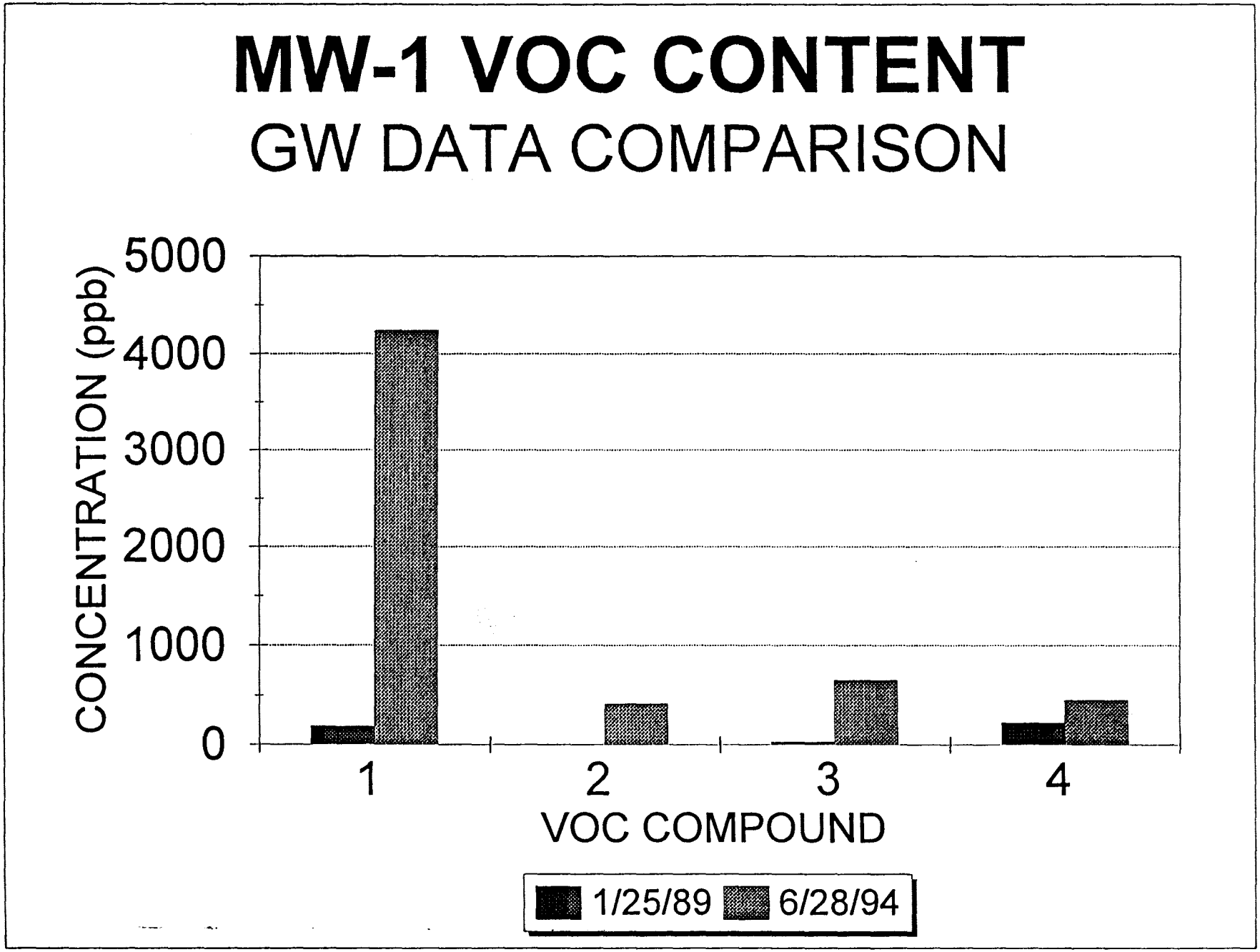

MW-1 VOC CONTENT
GW DATA COMPARISON
CONCENTRATION (ppb)
5000
4000
3000
2000
1000
0
1
2
3
4
VOC COMPOUND
1/25/89
6/28/94

FIGURE 3

