FINAL REPORT

STUDY OF GROUNDWATER CONTAMINATION IN ST. LOUIS PARK, MINNESOTA

NOVEMBER 1981

MINNESOTA DEPARTMENT OF HEALTH

Eugene A. Hickok and Associates, Inc.
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November 20, 1981

Dr. George Pettersen, M.D.
Commissioner of Health
Minnesota Department of Health
717 SE Delaware Street
Minneapolis, Minnesota 55440

Re: Study of Groundwater Contamination in
St. Louis Park, Minnesota

Dear Dr. Pettersen:

Transmitted herewith is the final report on our study of groundwater contamination in St. Louis Park, Minnesota. Appendices to this report are bound in a separate volume.

We appreciate the opportunity to assist the Department of Health through this study and are grateful for the Department's cooperation.

Sincerely,

EUGENE A. HICKOK AND ASSOCIATES

E. A. Hickok

E. A. Hickok, P.E.
President

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MINNESOTA DEPARTMENT OF HEALTH

Prepared by

EUGENE A. HICKOK AND ASSOCIATES
Wayzata, Minnesota

GERAGHTY AND MILLER, INC.

HENNINGSON, DURHAM AND RICHARDSON, INC.

FINAL REPORT

STUDY OF GROUNDWATER CONTAMINATION
IN ST. LOUIS PARK, MINNESOTA

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly registered Professional Engineer under the laws of the State of Minnesota.

John B. Erdmann — Nov. 20, 1981

John B. Erdmann
Reg. No. 14241

November 20, 1981

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I. EXECUTIVE SUMMARY

This report presents findings, preliminary designs and expense estimates for remedial actions relating to groundwater and soil contamination by coal-tar wastes from the former Republic Creosoting site in St. Louis Park, Minnesota. Polynuclear aromatic hydrocarbons (PAH), which are major constituents of creosote and coal-tar and which include several carcinogenic compounds, have been observed in St. Louis Park groundwater samples at concentrations exceeding proposed criteria for potable use.

The affected aquifers include the Prairie du Chien-Jordan, the major aquifer in the Twin Cities area. If groundwater movement is not controlled in the Prairie du Chien-Jordan and shallower aquifers, the generally eastward groundwater flow will eventually carry PAH to the Mississippi River or other tributary surface waters, which can be expected to preclude future potable use (without treatment) in the affected area.

A gradient control well system with wells in all aquifers can effectively control the groundwater PAH contamination, and such a system is feasible. Water produced from the gradient control wells could be treated for potable use or be discharged to sanitary sewers or to the Mississippi River via storm sewers. The gradient control well system would need to operate for an indefinite period in some aquifers.

Removal of highly contaminated fluid in the glacial drift and excavation of surficial peat and associated fluid at the south of the former Republic site could significantly benefit groundwater quality in the underlying bedrock aquifers.

It is recommended that a gradient control well system be implemented in order to protect downgradient groundwater. It is also recommended as an interim measure that surficial peat deposits at the south of the former Republic site be capped with low-permeability material. These measures can be undertaken at an estimated capital expense of approximately seven million dollars, with additional annual expenses of approximately one million dollars.

Further conclusions and recommendations appear in the final sections of the report and are fully documented in the report appendices.

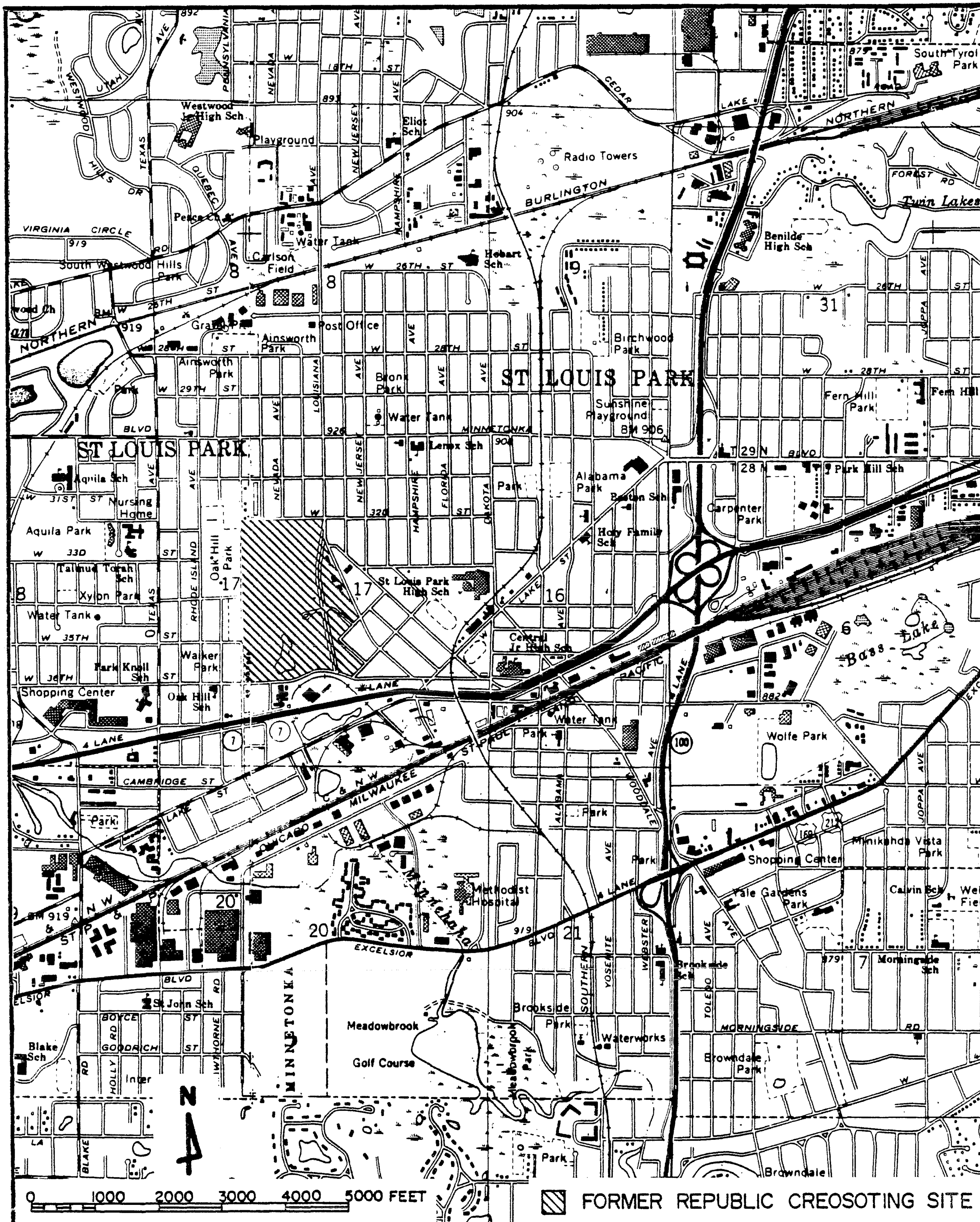
II. INTRODUCTION

In May 1980, the State of Minnesota, acting through its Commissioner of Health, retained the firm of E. A. Hickok and Associates of Wayzata, Minnesota to conduct a study relating to contamination of groundwater and soils by coal-tar wastes from Reilly Tar and Chemical Company's former Republic Creosoting plant site in St. Louis Park. The basic objectives of the study were to assess the feasibility of 1) controlling movement of contaminated groundwater by pumping from wells, 2) excavating contaminated soils, and 3) treating and disposing of the residual waste products. This report, which contains the findings of the assessment, presents preliminary designs and cost estimates for each of the remedial procedures. Separately bound appendices represent technical memorandums produced in the course of the study, and contain the detailed basis for the present report.

A. Background of the Situation

For a period of more than 50 years ending in 1971, the Republic Creosoting Company engaged in the distillation of coal-tar products and the impregnation of materials with creosote on an 80 acre site in St. Louis Park. The site (Figure 1) is west of the present Louisiana Avenue extension, east of Pennsylvania Avenue, north of Walker Street, and south of West 32nd Street.

As a result of the creosote plant operations, substantial amounts of soil on and south of the property have been contaminated with coal-tar wastes, and in addition, leachates from the wastes have



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moved downward to contaminate groundwater in aquifers that serve as sources of water supply in the region. The contaminated groundwater in the uppermost aquifer extends in an easterly direction approximately one mile. Leachate has infiltrated deeper aquifers through open boreholes and possibly through natural openings where the aquifers are not separated by relatively impermeable confining beds. To date, the contamination has resulted in the closure of seven municipal water supply wells and threatens the continued operation of other wells in St. Louis Park and adjoining municipalities.

The State of Minnesota has been concerned for many years over the negative health implications of this situation and has funded several previous investigations to better define the problem and to explore ways of remedying it. The major health concern is that some chemical components of the coal-tar wastes (polynuclear aromatic hydrocarbons) are known to be carcinogenic.

B. Previous Investigations

The Minnesota Department of Health reported in 1938 that liquid wastes were being discharged to a peat bog near the southern portion of the site. Phenol data for several wells in the area and for the liquid wastes were also reported.

A 1969 study by consultants to the City of St. Louis Park reported measurable phenols in 14 municipal wells and in soil samples in the vicinity of the site. The report observed that improperly constructed wells in the area could serve as conduits for vertical migration of contaminants.

A report completed by the Minnesota Department of Health in 1974 concluded that measurable amounts of phenolic compounds, in varying concentrations, had been found in water from more than 20 private and municipal wells in the St. Louis Park area. The report presented evidence of contamination of groundwater by phenolic compounds in several aquifer zones down to a depth of about 900 feet, with the highest concentrations of the compounds being at sites close to the former creosote plant. (The majority of analyses were for the Prairie du Chien-Jordan aquifer and ranged from less than 2 up to 7 parts per billion.) The report also pointed out that soil borings near the plant site showed the presence of a black viscous material with a strong creosote odor at depths of about 45 feet.

In July 1977, a two-phase study was completed by consultants to the Minnesota Pollution Control Agency to determine the amount and location of coal-tar derivatives in the surficial deposits and to define patterns of vertical and horizontal groundwater flow through the aquifers. The report of the study indicated that large quantities of coal-tar wastes were present at depths of 50 to 60 feet over a relatively large area and that excavation of those wastes undoubtedly would be very expensive. It also concluded that the slow movement of contaminated groundwater might be controlled or reversed by pumping from specially designed wells in the affected aquifers.

In 1977 and 1978, the Minnesota Department of Health released reports on the possible health effects from the contamination of the former Republic Creosoting site. The reports discussed the possibility of exposure of people through contact with the contaminated soils on the site and indicated that a study was needed on the feasibility of excavating and removing those soils in order to remedy this potential threat.

The U.S. Geological Survey (USGS) released a report on the groundwater contamination in St. Louis Park in January 1981. This report contains much useful data on the hydrogeology and nature of contamiantion.

C. Scope of this Investigation

The present investigation was designed to provide technical data and design concepts on the feasibility of controlling the movement of contaminated groundwater by pumping from wells and excavating contaminated soils. Both remedial actions involve removal from the subsurface of contaminated materials, which may have to be treated prior to disposal in order to reduce their threats to health and the environment. Thus, major objectives of the investigation were to suggest acceptable levels of contaminants and to determine the methods and costs of different treatment alternatives. The assessment of treatment methods includes results of pilot experiments conducted by and for the City of St. Louis Park.

The report also examines alternatives for the ultimate disposition of water and contaminated soil and explains the engineering requirements and their cost components. The potential environmental consequences also are discussed.

D. Sources of Information

The information upon which the present report is based has been derived from many sources, including the major reports referred to previously that dealt specifically with the contamination situation at the former creosote plant site. In addition, an intensive review has been made of published and unpublished data on the regional geology and hydrology, groundwater use, locations of buried bedrock valleys, experiences with coal-tar wastes in similar hydrogeologic environments, and standards for acceptable levels of contaminants in other parts of the nation.

E. Acknowledgements

E. A. Hickok and Associates was assisted in this project by the firms of Geraghty and Miller and of Henningson, Durham and Richardson. Geraghty and Miller were involved with the groundwater aspects of the study while Henningson, Durham and Richardson provided input for water treatment aspects.

E. A. Hickok and Associates expresses its appreciation for the valuable ideas and suggestions provided by the U.S. Geological Survey, the Minnesota Department of Health, the Minnesota Pollution Control Agency, the Office of the Attorney General of Minnesota, the Minnesota Department of Natural Resources, the City of St. Louis Park and others.

III. LITERATURE REVIEW

Several computerized bibliographic data bases and other sources were searched for information on creosote and polynuclear aromatic hydrocarbons (PAH). One topic of special concern is environmental criteria, or acceptable levels, for PAH. There are at present no official standards, on either the State or Federal level, for PAH in ambient waters or municipal water supplies. Another important topic is treatment technology for PAH removal. The literature review focused on these two topics.

A. Acceptable Contaminant Levels

A review of some 50 documents relevant to acceptable PAH levels is contained in Appendix G entitled "Literature Review - Acceptable Contaminant Levels." A brief review of critical documents and a discussion of criteria proposed during this study to provide a framework for the study's completion follows.

The primary concern over PAH contamination stems from the cancer-causing, or carcinogenic, property of a number of PAH compounds. Some 12 PAH compounds are listed as "having substantial evidence of carcinogenicity" in the July 14, 1980 EPA publication, "The Carcinogen Assessment Group's List of Carcinogens." These compounds are shown in Table 1 - Carcinogenic PAH. It should be noted that this list is almost surely incomplete since relatively few of the many PAH compounds have been thoroughly investigated for carcinogenicity. Also, other harmful chemical constituents may be present in St. Louis Park groundwater.

TABLE 1

Carcinogenic PAH

Benz(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(j)fluoranthene
Chrysene
Dibenz(a,h)anthracene
Dibenzo(a,e)pyrene
Dibenzo(a,h)pyrene
Dibenzo(a,i)pyrene
7,12-dimethylbenz(a)anthracene
Indeno(1,2,3-c,d)pyrene
3-Methylcholanthrene

SOURCE: U.S. Environmental Protection Agency, "The Carcinogen Assessment Group's List of Carcinogens," July 14, 1980.

Two agencies in recent years have established PAH criteria for waters. The World Health Organization in 1971 specified a maximum permissible concentration in drinking water of 200 nanograms per liter (ng/l), or parts per trillion, for the sum of six PAH compounds (fluoranthene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i) perylene and indeno (1,2,3-c,d) pyrene). This criterion does not have a firm toxicological basis and has generally come to be regarded as obsolete.

The U. S. Environmental Protection Agency (EPA) published a document entitled "Ambient Water Quality Criteria for Polynuclear Aromatic Hydrocarbons" in 1978, with an updated version in October 1980. It is widely held that there is no threshold level for carcinogens. Instead, it is believed that very low exposure does cause cancer, but at a proportionately low rate of incidence. This concept is embodied in the October 1980 EPA document, which states:

> For the maximum protection of human health from the potential carcinogenic effects due to exposure of polynuclear aromatic hydrocarbons through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical.
>
> However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6} and 10^{-7}. The corresponding recommended criteria are 28.0 ng/l, 2.8 ng/l and 0.28 ng/l, respectively.

These EPA criteria are based on a study of the specific compound benzo(a)pyrene (BaP). BaP is believed to be the most potent carcinogen of the PAH. Therefore it is conservative, and reasonable, to use BaP as a basis for other PAH criteria.

Potable Water. The criteria proposed during this study for potable water are based on the EPA criteria, as applied to individual PAH compounds. Although hundreds of PAH compounds are known, less than 20 specific PAH have been certainly identified in St. Louis Park groundwater. Separate criteria are proposed for those PAH known to be carcinogenic, and for all other PAH. Limits for "other PAH" are set due to concern for synergistic effects.

The Minnesota Department of Health has commonly adopted a risk level of 10^{-5} for single chemical species. However, a risk level of 10^{-6} is more appropriate for individual carcinogenic PAH compounds, since several such compounds can occur together in creosote-contaminated water. The 10^{-6} risk level corresponds to a concentration limit of 2.8 ng/l for carcinogenic PAH; however, it is proposed to consider the detection limit as the criterion whenever the detection limit exeeds 2.8 ng/l for a compound.