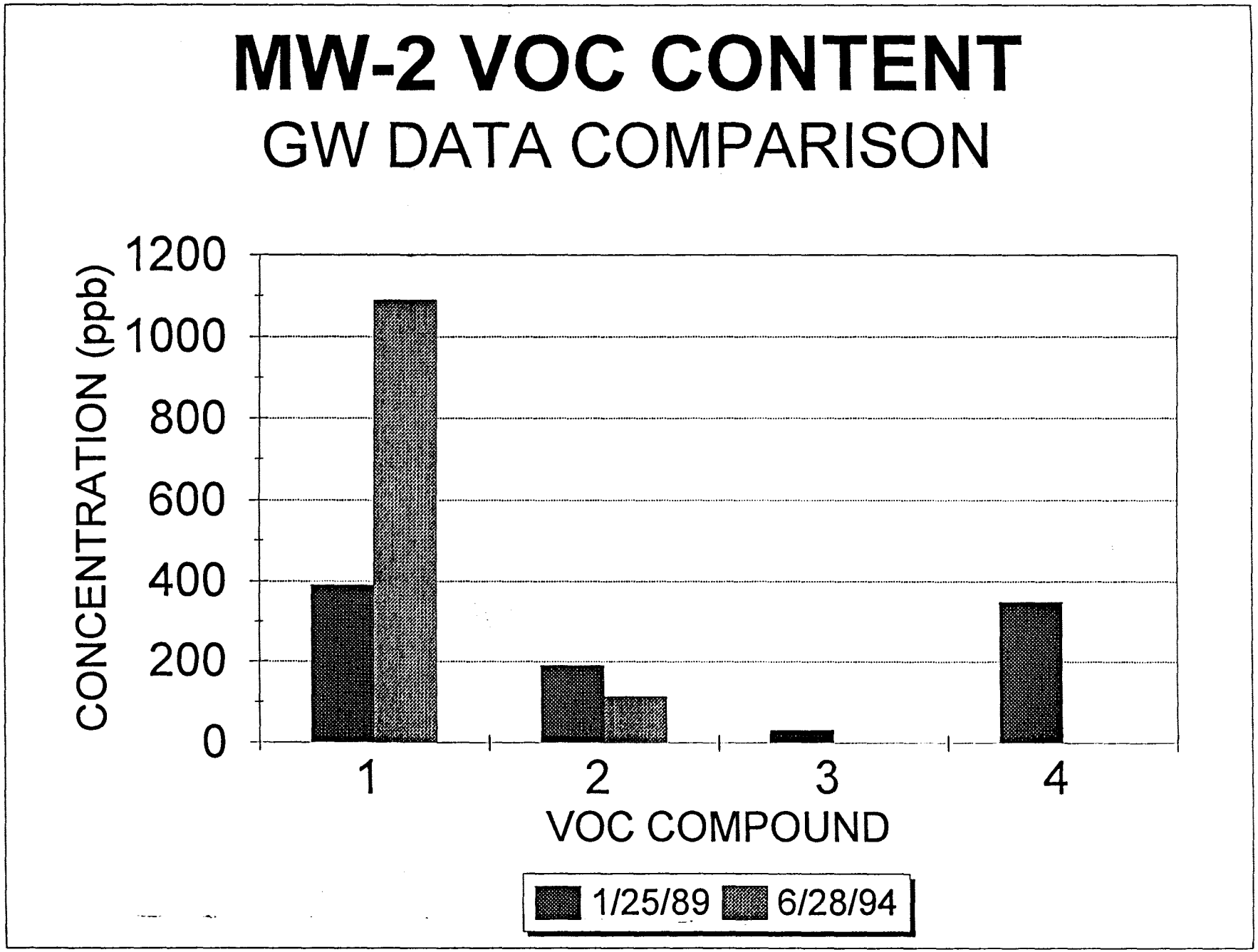

MW-2 VOC CONTENT
GW DATA COMPARISON
CONCENTRATION (ppb)
1200
1000
800
600
400
200
0
1
2
3
4
VOC COMPOUND
1/25/89
6/28/94