For other PAH, a concentration limit of 28.0 ng/l is proposed. This corresponds to a 10^{-5} risk level for BaP, but it cannot be related to a risk level for these "other PAH" since they are (at least presumably) non-carcinogenic. This is a purely judgmental limit. It is intended to prevent substantial synergism with carcinogenic PAH possibly present at low levels. As with the carcinogenic limit, whenever a detection limit exceeds 28.0 ng/l it serves to define the acceptable level in that case.

The proposed criteria are within the range of minimum detection limits (generally 0.5-10.0 ng/l for carcinogenic PAH in the Minnesota Department of Health laboratory), making their practical application difficult.

Groundwater. The proposed criteria for groundwater are identical with those for potable water. Groundwater in the region is generally of excellent quality, and is widely and heavily used for drinking water.

Soil. As discussed here, "soil" refers primarily to glacial drift material at any depth above the bedrock surface, rather than only the top few feet of the unconsolidated deposits. The proposed criteria for soil are determined by multiplying the potable water criteria (2.8 ng/l and 28.0 ng/l, respectively, for carcinogenic and "other" PAH) by a Sorption Factor, which describes the tendency for a compound to be adsorbed by (i.e., adhere to) soil particles. The Sorption Factor is the ratio of adsorbed to dissolved concentrations of a compound at equilibrium; it is also called the "partition coefficient."

The literature on PAH sorption concerns sorption on soil, sediment and artifical media. Values of the partition coefficient, K_p, are reported for eight PAH compounds on various natural and artificial media and range over several orders of magnitude (May, 1980; Means et al., 1979; Means et al., 1980; and Southworth, 1979). The generally lower values reported by May (1980) appear to be descriptive of the Middle Drift aquifer (see Section V), because it is a sand and gravel aquifer expected to be low in organic carbon content - a physical characteristic of soils which has been positively correlated with K_p values (Means et al., 1979; and Means et al., 1980).

Values of the octanol-water partition coefficient (a parameter related to K_p) reported for many PAH compounds by Yalkowsky and Valvani (1979) were used to extend the limited data of May (1980) by logrithmic regression. Resulting K_p values are 60 to 168 liters/kg for the five carcinogenic PAH, and 5 to 23 liters/kg for the five "other" PAH, most frequently showing highest concentrations in the monitored wells in St. Louis Park.

From this it is concluded that K_p values of 100 liters/kg for carcinogenic PAH and 10 liters/kg for "other" PAH are representative of the Middle Drift aquifer. These lead to soil criteria of 280 ng/kg for individual PAH compounds, whether carcinogenic or not.

Surface Water. Various criteria have been considered for surface waters and discharge into surface waters.

The most stringent surface water criteria were based on a high rate of fish consumption from the Mississippi River (one pound per capita daily), assumed for a critical population group in the Twin Cities (the Hmong). This resulted in a limit of 0.018 ng/l for each carcinogenic PAH in the Mississippi River, with a corresponding limit of 0.18 ng/l for each PAH not known to be carcinogenic. If these strict criteria were adopted for the Mississippi River, it would be consistent to apply them also to Minnehaha Creek and other local surface waters. Another set of criteria is based on meeting the potable water criteria in any surface receiving water. The potable criteria were discussed previously. In this and the previous criteria, detection limits would serve as criteria whenever exceeding the defined limits for individual compounds.

Two further criteria come directly from the October, 1980 EPA criteria document; they are 31.1 and 311 ng/l for "total" PAH, corresponding to risk levels of one in 1,000,000 and one in 100,000, respectively. These criteria are based on fish consumption only of 6.5 grams per day and a low bioconcentration factor. The Minnesota Pollution Control Agency suggests that these criteria be investigated, and that they be interpreted as applying to the sum of detectable concentrations only. That is, all concentrations reported "below detection limits" would be assumed to be zero for purposes of summing the "total" PAH, provided the minimum detection limits are sufficiently low. Specific guidelines would need to be established for the adequacy of detection limits.

In summary, four surface water criteria are considered here, as shown below in Table 2.

TABLE 2

Possible Surface Water Criteria for PAH*

	PAH Limits (ng/l)
1. Conservative Fish Intake Criteria	
Each Carcinogenic PAH	0.018
Each "Other" PAH	0.18
2. Potable Criteria	
Each Carcinogenic PAH	2.8
Each "Other" PAH	28.0
3. EPA Fish Intake Criterion (10^{-6} risk)	
"Total" PAH	31.1
4. EPA Fish Intake Criterion (10^{-5} risk)	
"Total" PAH	311.

*Fish consumption assumed to be one pound (454 grams) daily in criteria 1, and 6.5 grams daily in criteria 3 and 4. Different bioconcentration factors are used in criteria 3 and 4 versus criteria 1. Note that criteria 1 and 2 also are based on EPA criteria but apply to individual compounds.

B. Treatment Technology

Presented here is a concise review of treatment technology for PAH removal. Appendix C entitled "Collection and Treatment of Gradient Control Well Discharge" includes a more extensive review.

Polynuclear aromatic hydrocarbons (PAH) are compounds of two or more aromatic rings, where adjacent rings share two carbon atoms. Identification of PAH dates back at least to the 1940's, when solubility ranges for phenanthrene and benzo(a)pyrene were derived (David, 1942). The first investigations of PAH in surface and groundwaters were reported in Germany in the early 1960's (e.g., Borneff and Fischer, 1962). In the 1970's, significant studies were conducted on PAH levels in surface and ground waters in the United States (National Organic Monitoring Survey, 1978; Saxena et al., 1977; Basu et al., 1978).

Several investigators have found conventional treatment methods, including clarification and chlorination, to be capable of significant PAH removal. However, such methods favor removal of sorbed and higher molecular weight PAH. Clarification appears to be effective for surface waters, in which PAH are predominantly associated with particulates, but not for groundwaters. Removal of PAH through chlorination can result in synthesis of new compounds which may be more toxic and/or carcinogenic than the original PAH.

As early as 1962, Borneff and Fischer (1962) reported 99 percent PAH removal using activated carbon filtration. Later, 99 percent removal of PAH was demonstrated using ten types of activated carbon (Borneff, 1978). Further studies suggest that activated carbon, whether granular or powdered, is an effective method for removal of PAH. However, there is some evidence that activated carbon is not as effective for PAH removal at concentrations less than 20 ng/l for individual compounds (Borneff, 1977). Detection limits for PAH measurement probably play a role in this apparent reduced effectiveness at low initial concentrations, and 20 ng/l is not a lower limit of PAH treatability.

The U. S. Environmental Protection Agency has promulgated Interim Primary Drinking Water Regulations in accordance with the provisions of the 1974 Safe Drinking Water Act (PL 93-523). Considerable debate and research on many areas of the regulations, including the most appropriate technique for elimination of certain organics for drinking water, has occurred since their issuance. Proposed amendments to the regulations (Federal Register, February 9, 1978) strongly suggest the use of granular activated carbon as the treatment technique of choice for controlling synthetic organic chemicals. At present, alternative equivalent processes require a variance from the appropriate regulatory agency, though it appears this may change in view of recent research and experimental studies.

Other available treatment processes for removing organic chemicals include powdered activated carbon, aeration, synthetic resins, biologically mediated filtration, improved coagulation, chlorination, ozonation and ultraviolet light exposure. Much research and experimentation have been conducted on removal or control of such contaminants as trihalomethane with these processes. However, very little information is available on PAH removal with these processes.

In 1980-1981, E. A. Hickok and Associates conducted for the City of St. Louis Park a pilot plant study of three treatment techniques for PAH removal. The three techniques were powdered activated carbon (PAC), granular activated carbon (GAC) and hydrogen peroxide-ultraviolet light. The results of the pilot plant study were submitted to the City in a report entitled, "Drinking Water Treatment and Remedy Evaluation" (April 1981). The report concluded the following:

1. Additional studies are necessary in order to fully understand the effectiveness of PAC and GAC as a permanent treatment method.

2. Analytical procedures at the present time are unable to detect with any reliability and repeatability at the 1.0 ng/l level (one part per trillion).

3. Carcinogenic PAH compounds appear at relatively low concentrations (St. Louis Park municipal well 15).

4. PAH appear to be highly variable in concentrations within a 24-hour period.

5. Both PAC and GAC are capable of removing 95 to 99 percent of the PAH compounds providing the raw water concentrations are above 20 ng/l.

6. Removal efficiencies are generally better for the non-carcinogenic PAH compounds.

7. Hydrogen peroxide at a concentration of 6 mg/l and 2 mg/l followed by 20 seconds of ultraviolet light exposure does not remove PAH compounds.

While additional pilot plant studies are required to fully understand and verify the use of activated carbon for PAH removal, the results of the Hickok study and studies by others indicate that removal efficiencies as high as 99 percent can be achieved. Granular activated carbon is favored over powdered because of the significant problem with powdered carbon of treating or disposing of daily backwash water.

IV. STUDY METHODOLOGY

A. General Approach

The general approach of this study was to utilize existing data in the formulation of remedial measures for groundwater and soil contamination. The study did not include field investigations. Instead, it made use of field data from previous investigations and on-going monitoring by the Minnesota Department of Health, U.S. Geological Survey and others. Appendix F, "Review and Evaluation of Data," discusses information considered in the study. Information deficiencies relevant to the contamination of soil and groundwater and its remedy in St. Louis Park are described in Appendix H, "Information Deficiencies." Data through August 1981 have been incorporated into the present report.

More than 25 meetings plus additional frequent contacts with agency personnel and others in the course of the project facilitated the transfer of information to the consultant. The Minnesota Department of Health, Attorney General's Office, Pollution Control Agency, Department of Natural Resources, City of St. Louis Park, U.S. Geological Survey and Environmental Protection Agency participated in various meetings and provided the consultant with data.

In the development of the work plan for the investigation, it had been anticipated that use would be made of a U.S. Geological Survey three-dimensional digital computer model of solute transport in the Prairie du Chien-Jordan aquifer. The model has not been available, however, for the present study. In its absence, the gradient control well system design described in this report is based on mathematical models of the individual aquifers and a consideration of aquifer interrelationships. Future use of the computer model would be desirable for confirmation of the system design.

B. Fundamental Assumptions

The following assumptions are fundamental to the results of the study:

1. The hydrologic parameters describing the groundwater system are as given in Table 4.

2. The background groundwater gradients observed in the aquifers are uniform throughout the area of influence of proposed gradient control wells and incorporate the effects of current pumping. (Average 1979 and 1980 St. Louis Park municipal well discharge rates are listed in Table 3).

3. The extent of groundwater contamination is determined by the proposed criteria for PAH and is defined by groundwater sample analyses obtained prior to September 1, 1981.

4. Presently observed contamination of aquifers below the Platteville is due to multi-aquifer wells and possibly a buried bedrock valley east of the Republic site.

5. Contaminated groundwater pumped from outside the Republic site and adjacent area can, with the best technology available, be treated to meet the proposed potable criteria for PAH.

6. Sorption (adherence to the aquifer matrix) of PAH compounds is significant in the glacial drift and possibly the bedrock confining beds, but is negligible in the bedrock aquifers.

These assumptions accord with the available information and represent reasonable extensions or simplifications of the data.

TABLE 3

Average Discharge of St. Louis Park Municipal Wells During 1979 and 1980

Aquifer	Well No.	Average Discharge (gallons per minute) 1979	1980
St. Peter and Platteville	3	170	360
Prairie du Chien-Jordan	4	220	10
	5	40	250
	6	860	525
	7	0	20
	8	720	720
	9	0	20
	10	0	0
	14	35	205
	15	20	5
	16	740	515
Mt. Simon-Hinckley	11	600	565
	12	140	430
	13	175	495

V. GRADIENT CONTROL WELL SYSTEM

The principal aquifers of the St. Louis Park area considered here are the Middle Drift, Platteville, St. Peter, Prairie du Chien-Jordan, Ironton-Galesville and Mt. Simon-Hinckley. Polynuclear aromatic hydrocarbon (PAH) concentrations exceeding the proposed criteria have been observed in groundwater samples from all of these aquifers with the exception of the Mt. Simon-Hinckley. The source of the PAH compounds is believed to be the former Republic Creosoting site in St. Louis Park. PAH migration has been attributed to leakage from the disposal pond south of the site and the effects of multi-aquifer wells and a buried bedrock valley.

The proposed gradient control well system is designed to control the movement of groundwater contaminated with PAH compounds. Implementation of the proposed system would result in the eventual removal of PAH groundwater contaminants, possibly requiring thousands of years of system operation due to the effects of sorption and downward leakage. For the purpose of remedial plan design, groundwater contamination is defined according to the proposed potable criteria (see Section III) as the presence of 1) any individual carcinogenic PAH concentration greater than 2.8 nanograms/liter or 2) any other individual PAH concentration greater than 28 nanograms/liter.

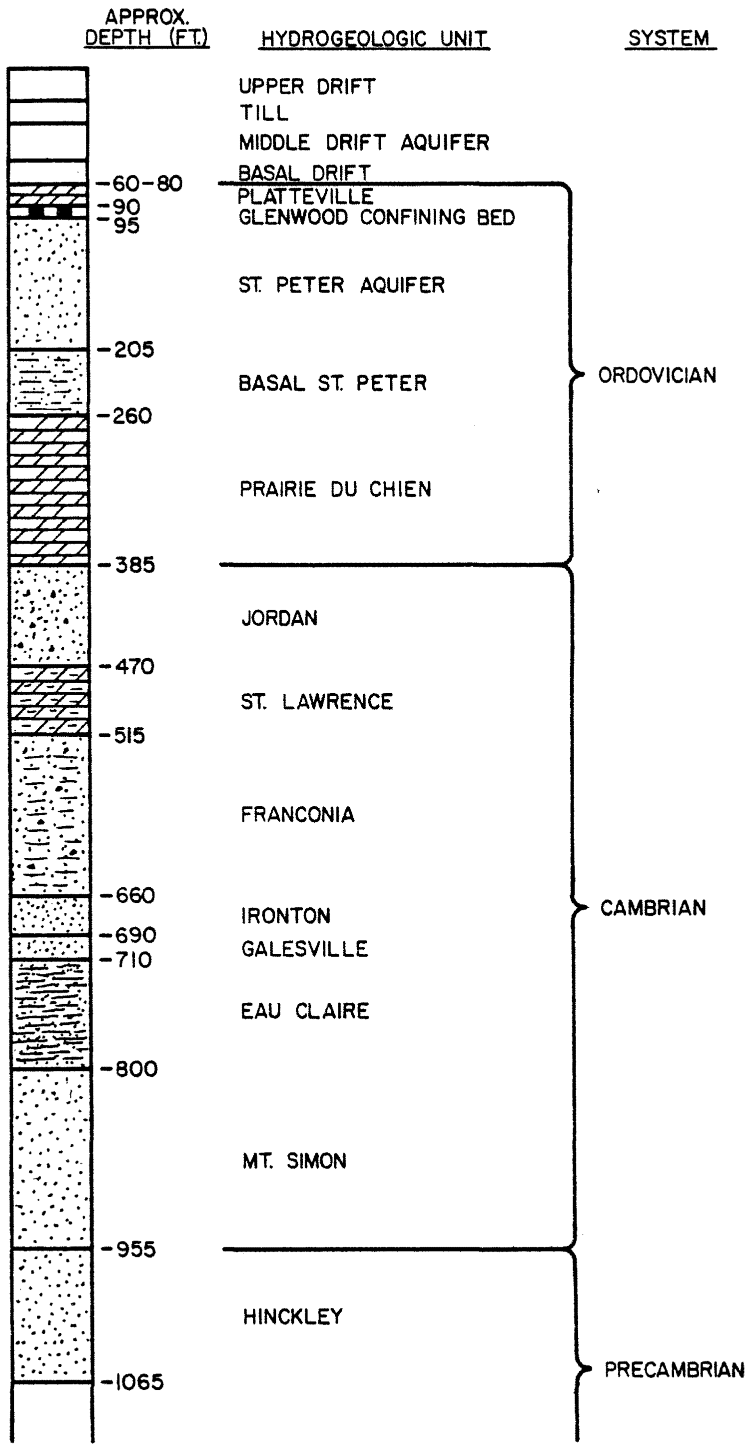
This section of the report is essentially the same as Appendix A, also entitled "Gradient Control Well System."

A. Hydrogeology

1. General Description

The stratigraphic sequence of the aquifers and separating aquitards in the St. Louis Park area is shown in Figure 2, and the corresponding hydrologic parameters are summarized in Table 4. The uppermost aquifer in the sequence is the Middle Drift, a glacial sand and gravel aquifer which varies in thickness from about 20 to 40 feet. The Middle Drift is overlain by a low hydraulic conductivity glacial till layer. Another low conductivity layer, the basal drift, separates the Middle Drift and underlying Platteville aquifer. At the base of the Platteville lies the Glenwood confining bed. This hydrologic unit consists of the Glenwood shale and a shaly transition zone in the upper St. Peter. The Glenwood confining bed greatly inhibits downward flow from the Platteville to the St. Peter. Above this bed, water from the disposal pond has flowed downward into the Middle Drift and Platteville aquifers through which it is conveyed in a generally eastward direction.

The St. Peter sandstone aquifer lies below the Glenwood confining bed. The basal St. Peter is consistently silty and thus behaves as an aquitard separating the St. Peter and Prairie du Chien aquifers. Underlying the Prairie du Chien dolomite is the Jordan sandstone aquifer. Since no confining bed separates these two aquifers, they are considered as a single unit, the Prairie du Chien-Jordan. Both the St. Peter and the Prairie du Chien-Jordan aquifers receive recharge from the Lake Minnetonka area and



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GENERALIZED STRATIGRAPHIC SEQUENCE IN ST. LOUIS PARK AREA	HYDROLOGISTS - ENGINEERS MINNEAPOLIS - MINNESOTA	2

Table 4

HYDROLOGIC PARAMETERS*

Hydrologic Unit	Approximate Upper Contact Elevation (ft above NGVD)	Approximate Thickness (ft)	Transmissivity (gpd/ft)	Horizontal Hydraulic Conductivity (gpd/ft^2)	Vertical Hydraulic Conductivity (gpd/ft^2)	Effective Porosity
Upper Drift	Variable	5-40	--	--	--	--
Till	Variable	2-10	--	--	--	--
Middle Drift	Variable	20-40	7,600-31,300	250-1,040		0.30
Basal Drift	Variable	10-30	--	--	0.03	--
Platteville	811-840	0-30	0-37,000	--	--	0.05
Glenwood Confining Bed	805-811	0-6	--	--	1.2×10^{-4}	0.25
St. Peter	805	110	20,000	180	--	0.30
Basal St. Peter Confining Bed	695	55	--	--	0.02	0.20
Prairie du Chien-Jordan	640	210	50,000-150,000	240-710	--	0.15
St. Lawrence-Franconia	430	190	--	--	0.01	0.10-0.30
Ironton-Galesville	240	50	1,050	21	--	0.25
Eau Claire	190	90	--	--	0.007	0.10-0.30
Mt. Simon-Hinckley	100	265	12,000	45	--	0.22

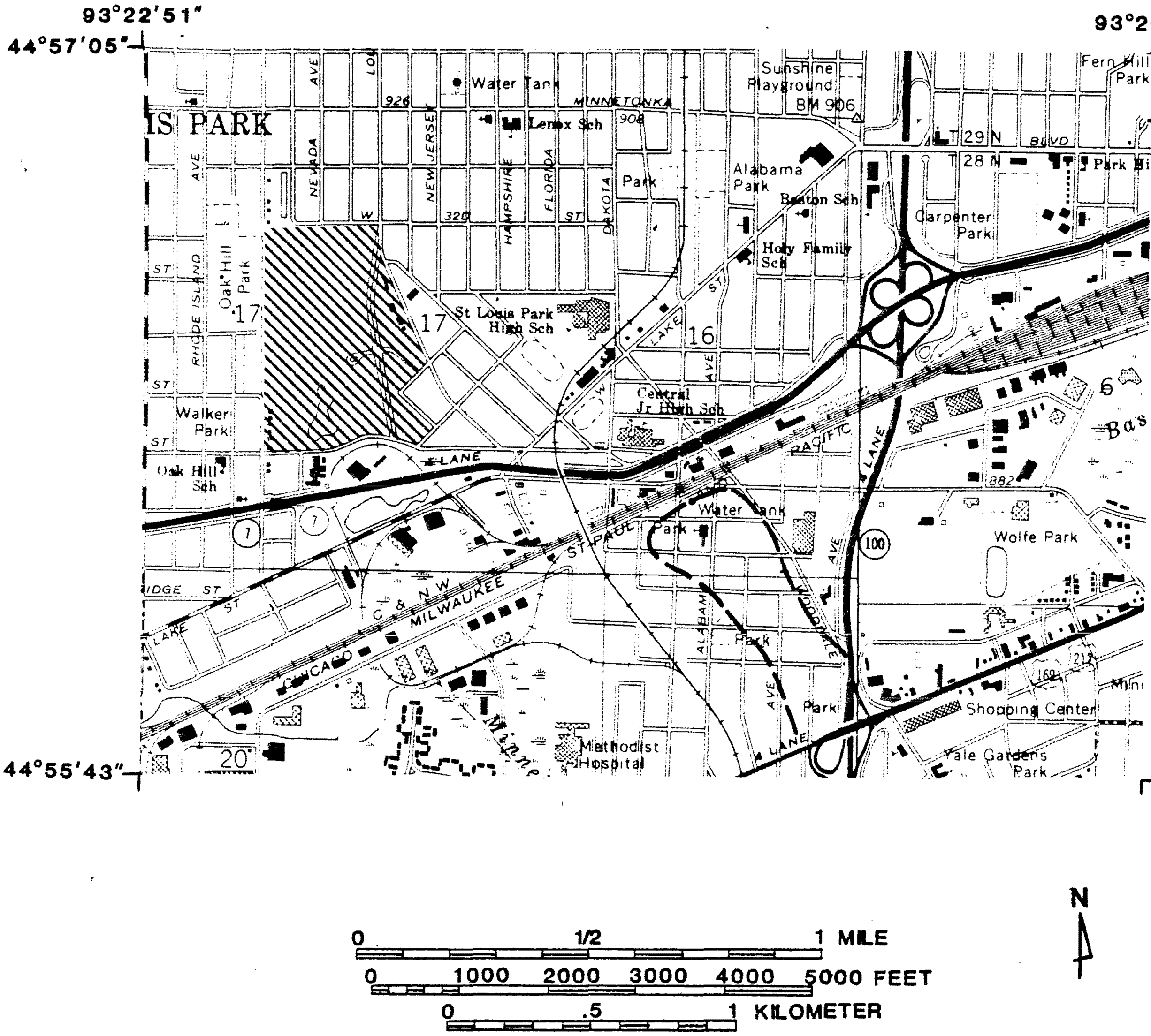
*Sources of information referenced in Appendix A.

discharge to the Mississippi River. Therefore a natural eastward flow through these aquifers occurs in the St. Louis Park area. Locally, the effects of pumping wells alter this flow pattern.

Below the Jordan sandstone lies the St. Lawrence dolomite-siltstone and Franconia sandstone. These two units comprise a thick aquitard separating the Jordan and Ironton-Galesville sandstone aquifers. The siltstone and shale sequences of the Eau Claire act as an aquitard separating the Ironton-Galesville from the Mt. Simon-Hinckley sandstone aquifer. Unlike the St. Peter and Prairie du Chien-Jordan, the Ironton-Galesville and Mt. Simon-Hinckley aquifers are not hydraulically connected to Lake Minnetonka or the Mississippi River. Therefore, no significant natural flow trend is presumed to exist in these aquifers as is indicated by contours of the Mt. Simon-Hinckley piezometric surface.

2. Bedrock Valley

A buried bedrock valley cutting through the Platteville and Glenwood into the St. Peter is believed to exist southeast of the site as shown in Figure 3. This is evidenced by geophysical investigations and logs of wells and soil borings in the area. The significance of the bedrock valley is attributed to the conveyance of contaminated water from the disposal pond to the valley through the Middle Drift and Platteville aquifers. In the buried valley the exposed St. Peter is expected to receive inflow from these aquifers due to natural hydraulic potential differences.



▧ FORMER REPUBLIC CREOSOTING SITE

— — ASSUMED ST. PETER BEDROCK VALLEY

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LOCATION OF BURIED BEDROCK VALLEY	HYDROLOGISTS-ENGINEERS MINNEAPOLIS-MINNESOTA	3

July 22-24 and March 3-4, 1981 water level data from Platteville monitoring wells display preferential groundwater flow directions to the east and southeast around the buried valley. This could be due to low hydraulic conductivity basal drift overlying the Platteville which diminishes toward the valley. Groundwater approaching the valley would tend to flow in the directions of continuous Platteville rather than into the low conductivity basal drift. Corresponding water level data from Middle Drift observation wells indicate flow in this aquifer is generally eastward across the valley. Downward leakage from the Middle Drift, through the basal drift and into the St. Peter could occur in the bedrock valley.

3. Multi-Aquifer Wells

Vertical flow between aquifers can occur through the bore of a multi-aquifer well. Multi-aquifer wells in St. Louis Park have been important conduits for downward movement of contaminants into bedrock aquifers (i.e., aquifers other than the Middle Drift). The Minnesota Department of Health has located and properly abandoned several multi-aquifer wells in the area and is currently pursuing a program aimed at thoroughly completing this task.

B. Remedial Plans

1. Conceptual Base

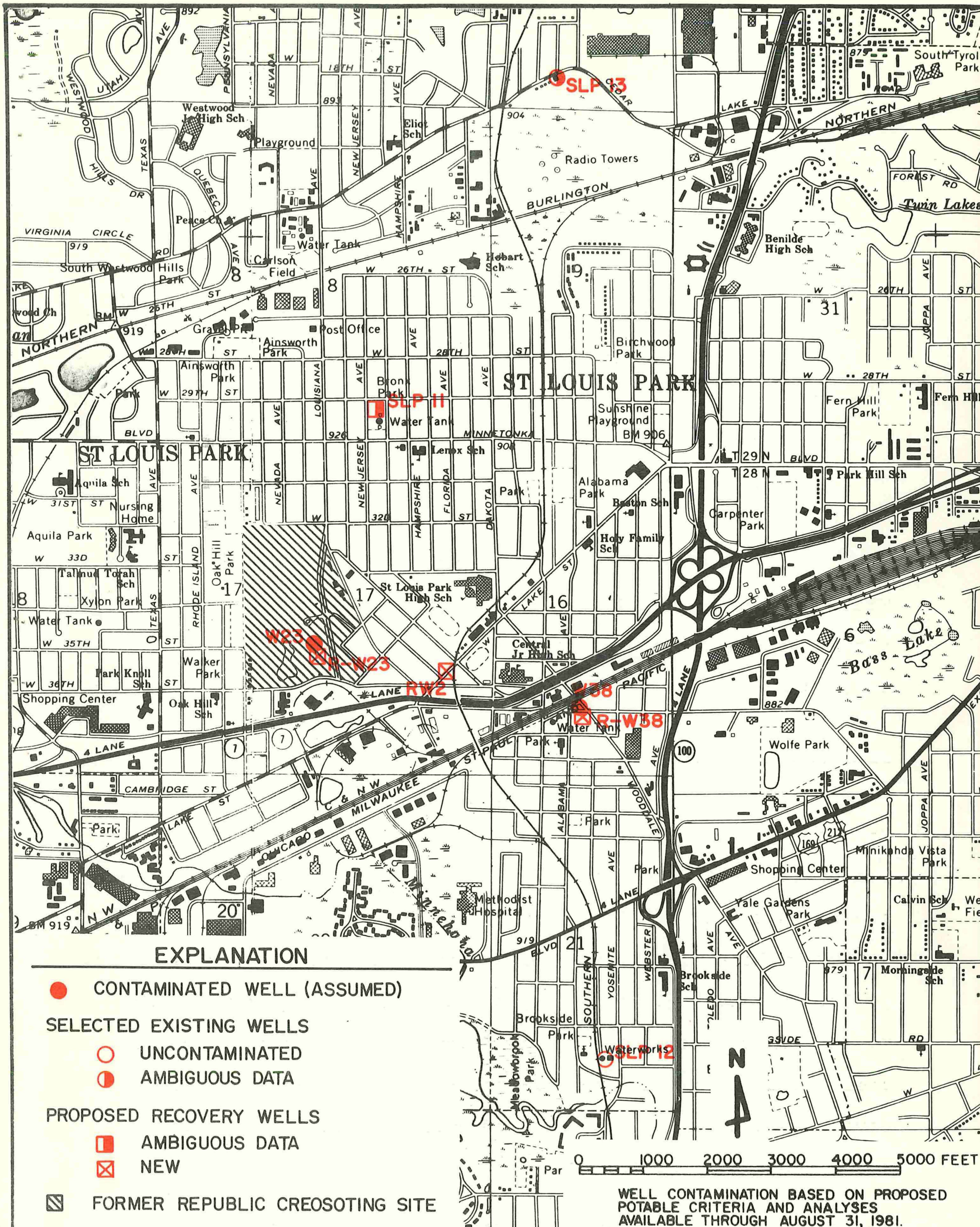
Groundwater flows in response to a hydraulic gradient. Natural gradients occur in aquifers possessing natural recharge and discharge areas. Pumping induced gradients exist due to aquifer discharge into wells. At any point within an aquifer, the resulting gradient due to pumping wells may be determined using groundwater flow equations. This approach was applied in the remedial plan designs for the Mt. Simon-Hinckley and Ironton-Galesville aquifers in which groundwater movement is assumed to be dominated by pumping induced gradients.

The Middle Drift, Platteville, St. Peter and Prairie du Chien-Jordan aquifers possess generally eastward natural gradients which must be incorporated in the design of gradient control (or "recovery" or "interception") well systems. A well pumping in these aquifers will have a corresponding area of influence in which all groundwater will flow toward and eventually be withdrawn by the well. The area of influence of the well may be approximated based on the hydraulics of a well pumping in a uniform flow field. This approach was used to determine recovery well locations and pumping rates required to intercept the flow of contaminated groundwater in these aquifers.

2. Mt. Simon-Hinckley Aquifer

Analyses of Mt. Simon-Hinckley groundwater samples obtained from St. Louis Park municipal wells 11, 12 and 13 (see Figure 4) have not indicated PAH contamination of this aquifer. However, the on-site Hinckley (W23)* and Milwaukee Railroad (W38) multi-aquifer wells may have allowed flow of contaminated water into the aquifer producing localized zones of groundwater contamination in the vicinities of these wells. Mt. Simon-Hinckley remedial plans were designed under the assumption that this has occurred. Further investigation to confirm this assumption should be conducted before any remedial measure is implemented.

*Well identification follows USGS notation as in Hult and Schoenberg (1981).



EXPLANATION

- ● CONTAMINATED WELL (ASSUMED)

SELECTED EXISTING WELLS

- ○ UNCONTAMINATED
- ◐ AMBIGUOUS DATA

PROPOSED RECOVERY WELLS

- ◧ AMBIGUOUS DATA
- ⊠ NEW

▧ FORMER REPUBLIC CREOSOTING SITE

WELL CONTAMINATION BASED ON PROPOSED POTABLE CRITERIA AND ANALYSES AVAILABLE THROUGH AUGUST 31, 1981.

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MT. SIMON-HINCKLEY CONTROL PLANS		4

Contours of the Mt. Simon-Hinckley piezometric surface indicate groundwater movement in the aquifer is dominated by pumping induced gradients. St. Louis Park (SLP) municipal wells 11, 12 and 13 are Mt. Simon-Hinckley wells in close enough proximity to exert pumping induced gradients in the assumed contaminated zones and thus influence the movement of this water. In the past decade, groundwater flow within the area has been convergent toward SLP 11 since it has maintained the highest discharge rate of the three municipal wells. Based on 1979 and 1980 total pumpage records, the present average pumping rates for these wells are approximately 600 gallons per minute (gpm) for SLP 11 and 300 gpm for SLP 12 and 13 each. Three remedial plans for the Mt. Simon-Hinckley were considered, all of which necessitate continued heaviest pumpage by SLP 11 or by newly constructed recovery wells nearer the assumed zones of groundwater contamination.