FIGURE 4

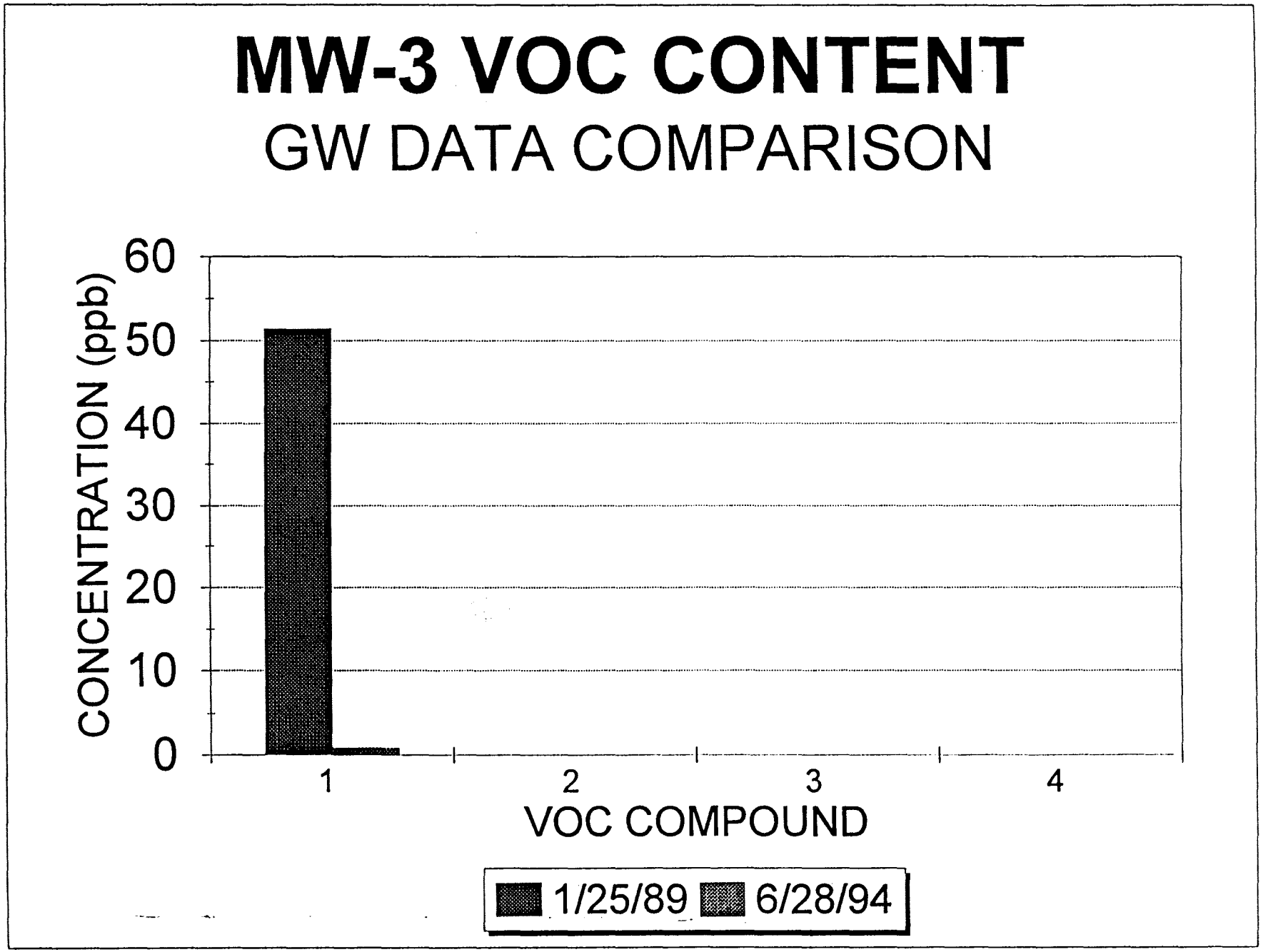

MW-3 VOC CONTENT
GW DATA COMPARISON
CONCENTRATION (ppb)
60
50
40
30
20
10
0
1
2
3
4
VOC COMPOUND
1/25/89
6/28/94

FIGURE 5