The first plan is to continue the 1979-80 pumping pattern in the aquifer with an average discharge of 600 gpm or greater from SLP 11 and average discharges from SLP 12 and 13 at rates up to one-half that of SLP 11. In so doing, contaminated groundwater originating at the two multi-aquifer wells would continue to move toward and eventually be withdrawn by SLP 11. This well would then require treatment when contamination occurs in order to continue providing municipal water supply.

The second plan is the rapid recovery of assumed groundwater contamination by two proposed recovery wells, R-W23 and R-W38 (Figure 4), constructed adjacent to the Hinckley (W23) and Milwaukee Railroad (W38) wells, respectively. To insure groundwater flow in the areas of concern is convergent toward the recovery wells, they should be pumped equally at an average rate of 300 gpm or greater each; use of SLP 11 should be discontinued; and the average discharges of SLP 12 and 13 should not exceed half the combined discharge of the recovery wells.

The third remedial plan is to withdraw all assumed contaminated groundwater through one recovery well, RW2 (Figure 4), located midway between the Hinckley (W23) and Milwaukee Railroad (W38) wells. Again, to insure groundwater flow in the area of concern converges toward the recovery well, it should be pumped at an average rate of 600 gpm or greater, SLP 11 should be shut down and wells SLP 12 and 13 should be used at rates less than or equal to half that of the recovery well.

3. <u>Ironton-Galesville Aquifer</u>

As in the Mt. Simon-Hinckley aquifer, contamination of the Ironton-Galesville is assumed to be localized in the vicinities of the multi-aquifer Hinckley (W23) and Milwaukee Railroad (W38) wells (Figure 4). Groundwater flow within the aquifer is assumed to be dominated by pumping induced gradients. Since little or no use of this aquifer occurs within the area, the migration of contaminated groundwater from the source multi-aquifer wells is expected to be minor. Based on these assumptions, Ironton-Galesville groundwater contamination could be retrieved by two recovery wells located adjacent to the multi-aquifer source wells or by one centrally located recovery well, analogous to the latter two Mt. Simon-Hinckley remedial plans. However, further investigation of the nature of groundwater movement and contamination in the Ironton-Galesville should be conducted before undertaking such remedial measures.

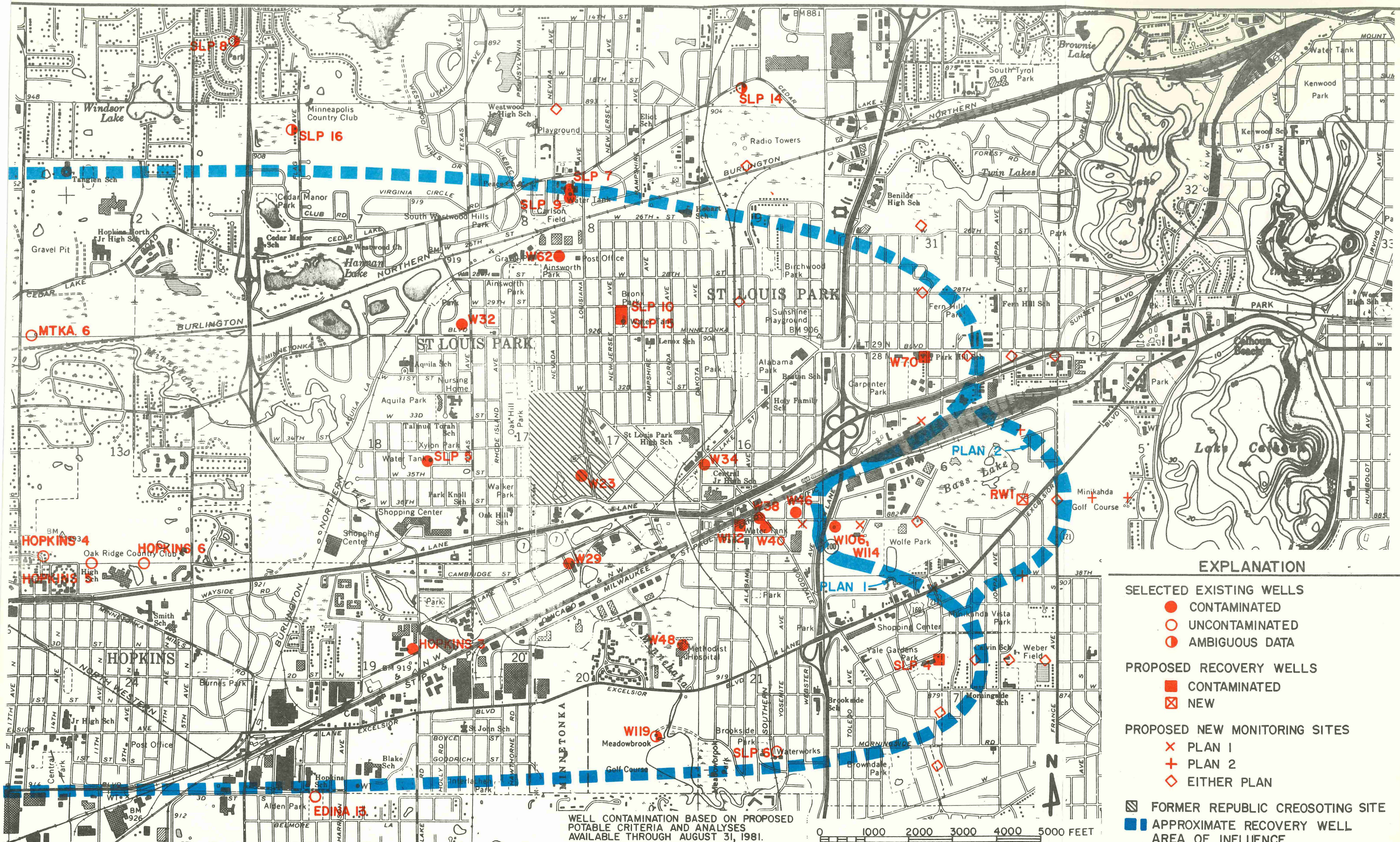
4. Prairie du Chien-Jordan Aquifer

Eastward trending groundwater flow occurs through the Prairie du Chien-Jordan aquifer in the St. Louis Park area. Potentiometric contours for the winter of 1970-71 and January and June 1979 indicate an eastward gradient of about 10 feet per mile. Two remedial plans were considered in which the eastward flow of contaminated groundwater would be intercepted and withdrawn by wells. The first plan is to maintain average discharges of 800 gpm from St. Louis Park municipal well 4 (SLP 4, Figure 5), 1000 gpm from the Park Theater well (W70) and 1500 gpm from Old SLP 1 (W112). The second plan is to pump SLP 4 and the Park Theater wells at average rates of 800 gpm and 1000 gpm, respectively, and construct a new well, RW1, just east of Bass Lake to be pumped at an average rate of 800 gpm. The resulting areas of influence for these pumping plans are shown in Figure 5.

In conjunction with either of these plans it is suggested that 1) municipal demands be partially met by treating a combined average discharge of 800 gpm or greater from SLP 10 and 15, and 2) heavy use of municipal wells located on or near the northern, southern and western extent of presently known contamination be discouraged. This additional action will tend to contract the contaminant plume and allow a somewhat shorter cleanup duration.

5. St. Peter Aquifer

As in the Prairie du Chien-Jordan aquifer, groundwater flow through the St. Peter is generally west to east in the St. Louis Park area. Water levels in St. Peter wells during March 3-4 and July 22-24, 1981 indicate a maximum eastward gradient of about 10



MINN. DEPT. OF HEALTH

PRAIRIE DU CHIEN-JORDAN CONTROL PLANS

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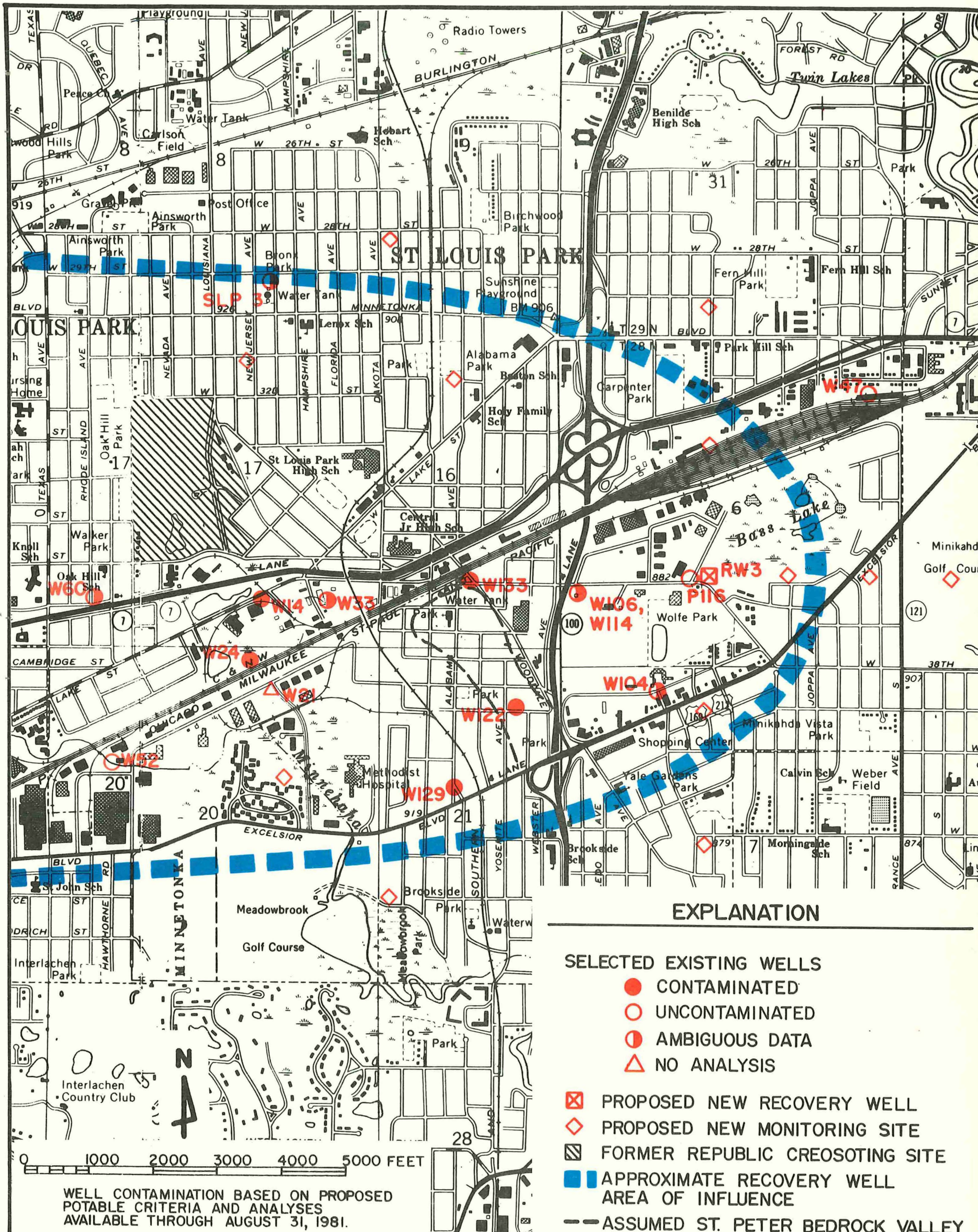
feet per mile. The eastward flow of contaminated groundwater could be collected by one proposed well, RW3 (Figure 6), pumping at an average rate of 300 gpm. This well would also capture groundwater which may enter the St. Peter from the overlying Platteville or Middle Drift aquifers through the bedrock valley.

6. Platteville Aquifer

March 3-4 and July 22-24, 1981 water level data from Platteville monitoring wells indicate local groundwater flow diverges to the southeast and east in the vicinity of the buried bedrock valley. Two recovery wells, RW4 and RW5 (Figure 7), are proposed to intercept the southeastward and eastward trending flow of contaminated groundwater. The maximum southeastward and eastward gradients displayed by the water level data are about 20 and 10 feet per mile. The capture area shown in Figure 7 would be produced by pumping wells RW4 and RW5 at average rates of 150 gpm and 75 gpm, respectively.

Existing well W100, located just north of the former site, should be pumped at 50 gpm to remove what is presently believed to be local groundwater contamination. The observed contamination of well W100 implies the possible existence of surficial contaminant sources other than the pond south of the former site. Contamination of W100 could be attributed to seepage from the adjacent pond at 32nd and Oregon. Water from this pond was occasionally pumped into storm sewers which discharge into Bass Lake. Further Platteville groundwater investigations should be conducted in these areas.



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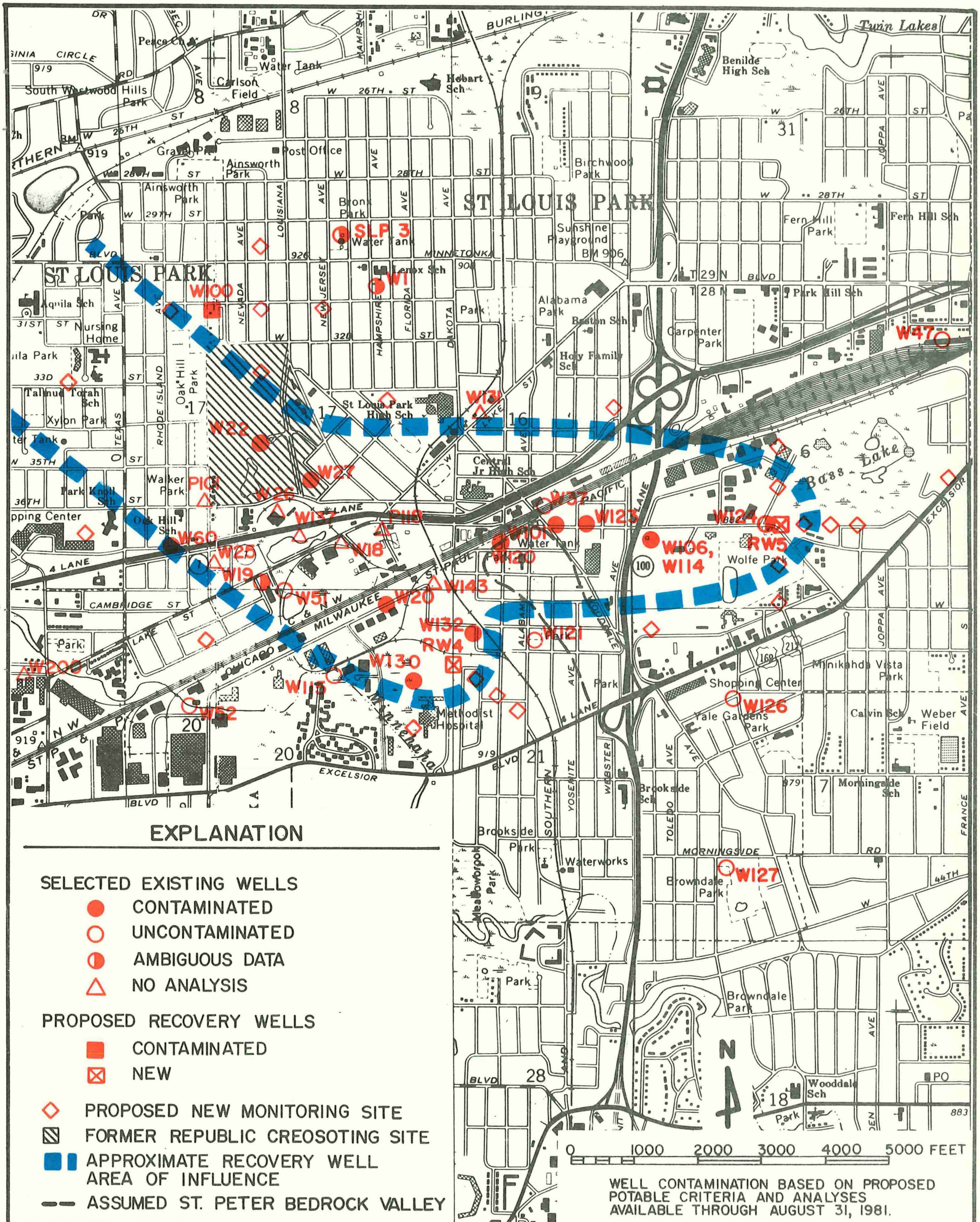
ST. PETER CONTROL PLAN	HYDROLOGISTS - ENGINEERS MINNEAPOLIS - MINNESOTA	6



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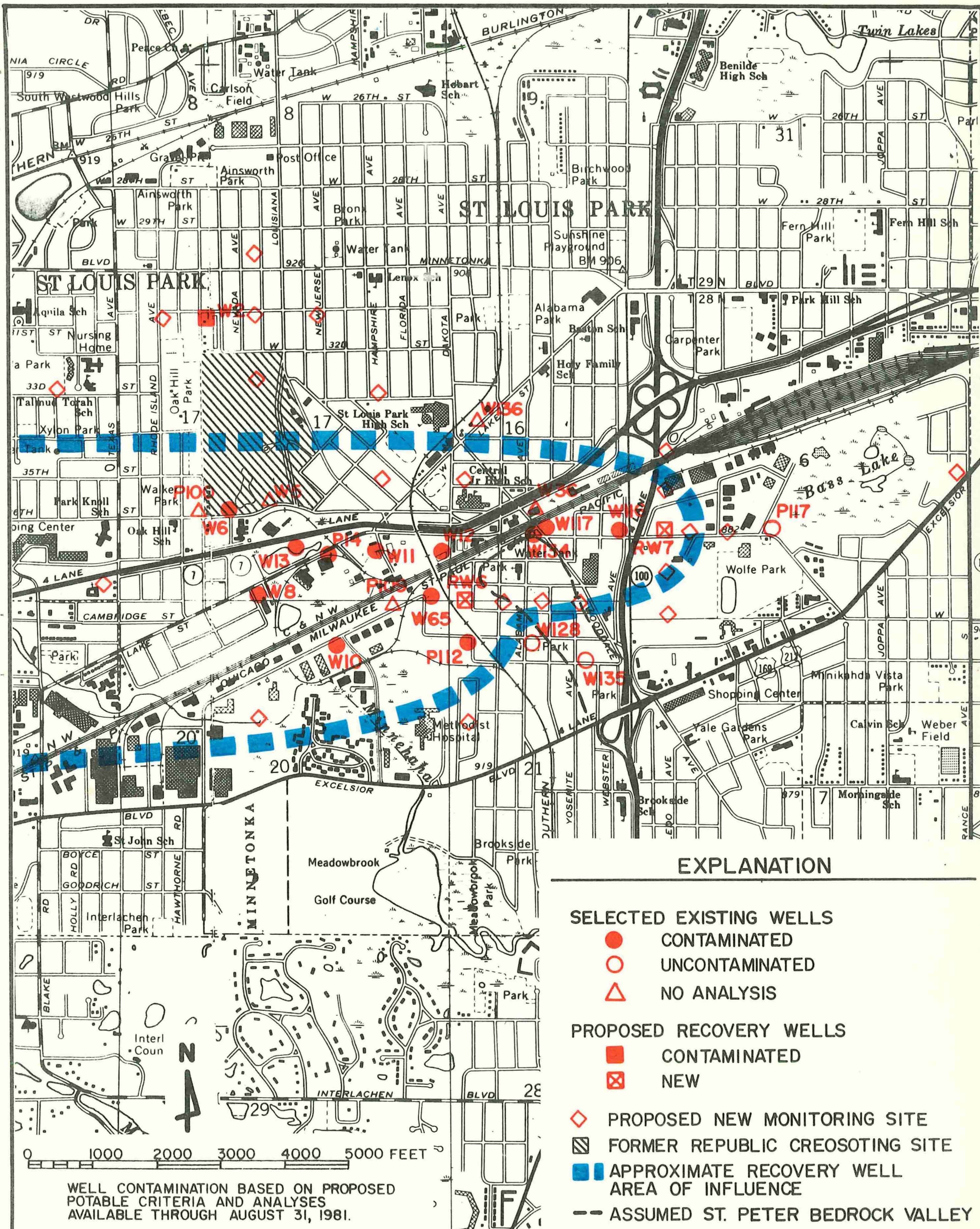
PLATTEVILLE CONTROL PLAN		7

7. Middle Drift Aquifer

March 3-4 and July 22-24, 1981 water level data from Middle Drift observation wells indicate natural groundwater movement is generally eastward in the area of known contamination (Figure 8). Two west-east cross-sections including wells W13, W11, W134, W117 and W116 with corresponding water level data for June 6, 1981 and March-April, 1978 were constructed by the USGS. The maximum eastward gradient observed from these four data sources is about 12 feet per mile.

Similar to the remedial plan for the Platteville, three wells are proposed for the withdrawal of contaminated Middle Drift groundwater. The first well, RW6, would be pumped at an average rate of 125 gpm to intercept contaminated groundwater moving eastward toward the bedrock valley (Figure 8). A second well, RW7, located east of the presently known extent of contamination, would be pumped at an average rate of 75 gpm to capture contaminated groundwater north and east of the bedrock valley. The third well, existing well W2 (located next to Platteville well W100), would be pumped at 50 gpm to withdraw local contamination due to the adjacent pond. The observed contamination of well W2 further implicates the adjacent pond and Bass Lake as possible surficial contaminant sources, as mentioned in the Platteville discussion. Further Middle Drift groundwater investigations should be conducted in these areas.

An independent alternative considered in the Middle Drift aquifer is the use of a pumpout well near well W13 to remove the most heavily contaminated groundwater. A low pumping rate of 10 gpm is proposed for this well since disposal of the effluent would probably necessitate transport from the site.



MINN DEPT. OF HEALTH	E.A. HICKOK & ASSOCIATES	NOV. 1981
MIDDLE DRIFT CONTROL PLAN	HYDROLOGISTS - ENGINEERS MINNEAPOLIS - MINNESOTA	8

8. Summary

The recovery wells and corresponding discharge rates proposed in the remedial aquifer pumping plans are summarized in Table 5. The proposed new recovery well locations shown in Figures 4 through 8 need not be considered exact, but rather as defining the locations to within a few hundred feet. Municipal or other existing wells were incorporated in the remedial plans if they were of suitable construction and location. It is important to note that municipal wells proposed for recovery purposes may be pumped at greater than specified rates to meet municipal demands. Discharge from these wells may require treatment for municipal use.

C. Groundwater Quality Aspects

Groundwater quality in terms of PAH concentrations is considered here from both short-term and long-term perspectives. Projections of gradient control well discharge quality are made for an initial 20-year period of operation. Effects of sorption, leakage and contaminated soil excavation are discussed in relation to the long-term prospect of "cleaning up" the groundwater contamination.

1. Gradient Control Well Discharge Quality Projections

Estimation of gradient control well discharge quality requires definition of the distributions of both PAH concentrations and groundwater travel time to the well within its area of influence. Discharge quality projections for gradient control wells in the Mt. Simon-Hinckley were not attempted since contamination of this aquifer has not been confirmed or quantified. Areal concentration distributions in each of the Middle Drift, Platteville, St. Peter

Table 5

Summary of Remedial Pumping Plans

Aquifer	Plan	Well	Discharge (gpm)
Middle Drift	1	RW6*	125
		RW7*	75
		W2	50
Platteville	1	RW4*	150
		RW5*	75
		W100	50
St. Peter	1	RW3*	300
Prairie du Chien-Jordan	1	SLP 10,15† (combined)	800
		Park Theater (W70)	1000
		SLP 4	800
		Old SLP 1 (W112)	1500
	2	SLP 10,15 (combined)	800
		Park Theater (W70)	1000
		SLP 4	800
		RW1*	800
Mt. Simon-Hinckley	1	SLP 11	600
	2	R-W23*	300
		R-W38*	300
	3	RW2*	600

† SLP denotes St. Louis Park municipal well

* Proposed new well; RW denotes recovery well at new site, while R-W stands for recovery well at location of existing wells (W23 and W38).

NOTE: Total gradient control well system discharge is dependent on implementation of Mt. Simon-Hinckley remedial measures and choice of Prairie du Chien-Jordan remedial plan.

Well identification (W23, W70, etc.) follows USGS notation as in Hult and Schoenberg (1981).

and Prairie du Chien-Jordan aquifers were defined by constructing Thiessen polygons around wells for which PAH analyses were obtained prior to September 1, 1981*. Groundwater in the aquifer area delineated by each polygon was assigned the quality indicated by the most recent analysis of water from the corresponding well. Quality was characterized for each well by "total" PAH, highest carcinogenic PAH, and highest "other" PAH concentrations.

The distribution of groundwater travel time to a gradient control well within its area of influence is dependent on the pumping rate and hydrologic aquifer parameters. An analytical expression defining the travel time distribution as a function of these parameters was used to construct contour lines of equal travel time within the area of influence of proposed gradient control wells.

Each gradient control well travel time map was overlayed on the corresponding aquifer quality map. Two adjacent travel time contours define a time interval during which groundwater in the area between the contours will be withdrawn. For a given time interval, the average well discharge quality is obtained by computing an areally weighted average of the groundwater concentrations associated with the polygon areas contained between the travel time contours. This was performed for each time interval and each gradient control well. Initial 20-year averages were then computed from these results.

*Subsequently obtained data may affect gradient control well discharge quality projections presented here.

Table 6, Gradient Control Well Discharge Quality Projected 20-Year Averages, shows the projections. The aggregate flow-weighted averages are on the order of 100 ng/l, 3,000 ng/l and 4,000 ng/l, respectively, for highest carcinogenic, "other" and "total" PAH, with the drift pumpout well in the area of worst contamination excluded. The list of PAH compounds monitored in area wells has not been consistent nor necessarily exhaustive. Estimates of "total" PAH are thus quite tentative. In projecting gradient control well quality, the highest carcinogenic PAH concentrations for different monitored wells were treated as though representing the same compound even though, for example, the compound is chrysene in one well and benzo(a)pyrene in another. "Other" PAH were treated in the same way. This procedure introduces a conservatism into the analysis which is warranted in light of the data uncertainties.

The PAH concentrations initially expected in a drift pumpout well are more than a million times higher than in the other gradient control wells. In the area of worst contamination (well W13, Figure 8), some measured PAH concentrations exceed reported solubilities by several orders of magnitude. This indicates the existence of a distinct fluid zone with a predominantly hydrocarbon character. A pumpout well in this case could reasonably operate at low pumping capacity and continue until the discharge concentrations decreased to levels below the reported solubilities.

TABLE 6

Gradient Control Well Discharge Quality
Projected 20-Year Averages

Aquifer	Plan	Well	PAH Concentrations (ng/l) Highest Carc.	Highest "Other"	"Total" PAH
Middle Drift	1	RW6	200	1,000	2,000
		RW7	100	400	1,000
		W2**	200	50.	400
		Pumpout (W13)**	$0.3x10^9$	$0.6x10^9$	$2.5x10^9$
Platteville	1	RW4	9.	2,000	2,000
		RW5	70.	3,000	5,000
		W100**	30.	2,000	3,000
St. Peter	1	RW3	30.	200	500
Prairie du Chien-Jordan	1	SLP 10,15	200	9,000	10,000
		W70	30.	2,000	4,000
		SLP 4	5.	200	300
		W112	30.	3,000	5,000
	2	SLP 10,15	200	9,000	10,000
		W70	30.	2,000	4,000
		SLP 4	5.	200	300
		RW1	20.	800	1,000

**Estimated initial quality.

NOTE: Quality projections based on analyses obtained prior to September 1, 1981

See Table 5 for well identifications.

The gradient control well quality projections account for sorption in the Middle Drift aquifer, but otherwise do not incorporate the effects of dispersion, sorption or leakage between aquifers. Dispersion or spreading of contaminants will occur as groundwater flows toward a pumping well. This spreading occurs primarily in the direction of flow. Peak groundwater concentrations presently observed in an aquifer would thus be reduced along the flow path to a well. The net effect of dispersion would be a smoothing of the gradient control well concentration history. The effects of sorption and leakage on gradient control well discharge quality are discussed in the following sections.

2. Sorption Effects

Sorption is the process by which PAH compounds adhere to the aquifer matrix. This process causes a partitioning of the compound between the groundwater solution and sorbed matrix phases. The distribution of a solute between these phases may be represented by a partition coefficient, K_p.

The significance of the sorption process is that it retards the velocity of PAH movement through an aquifer relative to the velocity of groundwater flow. The amount of retardation is directly related to the partition coefficient. The K_p values discussed in section III imply the rate of PAH movement in the Middle Drift would be retarded by factors of approximately 600 for carcinogenic PAH and 60 for "other" PAH as compared to the velocity of groundwater flow.

No information directly concerning PAH sorption in bedrock has been found in the literature. However, existing field data imply sorption effects are negligible in the bedrock aquifers. For example, monitoring of the Prairie du Chien-Jordan aquifer has shown rapidly changing PAH concentrations which apparently result from pumping stress changes, and such observations are consistent with very low sorption. In addition, the widespread extent of contamination in the Prairie du Chien-Jordan appears to be the consequence of PAH transport at rates comparable to those for groundwater flow in the aquifer.

3. Leakage Effects

Existing water levels in the aquifer sequence indicate in all cases a potential for downward leakage through the separating confining beds, or aquitards. The groundwater quality in an aquifer will be affected by the rate and quality of inflow received from the overlying aquifer and the time required for this inflow to cross the separating aquitard. The rate of leakage and time of travel through an aquitard are dependent on the difference in hydraulic potential between the overlying and underlying aquifers and the hydrologic characteristics of the aquitard.

The proposed gradient control well system itself would alter leakage rates in the contaminated area. Due to different pumping rates and hydrologic characteristics in the aquifers, the proposed system in most cases would increase the downward leakage. As approximations over the area of contamination, the pumping would increase average leakage rates to the Platteville (from the Middle Drift) several-fold, to the St. Peter (from the Platteville and

Middle Drift) by 50 percent, and to the Prairie du Chien-Jordan (from the St. Peter) by 25 percent. Leakage to the deeper aquifers would actually decrease somewhat because of the high pumping rates proposed in the Prairie du Chien-Jordan.

Estimated leakage travel times through the aquitards are on the order of 1 to 40 years through the basal drift, 70 years through the Glenwood confining bed, 50 years through the basal St. Peter and 700 years through the St. Lawrence-Franconia and Eau Claire formations. These estimates assume gradient control system operation as previously proposed and represent fluid travel times. Longer travel times apply for current conditions (except through the St. Lawrence-Franconia-Eau Claire). Sorption in the aquitards could substantially slow the movement of PAH relative to the groundwater.

Volumetric leakage rates in the area of contamination are sufficient to imply potential groundwater quality impacts in the bedrock aquifers. PAH have not yet leaked substantially through the basal drift, as evidenced south of the Republic site by very high concentrations in the Middle Drift (PAH >1,000,000,000 ng/l) and fairly low concentrations in the Platteville (PAH <100 ng/l).

However, PAH leakage into the Platteville will eventually occur, and because of the very slow PAH movement in the Middle Drift due to sorption, it will occur over a long period.

Leakage from the Middle Drift contaminated area could comprise 10 percent or more of the pumpage from Platteville recovery wells. This means that at best, a 10-fold dilution of inflow from the Middle Drift would occur in the Platteville. Therefore, significant groundwater quality impacts in the Platteville are expected to result from leakage.

Leakage enters the St. Peter from both the Platteville, through the Glenwood confining bed, and the Middle Drift, through till in the buried valley near the Republic site. A small portion of St. Peter recovery well pumpage (on the order of 1 percent) would be leakage from the contaminated area of the Platteville. The Platteville leakage would thus be diluted approximately 100-fold. Impact on groundwater quality in the St. Peter could be significant, especially under future conditions of PAH leakage into the Platteville from the Middle Drift.

There are no monitoring data indicating that Middle Drift groundwater contamination extends into the area of the buried valley. If it does, significant groundwater quality impacts could result in the St. Peter since Middle Drift leakage through the buried valley could comprise 10 percent or more of the St. Peter recovery well pumpage.

Leakage from the Middle Drift will affect successively deeper bedrock aquifers in the long term. The groundwater quality impacts will be lessened at greater depths due to dilution in each successive aquifer.