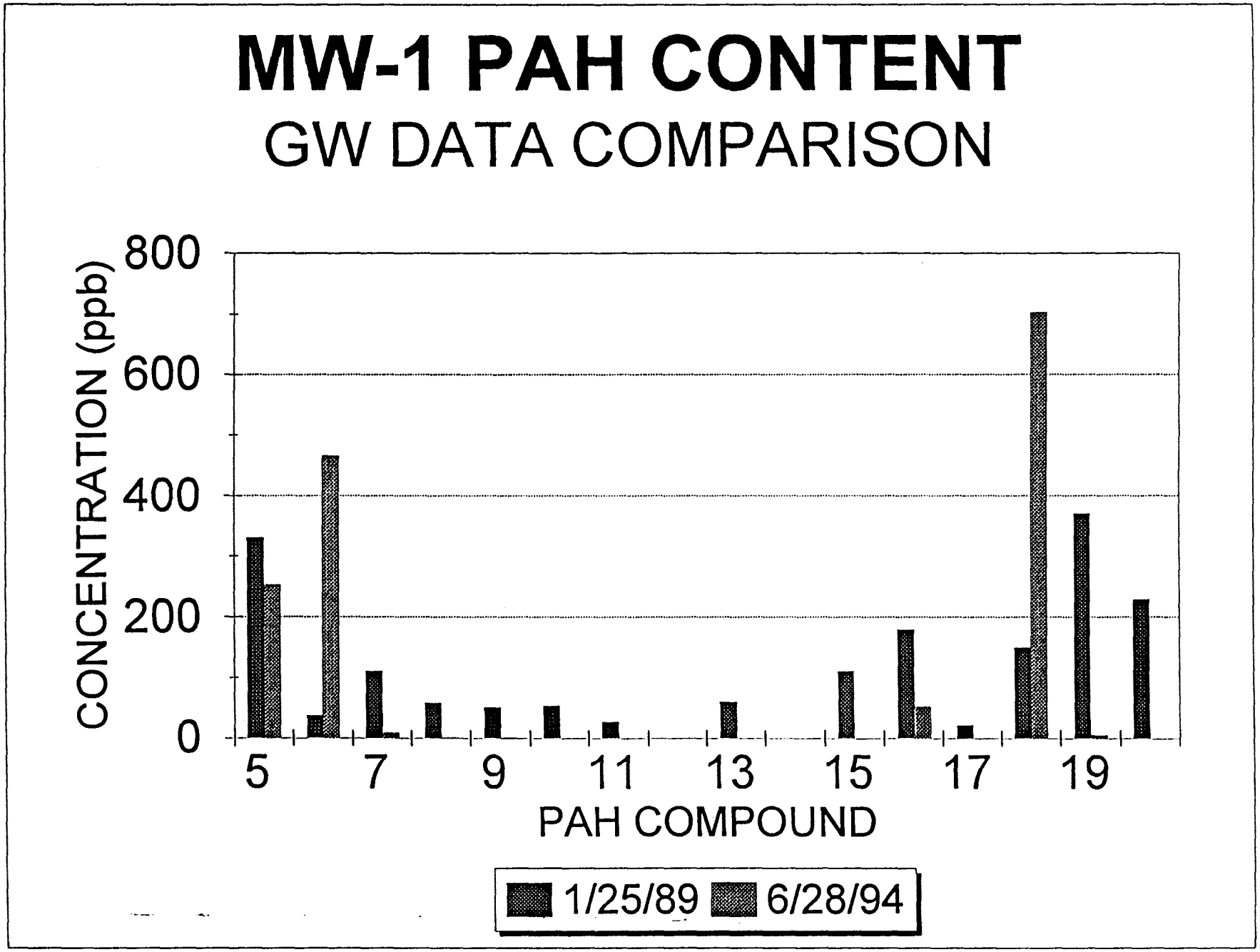

MW-1 PAH CONTENT
GW DATA COMPARISON
CONCENTRATION (ppb)
800
600
400
200
0
5
7
9
11
13
15
17
19
PAH COMPOUND
1/25/89
6/28/94