Groundwater quality in the Prairie du Chien-Jordan aquifer could be significantly affected by leakage depending on the groundwater quality of the St. Peter. Leakage from the St. Peter in the area of contamination would represent an estimated 1 to 10 percent of the pumpage from Prairie du Chien-Jordan recovery wells.

The Ironton-Galesville and Mt. Simon-Hinckley aquifers could be subject to future "slug loads" of PAH contamination by leakage. However, travel times of hundreds of years through the intervening aquitards are involved.

4. Soil Excavation Effects

The possible excavation of contaminated soils in the Republic site vicinity is discussed in Section VI. That section identifies peat deposits at the south of the site as probable continuing "sources" of groundwater contamination in the Middle Drift.

Excavation of contaminated soils would be expected to yield little benefit to groundwater quality, unless coupled with removal and disposal of fluid from the "source" area and the underlying Middle Drift. Soil excavation alone would leave fluid in-place with PAH concentrations exceeding 1,000,000,000 ng/l. Although a substantial mass of PAH could be excavated with the soil, the remaining fluid presents a serious groundwater quality problem. Available information on PAH sorption implies that high PAH levels will persist in the Middle Drift groundwater for very long periods, perhaps thousands of years. Therefore excavation without removal of the hydrocarbon fluids would not be a significant benefit to the groundwater quality.

Excavation coupled with fluid removal from the "source" area and the underlying Middle Drift could significantly reduce the impacts of leakage on groundwater quality in the bedrock aquifers. This would be a benefit if it could lower the peak groundwater concentrations of PAH in the Middle Drift by several orders of magnitude. High PAH concentrations would still persist in the Middle Drift, and gradient control wells there would need to continue pumping for an indefinite period. However, by reducing the peak concentrations substantially, the major long-term effects of PAH leakage from the Middle Drift could be restricted to the shallower bedrock aquifers.

Fluid removal would require one or more pumpout wells in the area of worst contamination in the Middle Drift as well as special handling of fluid encountered in excavating the shallower peat deposits. Disposal of the fluid would probably entail truck or rail transport because the extremely high PAH concentrations preclude treatment and disposal locally.

It is important to note that available field data do not adequately define the "source" peat deposits and the zone of worst PAH contamination in the Middle Drift. In fact, as of September 1981 there are no PAH data for the peat deposits immediately south of the site, and the inference that they behave as PAH "sources" is based on indirect evidence. The zone of worst contamination in the Middle Drift is at present defined by two monitoring wells (W6 and W13, Figure 8) showing PAH concentrations exceeding solubility in water. Systematic field investigation must be conducted south of the Republic site to define the extent and nature of extreme PAH contamination prior to undertaking remedial measures there.

5. Long-Term Perspective

The long-term prospect of "cleaning up" the groundwater contamination depends primarily on hydraulic flushing times and the effects of sorption and leakage. The proposed gradient control wells would hydraulically flush the contaminated aquifer areas in an estimated one to three decades in most cases. Longer flushing times are estimated for the St. Peter (approximately one century) and the Mt. Simon-Hinckley under pumping Plan 1 (one to two centuries).

It appears that PAH contamination in the Middle Drift aquifer will require many times longer than the flushing time to clean up, due to sorption. Carcinogenic PAH are estimated to move 600 times more slowly than the groundwater in the Middle Drift. This implies a clean up time of many thousands of years. It is therefore concluded that gradient control wells in the Middle Drift must operate indefinitely.

The long-term prospect for the Platteville and St. Peter aquifers reflects that of the Middle Drift, because of the impacts of leakage. Contaminated soil excavation coupled with fluid removal in the "source" area and the underlying Middle Drift could benefit these bedrock aquifers. These remedial measures could significantly reduce the degree of leakage impact, but the clean up times would probably remain very long. These bedrock aquifers would also appear to require indefinite operation of gradient control wells.

The Prairie du Chien-Jordan aquifer could be initially cleaned up in a few decades, but at least minor leakage effects would probably continue after that time. Leakage from the St. Peter reflecting that aquifer's current levels of contamination could imply significant impacts in the Prairie du Chien-Jordan for a century or more. These impacts appear to be of sufficient magnitude to preclude potable use without treatment of groundwater from some areas of the Prairie du Chien-Jordan.

The deeper Mt. Simon-Hinckley and Ironton-Galesville aquifers could also be cleaned up initially in a relatively short time. These aquifers will probably experience significant "slug loads" of contaminated leakage after a few centuries.

D. Monitoring and Supplemental Control

The proposed monitoring plan is designed to insure effective control of groundwater contamination by the gradient control well system. Additional monitoring of municipal and gradient control well discharge will be required to determine its suitability for municipal use or disposal to sanitary or storm sewers. The monitoring frequency and quality criteria for municipal use would be determined by the Minnesota Department of Health. Monitoring of discharge to sanitary or storm sewers would be in compliance with Metropolitan Waste Control Commission and National Pollutant Discharge Elimination System requirements.

Monitoring of the Mt. Simon-Hinckley aquifer would consist of discharge quality monitoring of municipal wells and possible recovery well(s). Water levels in existing Mt. Simon-Hinckley wells in the area should also be monitored to insure flow is convergent to the recovery well(s) in this aquifer.

The proposed groundwater monitoring plan for the Middle Drift, Platteville, St. Peter and Prairie du Chien-Jordan aquifers would require installation of new monitoring wells. The locations of proposed new monitoring sites in each aquifer are shown in Figures 4 through 8. Approximately one-third of the proposed new monitoring locations in each aquifer should consist of nests of three or more observation wells at different depths within the aquifer. All existing and proposed new wells would be monitored for water level and PAH concentrations during operation of the gradient control well system. Monitoring should be conducted by aquifer, with all water level measurements and samples from wells in the same aquifer obtained during the course of a few days. The monitoring data would be used to periodically construct maps defining groundwater flow and quality in each aquifer. The resulting descriptions of contaminant movement in each aquifer would provide an indication of the gradient control well system effectiveness.

Monitoring and control of groundwater use in the St. Louis Park area is also essential to effective gradient control well system performance. This pertains particularly to the Platteville, St. Peter, Prairie du Chien-Jordan and Mt. Simon-Hinckley aquifers. The gradient control well system was designed for flow conditions existing under present use of these aquifers. The addition or removal of pumping stresses in these aquifers may change the flow pattern depending on the location and magnitude of the stress. The proposed monitoring plan would allow observation of the aquifer response to these changes in groundwater use. In general, groundwater pumping inside areas of observed contamination is favorable, but would require quality monitoring. Control of groundwater use outside these areas may be necessary if it adversely affects the flow of contaminated groundwater.

The gradient control well system must be flexible. Adjustment of pumping rates or installation of additional gradient control and monitoring wells may be necessary due to unforseen changes in flow patterns or the discovery of new zones of contamination. The ability to perform such modifications allows for a high level of confidence in the effectiveness of the system.

Successful implementation of the gradient control well system would require the oversight of a designated operator or operating agency. The operator's responsibilities would include compilation and interpretation of monitoring data, documentation and control of water use, and prescription of necessary gradient control well system modifications.

E. Secondary Impacts

Contaminated groundwater flowing toward gradient control or recovery wells may enter previously uncontaminated aquifer areas. This would preclude unmonitored use of groundwater at any location between gradient control wells and zones of observed contamination in an aquifer. Present or future non-municipal groundwater use in these areas would require quality monitoring and appropriate controls. Other impacts on non-municipal users in the St. Louis

Park area may include restriction of water use if it is detrimental to the gradient control well system effectiveness, and lowering of water levels from gradient control well pumping.

Land subsidence due to proposed gradient control well pumping is expected to be negligible. This is attributed to the structural integrity of the bedrock and the non-excessive proposed discharge rates. Large groundwater withdrawal from the Middle Drift or overlying peat deposits near the pond south of the former site could result in compaction of the peat.

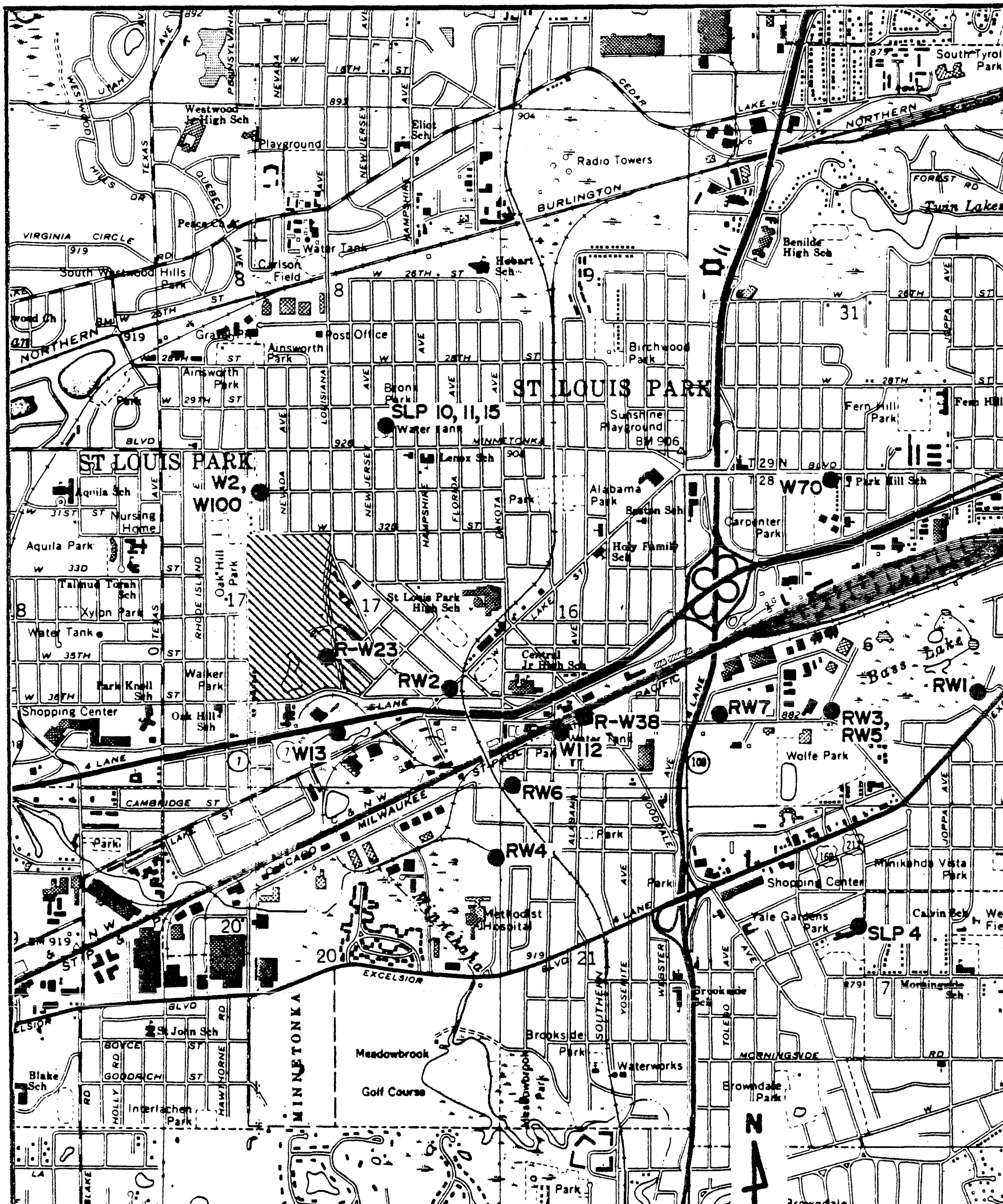
Implementation of the gradient control well system would require acquisition of land for the emplacement of new monitoring and pumping wells. Additional land may be required for possible treatment facilities and pipelines routing gradient control well discharge to sewer systems.

VI. DISPOSITION OF GRADIENT CONTROL WELL DISCHARGE

The locations of gradient control wells proposed to remedy the St. Louis Park groundwater contamination problem are shown in Figure 9. Gradient control well discharge quantities and quality are presented in Tables 5 and 6 in Section V. For the purpose of evaluating disposition alternatives, it is assumed that Plan 2 for the Prairie du Chien-Jordan is incorporated into the gradient control well system. The collection and treatment schemes discussed here also include discharge from the Mt. Simon-Hinckley (Plan 1 assumed), because contamination of this aquifer is inferred from hydrogeologic information. The system would have a combined discharge of approximately 4,800 gallons per minute (gpm). Several alternatives for the ultimate disposition of water discharged from gradient control wells have been addressed.

The analysis of ultimate disposition alternatives is based on the PAH criteria discussed in section III. However, in the case of the Mississippi River and other surface waters the conservative fish intake criteria are not considered here. These criteria, if applicable, would generally imply treatment requirements beyond those for potable use.

Dilution in the Mississippi River assumes low flow values of 1,138 and 1,633 cubic feet per second (cfs), respectively, in Minneapolis and in St. Paul, and 172 million gallons daily (266 cfs) for the Metropolitan Wastewater Treatment Plant at Pig's Eye (Minnesota Pollution Control Agency, 1981). No dilution is allowed for in Minnehaha Creek, an intermittent stream, or in the Minneapolis



FORMER REPUBLIC CREOSOTING SITE

0 1000 2000 3000 4000 5000 FEET

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GRADIENT CONTROL WELL LOCATIONS

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Chain of Lakes, which is tributary to the Creek. No allowance is made for PAH removal through wastewater treatment at the Pig's Eye plant, although some removal can be expected.

In the following, the disposition alternatives are discussed and three feasible disposition schemes are defined. Further information is then presented on granular activated carbon treatment technology. Appendices B ("Alternatives for Ultimate Disposition of Gradient Control Well Discharge"), C ("Collection and Treatment of gradient Control Well Discharge") and D ("Supplemental Testing, Bench Scale and Pilot Test Programs") include more detailed information on these topics.

A. Alternatives for Ultimate Disposition

Water discharged from gradient control wells could be used for potable or other beneficial purposes or be discharged into locally or regionally draining surface waters. If used for potable purposes, the City of St. Louis Park would be the logical user. Otherwise, the alternative discharge points are the sanitary sewer, Mississippi River, Minneapolis Chain of Lakes and Minnehaha Creek.

It should be noted that existing industrial and commercial use of contaminated groundwater in the area is beneficial from the viewpoint of gradient control. Such water use could be part of an overall gradient control scheme. To this end, the State of Minnesota might appropriately give special consideration to the ultimate disposal of such water. This report, however, considers only the discharge of proposed gradient control wells.

For a pumpout well in the most contaminated portion of the drift, none of the disposal alternatives considered is feasible under any of the possible PAH criteria, due to unattainably high treatment requirements. Therefore, if a drift pumpout well or wells were to be implemented in the most contaminated zone, some other means of disposal would be required, perhaps entailing transport by rail or tank truck.

A brief discussion of each alternative use or disposition point follows. The discussion excludes a drift pumpout well in the most contaminated zone but includes all other gradient control wells.

1. Municipal Water Supply

Using the gradient control well discharge for municipal water supply arises as a natural idea because several municipal wells have been closed due to PAH contamination, and the City of St. Louis Park has investigated treatment methods aimed at putting closed wells back into use. The use of one or more of the presently contaminated City wells as gradient control wells would eliminate the need to construct new wells. The discontinued use of St. Louis Park wells 4, 5, 7, 9, 10 and 15 has reduced the City well capacity by approximately 50 percent of design capacity and 30 percent of present pumping capacity. Therefore, the use of gradient control wells for municipal purposes would be helpful in meeting St. Louis Park water demands in addition to controlling groundwater movement.

The best information available indicates that gradient control well effluent could, with the best technology available, be treated for municipal water supply use. The estimated treatment requirements are generally 95 percent PAH removal for carcinogenic compounds and 99 percent for "other" PAH, based on the total discharge from all wells (again, except for a drift pumpout well). Treatment requirements would, of course, vary from well to well. For example, greater removal may be required for St. Louis Park well 15, showing very high levels of non-carcinogenic PAH. The recent pilot plant studies for St. Louis Park found these "other" PAH tend to be removed more efficiently than carcinogenic PAH. The Minnesota Department of Health and Pollution Control Agency are planning further pilot treatment studies to include well 15.