FIGURE 6

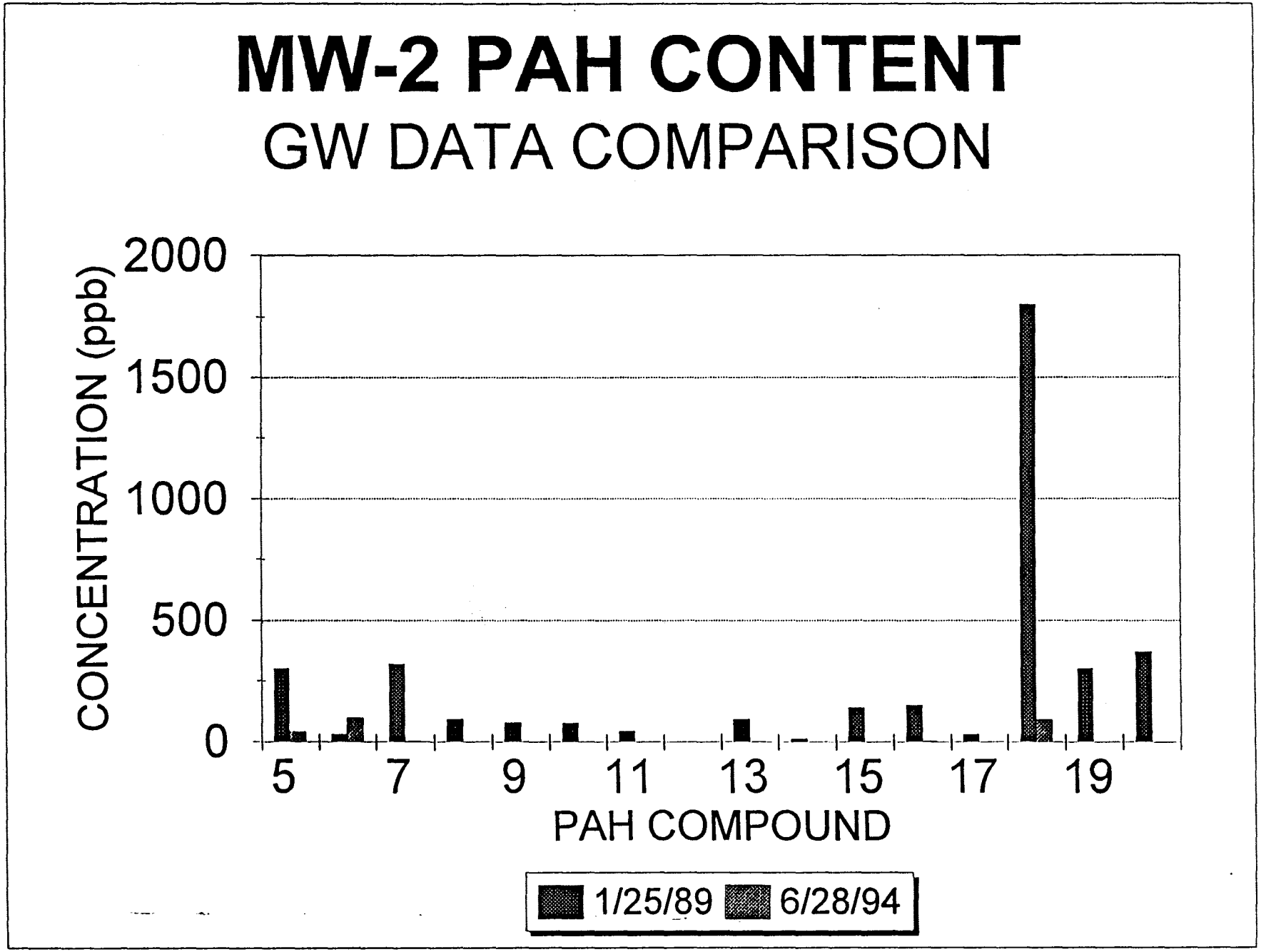

MW-2 PAH CONTENT
GW DATA COMPARISON
CONCENTRATION (ppb)
2000
1500
1000
500
0
5
7
9
11
13
15
17
19
PAH COMPOUND
1/25/89
6/28/94