2. Sanitary Sewer

Contaminated effluent from gradient control wells could be discharged directly into the existing sanitary sewer system. Discharging into sanitary sewers in St. Louis Park ultimately results in discharge to the Mississippi River via the Metropolitan Wastewater Treatment Plant at Pig's Eye. The Mississippi River provides the greatest dilution available in the Twin Cities area because it is the regional drainageway for surface and ground waters.

Two major gravity trunk sewers and a major force main serve the City. One trunk line basically serves the northern third of St. Louis Park in an area generally north of the Burlington Northern Railroad. This trunk runs from west to east and discharges into the City of Minneapolis system in the vicinity of France Avenue and the Burlington Northern Railroad.

Another major trunk sewer serves the remaining portion of St. Louis Park and runs in a general west to east direction. This trunk follows Wooddale Avenue southeast to 40th Street and northeast to the corner of France Avenue and West 39th Street. At this point the trunk discharges into the City of Minneapolis system. The force main runs along Highway 7, and its use would require special pumping considerations.

The surface water criteria considered here imply that gradient control wells could be discharged without treatment to sanitary sewers.

3. Mississippi River

Discharge to the Mississippi River could be accomplished via storm sewers in Minneapolis. This would require pumping the well effluent some distance through force mains in order to connect with major storm drains in Minneapolis. Conveyance by gravity flow is not feasible due to a topographic low in the vicinity of the Minneapolis Chain of Lakes.

Several discharge points are possible via a force main to existing storm sewers serving Minneapolis. It appears that a force main could be constructed along the Burlington Northern Railroad right-of-way eastward into the City of Minneapolis to any one of several large storm sewers which discharge to the Mississippi River.

Another possible route is a force main along the Chicago, Milwaukee, St. Paul and Pacific Railroad right-of-way eastward into Minneapolis to another large storm sewer which discharges into the Mississippi River.

Discharge of all gradient control wells directly to the Mississippi River would require minimal or no treatment. Whether any treatment would be required, and to what degree if it is, depends on the particular criteria adopted.

4. Minneapolis Chain of Lakes

Discharge of gradient control wells to the Minneapolis Chain of Lakes system is feasible at several points. There are seven major storm sewers which presently originate in St. Louis Park and discharge into the lakes.

The effluent PAH criteria for this disposal alternative equal the corresponding surface water criteria, because no allowance for dilution is made. The criteria considered imply treatment requirements roughly comparable to those for potable use in all cases.

5. Minnehaha Creek

Water pumped from gradient control wells could be discharged into Minnehaha Creek, either directly or via existing storm sewers serving St. Louis Park. There are several storm sewers which presently discharge into Minnehaha Creek that could be utilized depending on the location of the gradient control wells. The treatment requirements for this alternative are exactly as for the Minneapolis Chain of Lakes alternative.

B. Disposition Schemes

From the above discussion, three disposition alternatives stand out as preferable. These are treatment for municipal water supply, discharge to sanitary sewer and discharge directly to the

Mississippi River. Various combinations of these have been considered from the viewpoint of feasibility and cost. Three disposition schemes are presented here.

<u>Scheme A</u> - Treat four wells (2,200 gpm) for St. Louis Park municipal water supply; discharge nine wells (2,625 gpm) to sanitary sewer.

<u>Scheme B</u> - Treat four wells (2,200 gpm) for St. Louis Park municipal water supply; discharge five wells (450 gpm) to sanitary sewer; discharge four wells (2,175 gpm) to the Mississippi River.

<u>Scheme C</u> - Discharge all wells (4,825 gpm) to the Mississippi River.

Table 7 shows the disposition of each well's effluent under the above schemes.

TABLE 7

Disposition Schemes for
Gradient Control Well Discharge

	Treat for Municipal Water Supply	Discharge to Sanitary Sewer		Discharge to Mississippi River
Scheme A	SLP 4	RW1	RW7	None
	SLP 10	RW3	W2	
	SLP 11	RW4	W70	
	SLP 15	RW5	W100	
		RW6		
Scheme B	SLP 4	RW4		
	SLP 10	RW6		RW1
	SLP 11	RW7		RW3
	SLP 15	W2		RW5
		W100		W70
Scheme C	None	None		All Wells

Schemes A and B utilize four municipal wells for water supply and gradient control. This entails treatment of the well effluent, as discussed in the following subsection.

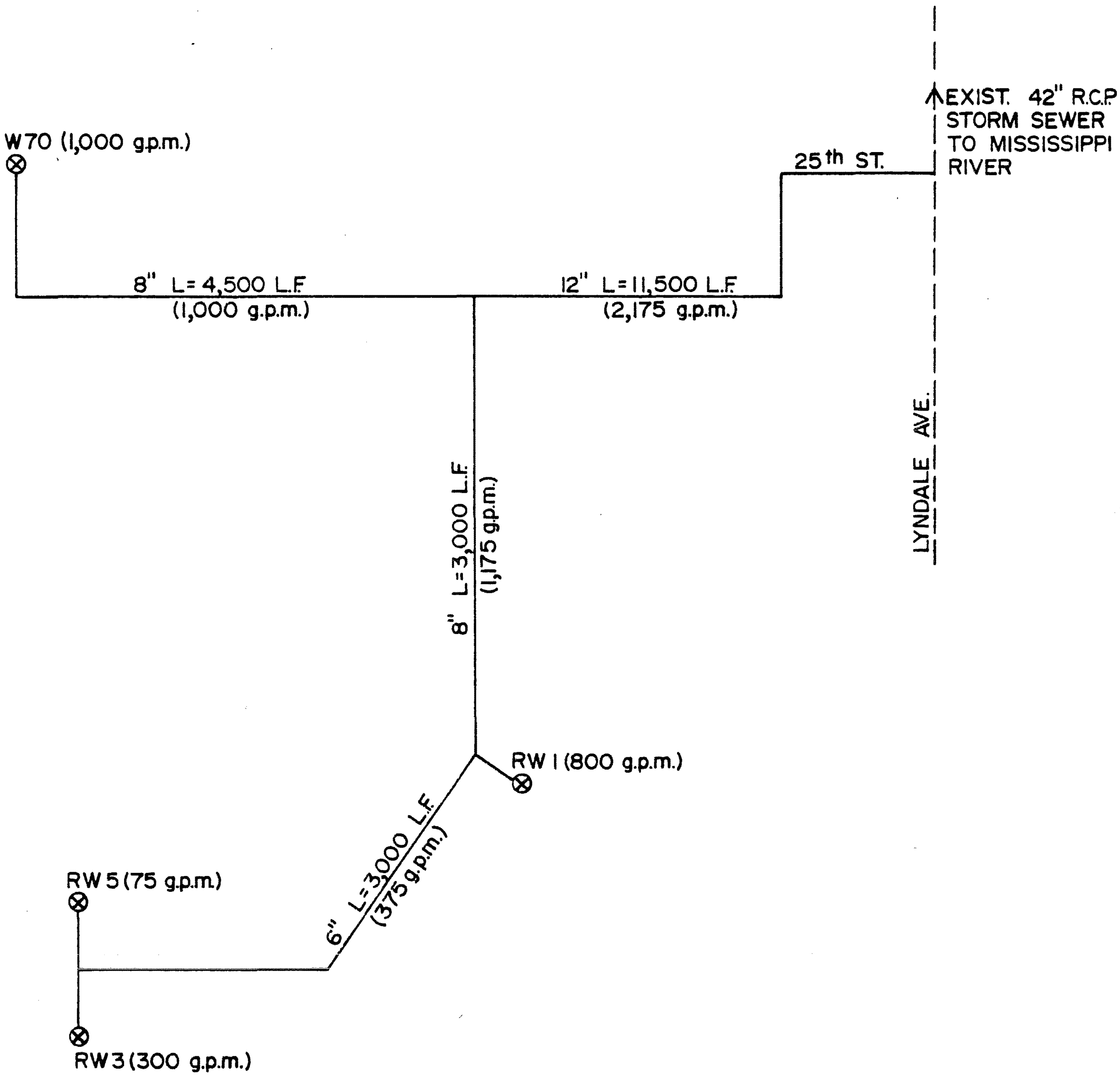
Schemes B and C include discharge to the Mississippi River. A system of collecting pipes, with a force main for conveying effluent to major storm drains in Minneapolis, is required for this purpose. Figures 10 and 11 show schematic flow diagrams for the systems required in schemes B and C, respectively.

C. Granular Activated Carbon Technology

As discussed in Section III, granular activated carbon appears to be the best available treatment method for PAH removal from gradient control well discharge. A preliminary pilot plant study indicates that this technique can achieve 99 percent removal of PAH compounds. The Minnesota Department of Health and Minnesota Pollution Control Agency are planning additional studies of activated carbon treatment in connection with the St. Louis Park groundwater contamination. Information on granular activated carbon (GAC) treatment technology follows.

1. GAC System Components

Systems utilizing granular activated carbon are rather simple. In general, they provide for 1) contact between the carbon and the water to be treated for the length of time required to obtain the necessary removal of organics, 2) reactivation or replacement of spent carbon, and 3) transport of makeup or reactivated carbon into the contactors and of spent carbon from the contactors to reactivation or hauling facilities.



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SCHEMATIC OF DISCHARGE TO MISSISSIPPI RIVER FOR SCHEME B

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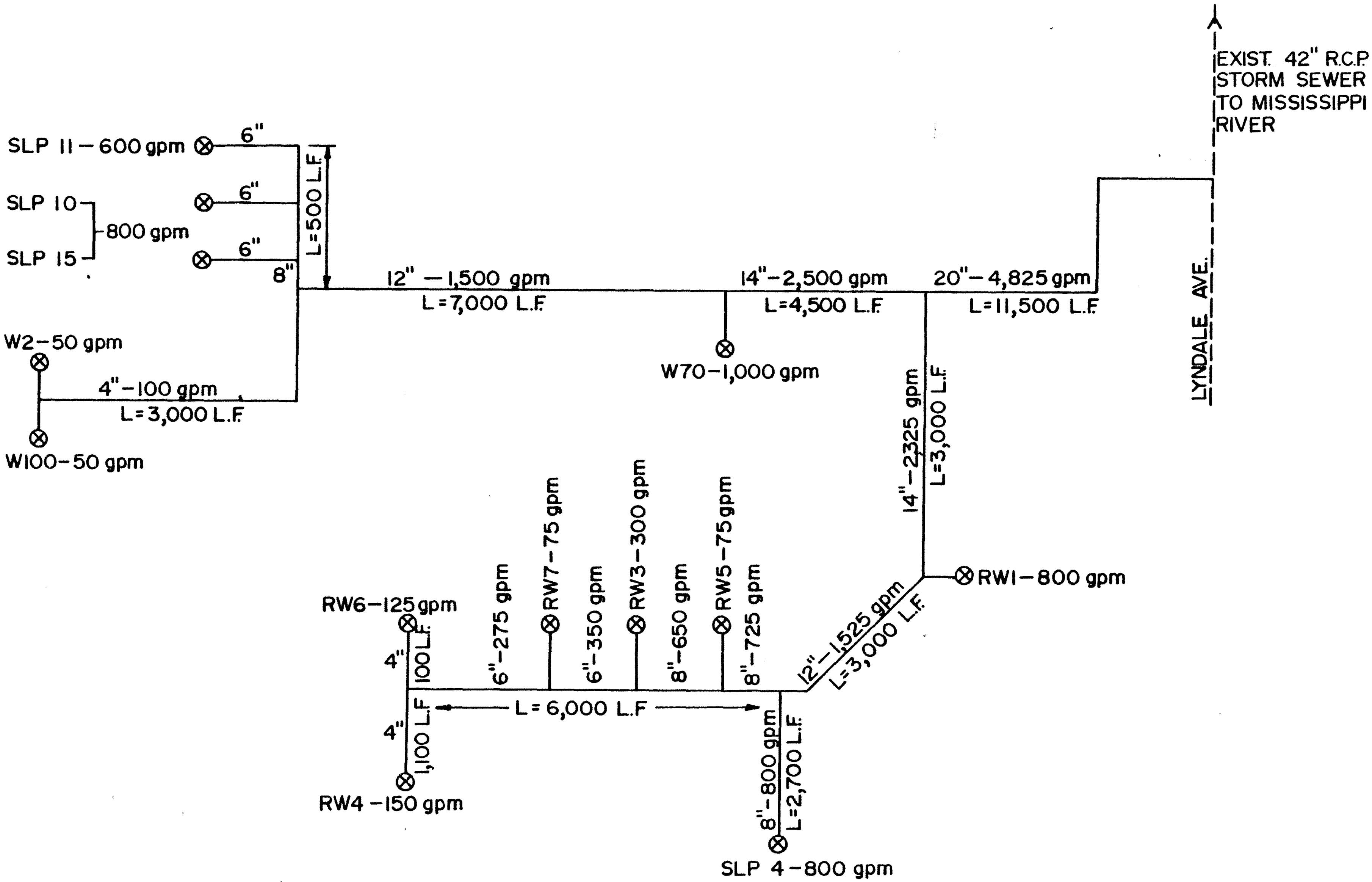

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SCHEMATIC OF DISCHARGE TO MISSISSIPPI RIVER FOR SCHEME C		11

2. Selecting Carbon and Plant Design Criteria

Laboratory and pilot plant tests are a mandatory prelude to carbon selection and plant design for water treatment projects. Pilot column tests make it possible to 1) select the best carbon for the specific purpose based on performance, 2) determine the required contact time, 3) establish the required carbon dosage, which, together with laboratory tests of reactivation, will determine the capacity of the carbon reactivation furnace or the necessary carbon replacement costs, and 4) determine the effects of influent water quality variations on plant operation.

One of the principal differences in GAC treatment between water and wastewater is the more frequent reactivation required in water purification due to earlier breakthrough of the organics of concern. In wastewater treatment, GAC may be expected to adsorb 0.30 to 0.55 pounds of organics per pound of carbon before the carbon is exhausted. From the limited amount of data available from research studies and pilot plant test (most of it unpublished), it appears that some organics of concern in water treatment may break through at carbon loadings as low as 0.15 to 0.25 pounds of organic per pound of carbon. The actual allowable carbon loading or carbon dosage for a given case must be determined from pilot plant tests.

Because the organics adsorbed from water are generally more volatile than those adsorbed from wastewater, the increased reactivation frequency due to lighter carbon loading may be partially offset, or more than offset, by the reduced reactivation requirements of the more volatile organics. The times and temperatures required for reactivation may be reduced due to both the greater volatility and to the lighter loading of organics in the carbon.

From the limited experimental investigations to date, it appears that reactivation temperatures may be reduced from the 1,650° to 1,750° F required for wastewater carbons to about 1,500°F for water purification carbons. The shorter reactivation times required for water purification carbons may allow the number of hearths in a multiple hearth reactivation furnace to be reduced. Also, less fuel may be required for reactivation. These factors must be determined on a case-by-case basis.

3. GAC Contactors

Selection of the type of carbon contactor to be used for a particular water treatment plant generally would be made from three types of downflow vessels:

1. Deep-bed, factory-fabricated, steel pressure vessels of 12-foot maximum diameter. These vessels might be used over a range of carbon volumes from 2,000 to 50,000 cubic feet.

2. Shallow-bed, reinforced concrete, gravity filter-type boxes. These may be used for carbon volumes ranging from 1,000 to 200,000 cubic feet. Shallow beds probably will be used only when long service cycles between carbon regenerations can be expected, based on pilot plant test results.

3. Deep-bed, site-fabricated, large (20 to 30 feet) diameter, open steel, gravity tanks. These may be used for carbon volumes ranging from 6,000 to 200,000 cubic feet, or larger.