FIGURE 7

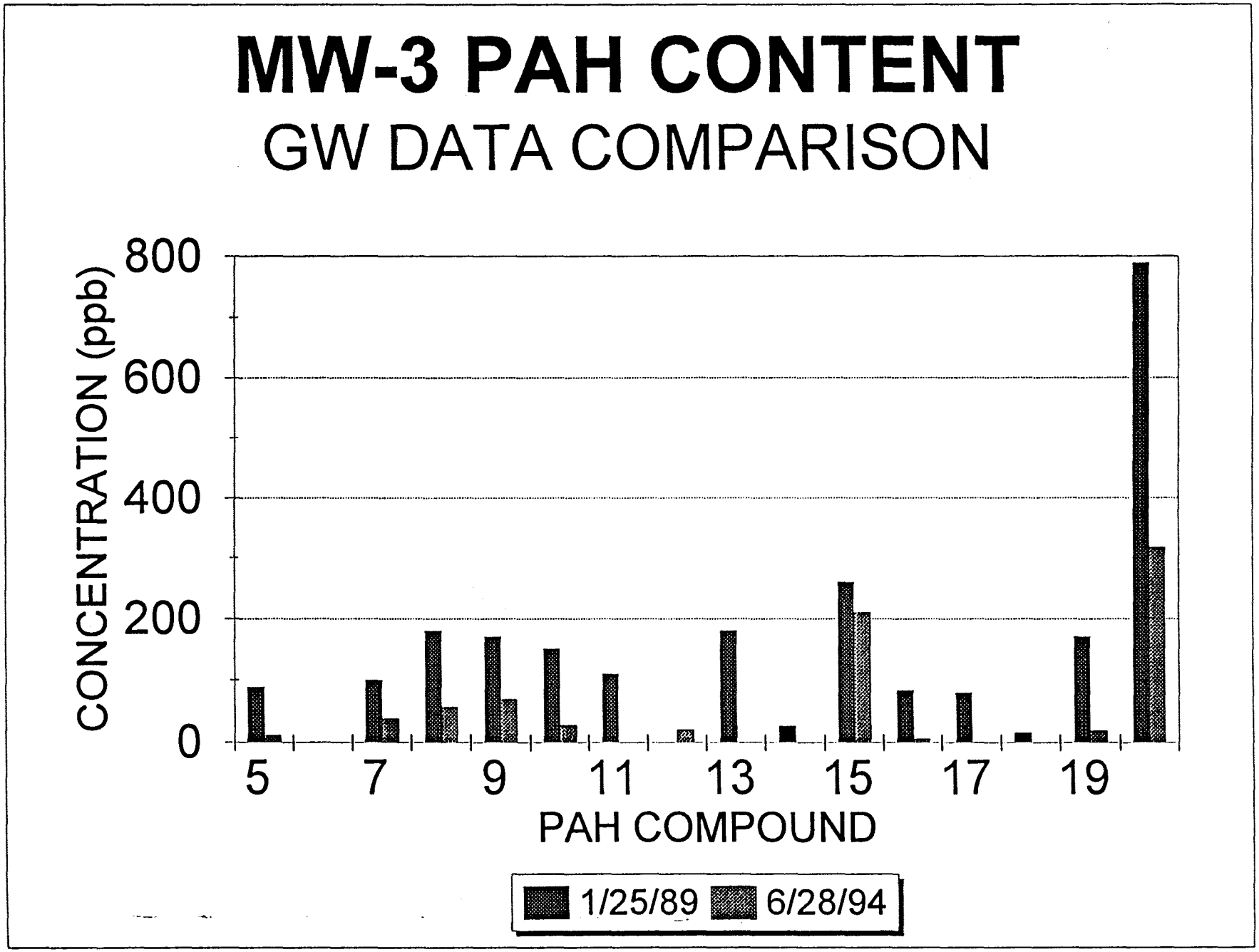
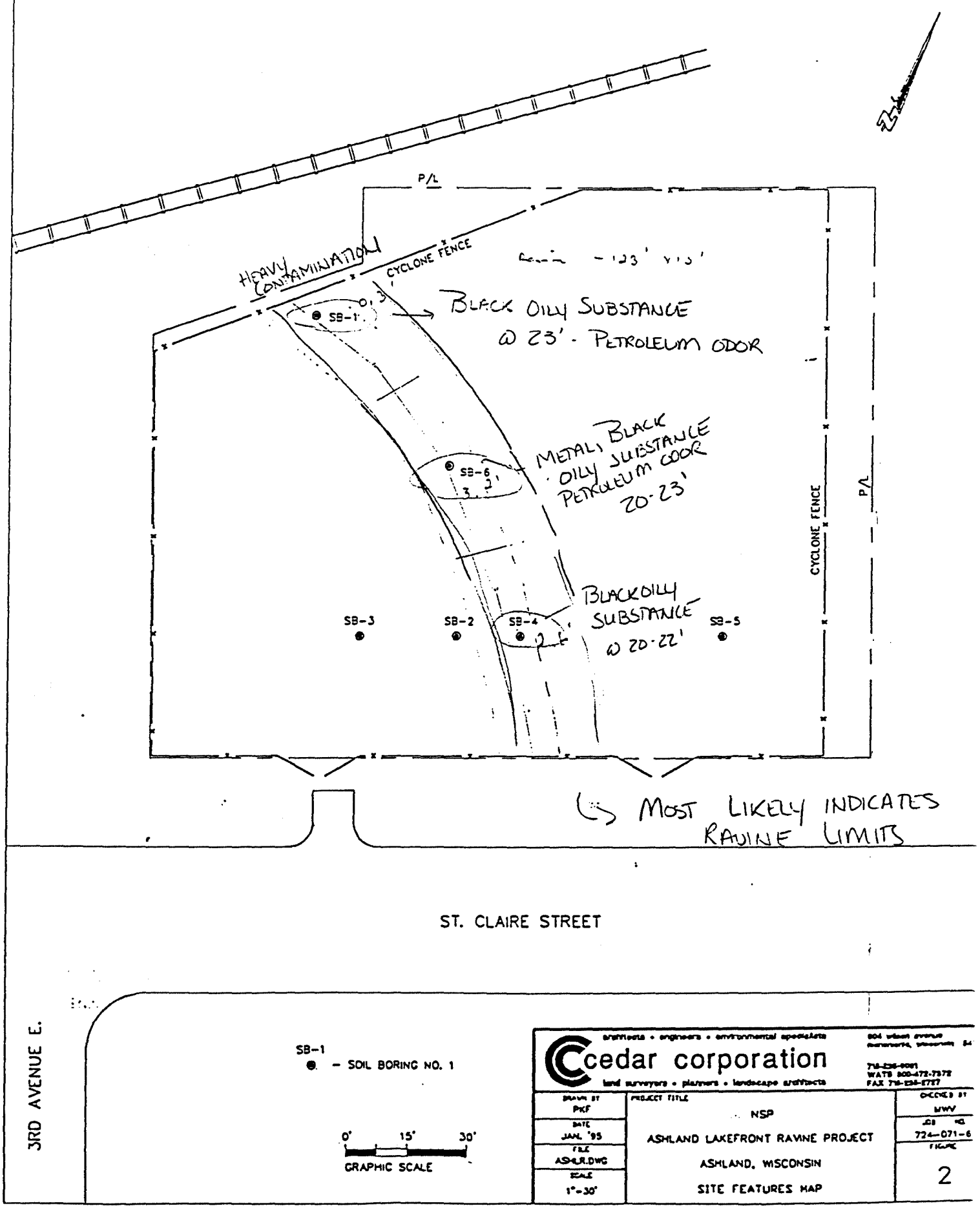

MW-3 PAH CONTENT
GW DATA COMPARISON
CONCENTRATION (ppb)
800
600
400
200
0
5
7
9
11
13
15
17
19
PAH COMPOUND
1/25/89
6/28/94

FIGURE 8



P/L
CYCLONE FENCE
HEAVY CONTAMINATION
SB-1
BLACK OILY SUBSTANCE @ 23' - PETROLEUM ODOR
SB-6
METAL, BLACK OILY SUBSTANCE PETROLEUM ODOR 20-23'
BLACK OILY SUBSTANCE @ 20-22'
SB-3
SB-2
SB-4
SB-5
CYCLONE FENCE
P/L
MOST LIKELY INDICATES RAVINE LIMITS
ST. CLAIRE STREET
3RD AVENUE E.
SB-1 - SOIL BORING NO. 1
0' 15' 30'
GRAPHIC SCALE
architects • engineers • environmental specialists
cedar corporation
land surveyors • planners • landscape architects
DRAWN BY PKF
DATE JAN. '95
FILE ASHLR.DWG
SCALE 1"=30'
PROJECT TITLE
NSP
ASHLAND LAKEFRONT RAVINE PROJECT
ASHLAND, WISCONSIN
SITE FEATURES MAP
CHECKED BY MWV
JOB NO. 724-071-6
FIGURE 2