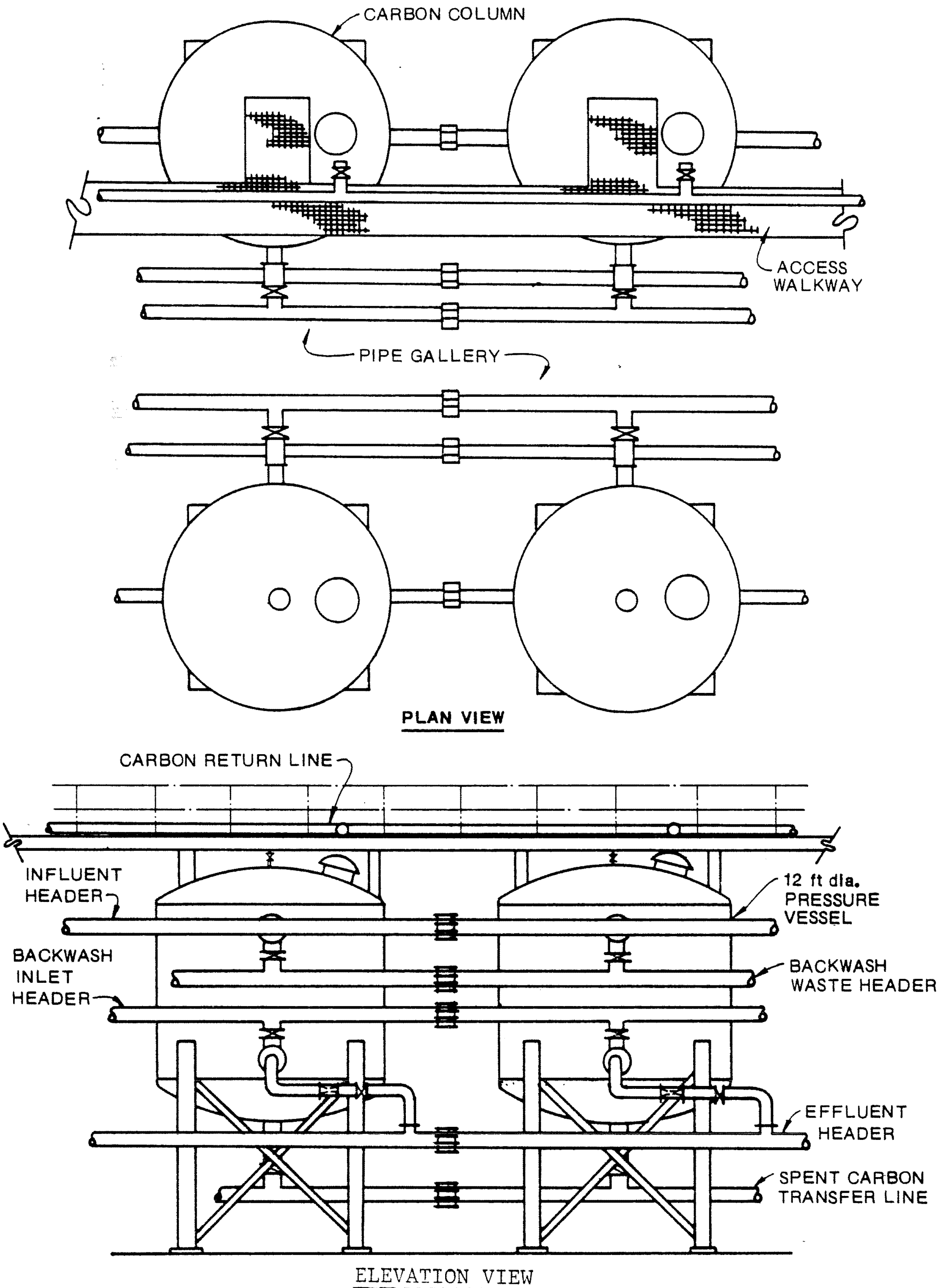
Single beds or two beds in series may be used. Open gravity beds or closed pressure vessels may be used. Structures may be properly protected steel or reinforced concrete. In general, small plants will use steel, and large plants may use steel or reinforced concrete.

In some instances where GAC has been used in existing water filtration plants, sand in rapid filters has been replaced with GAC. In situations where GAC regeneration or replacement cycles are exceptionally long (several months or years), as may be the case in taste and odor removal, this may be a solution. However, with the short cycles anticipated for most organics, conventional concrete box style filter beds are not well suited to GAC contact. For most, if not all, GAC installations for precursor organic removal, or synthetic organic removal, the use of conventional filter boxes will not be a permanent solution and specially designed GAC contactors should be installed.

Substantial cost savings can be realized in GAC treatment of water through proper selection and design of the carbon contactors. A typical deep-bed, steel pressure GAC contactor installation is illustrated in Figure 12.

4. GAC Reactivation or Replacement

Spent carbon may be removed from contactors and replaced with virgin carbon, or it may be reactivated either on-site or off-site. The most economical procedure depends on the quantities of GAC involved. For larger volumes, on-site reactivation is the answer. Only for small quantities of carbon will carbon replacement or off-site reactivation be economical.



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TYPICAL GAC TREATMENT INSTALLATION	HYDROLOGISTS-ENGINEERS MINNEAPOLIS-MINNESOTA	12

Carbon may be thermally reactivated to very near virgin activity. However, carbon burning losses may be excessive under these conditions. Experience in industrial and wastewater treatment indicates that carbon losses can be minimized (held to 8 to 10 percent per cycle) if the GAC activity of reactivated carbon as indicated by the Iodine Number, is held at about 90 percent of the virgin activity.

5. Thermal Reactivation Equipment

GAC may be reactivated in a multiple-hearth furnace, a fluidized bed furnace, a rotary kiln, or an electric infrared furnace. Spent GAC is drained dry in a screen-equipped tank (40 percent moisture content) or in a dewatering screw (40 to 50 percent moisture) before introduction to the reactivated furnace. Dewatered carbon is usually transported by a screw conveyor. Following thermal reactivatin, the GAC is cooled in a quench tank. The water-carbon slurry may then be transported by means of diaphragm slurry pumps, eductors or a blow-tank. The reactivated carbon may contain fines produced during conveyance, and these fines should be removed in a wash tank or in the contactor. Maximum furnace temperatures and time of retention in the furnace are determined by the amount (pounds of organics per pound of carbon) and nature of the organics adsorbed. Off-gases from regeneration of PAH-laden carbon would probably require additional high temperature treatment to prevent harmful PAH emissions to the atmosphere.

VII. CONTAMINATED SOILS MANAGEMENT

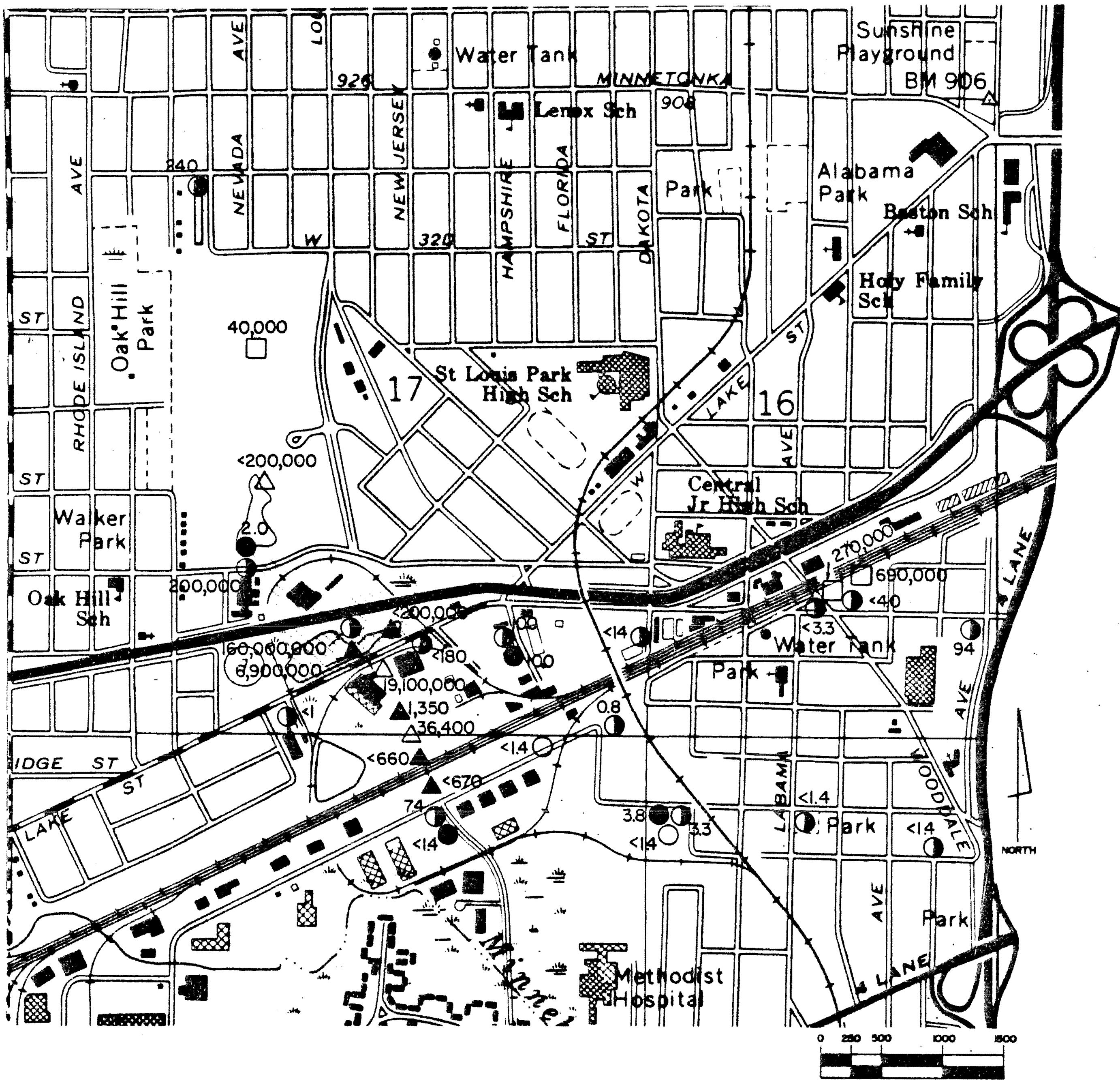
This section discusses the extent of soil contamination and alternatives for managing the contaminated soil. A more detailed discussion appears in Appendix E also entitled "Contaminated Soils Management."

A. Extent of Contamination

On and near the Republic site, soil (taken to include all unconsolidated material overlying the bedrock) comprises near-surface peat deposits and/or fill throughout much of the area, with the underlying material consisting predominantly of sand with clay layers. Monitoring of groundwater and soil in the vicinity of the site indicates contamination of the soil with creosote-related compounds. The primary indicators of contamination are considered to be polynuclear aromatic hydrocarbons (PAH).

In section III it is suggested that PAH criteria for soil be derived from groundwater criteria by means of a "sorption factor," or partition coefficient. On this basis, the soil is contaminated (i.e., violates the criteria) wherever the groundwater is contaminated and vice versa. For carcinogenic PAH compounds the criteria proposed in section III are 2.8 ng/l for groundwater and 280 ng/kg for soil.

Soil and groundwater PAH data from various sources are mapped on Figure 13 - Soil Contamination in Vicinity of Former Republic Creosoting Site. Data shown are benzo(a)pyrene concentrations in units equivalent to parts per trillion for both soil and groundwater. Benzo(a)pyrene was chosen as an indicator because its data are most extensive and it is strongly carcinogenic.



EXPLANATION

SOIL BORINGS:

- □ UNSATURATED
- △ SATURATED, DEPTH < 20FT.
- ▲ SATURATED, DEPTH > 20FT.

MONITORED WELLS:

- ○ WATER TABLE
- ◑ MIDDLE DRIFT
- ● BASAL DRIFT

NOTE:
NUMBERS ARE BENZO(a)PYRENE CONCENTRATIONS IN ng/kg (SOIL) OR ng/l (WELL)

SHOWN ARE MOST RECENT DATA AS OF AUGUST 1981

▨ SUSPECTED "SOURCE" PEAT ZONE

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SOIL CONTAMINATION IN VICINITY OF FORMER REPUBLIC CREOSOTING SITE	HYDROLOGISTS-ENGINEERS MINNEAPOLIS-MINNESOTA	13

Figure 13 shows soil contamination at locations north and south and as far as one mile east of the site, as well as on the site itself. Note that in most of this area the surface soils are probably not contaminated, and gradient control wells provide a reasonable means for alleviating contamination.

The extent of contamination is not fully defined because nearly all the existing monitored locations exhibit elevated benzo(a)pyrene levels. Whether or not contamination is continuous between monitored points is not known. Evidence exists for local sources of PAH separate from the Republic site itself, at 36th and Wooddale (believed by the Minnesota Pollution Control Agency and Department of Health to have originated from D & A Lubricant Company) and near 31st Street and Oregon Avenue. It appears very unlikely that PAH contaminants have migrated from the site to either of these two locations by way of groundwater flow. Thus, there may be several separate zones of contamination in the soil.

Evidence suggests that peat deposits at the south of the site behave as continuing sources of groundwater contamination. Although there are no PAH data available for the peat in the wetland immediately south of the site, liquid waste disposal into this area was documented as early as 1938 and still occurred in the final years of plant operation. In addition, investigators have found that sorption in a variety of soils is proportional to organic carbon content. On this basis, sorption in the peat deposits is probably one or more orders of magnitude greater than in the sandy drift underlying the peat. These considerations implicate the peat deposits as highly contaminated zones which may continue to act as sources of groundwater contamination.

If excavation or treatment of soils in the Republic site vicinity is to be implemented to remedy contamination, then highly contaminated peat deposits are the logical soils to manage. The peat deposits south of the site extend to a maximum depth of approximately 27 feet in some lcoations between Highway 7 and Lake Street. A few borings north of Highway 7 indicate shallower peat deposits there. As an approximate gross estimate, the peat deposits at the south of the site are considered to cover 15 acres with an average depth between 15 and 20 feet. The estimated volume is approximately 400,000 cubic yards.

Definition of the contamination pattern and concentration levels in the peat deposits, and of the extent of the peat, will require systematic field investigations. Measurement of PAH in earth materials depends on extraction efficiencies, which are expected to be quite low in peat thereby yielding special measurement difficulties there. Note that peat naturally contains some PAH, and the above discussion of peat removal concerns peat with extremely elevated PAH levels due to man-induced contamination.

B. Soil Management Alternatives

The following alternatives for managing contaminated soil have been considered.

- No Action
- Capping
- Solidification
- Fixation/Stabilization
- Secure Landfill
- Encapsulation or Containerization with Landfill
- Land Spreading
- Resource Recovery As-Is
- Modification and Resource Recovery
- Warehousing
- Admixing
- Incineration

Appendix E evaluates each of these alternatives. A brief summary of the evaluation is as follows:

No Action	No neighborhood disruption but long-term adverse groundwater impacts remain.
Capping	Partial remedy useful as interim measure.
Solidification	Problem with chemical compatability of PAH with solidifying agents.
Fixation/ Stabilization	Similar to solidification.
Secure Landfill	Difficulties with excavation and landfill availability in State but sound ultimate disposal technique.
Encapsulation or Containerization with Landfill	Possibly a desirable variation on secure landfill alternative.
Land Spreading	Unknowns regarding effectiveness for PAH but technique has good potential.
Resource Recover As-Is	Not practical.
Modification and Resource Recovery	Experimental at this time.
Warehousing	Not an ultimate disposal technique yet very expensive.
Admixing	Not practical.
Incineration	Unknowns regarding effectiveness for PAH but technique has good potential.

Four methods from the above were selected for further consideration and are described below.

1. Capping

This action leaves the contaminated soil in place and covers the area of contamination with compact clay or other impermeable cover. The impermeable cap serves to minimize infiltration of precipitation. This reduces vertical groundwater movement, but significant horizontal groundwater movement and contaminant transport would likely remain. The site under this option would also be graded in order to minimize surface runoff impacts and further reduce opportunities for infiltration. Standing surface water in the contaminated area would need to be monitored and disposed of appropriately in order to cap the area.

Capping by itself is not a complete, long-term solution for contaminated soils. However, it has significant environmental benefits and is attractive as an interim measure. In addition, capping entails minimal disruption of the residential and commercial neighborhood, relative to the disruption associated with excavation of the contaminated soils.

2. Secure Landfill

The secure landfill alternative entails excavating the contaminated soil in a non-consolidated form and transporting it to a secure facility. A secure landfill is an ultimate disposal site specifically designed to contain hazardous wastes and minimize environmental contamination. A secure landfill generally has impermeable lining and a leachate collection system, surface runoff diversion and an ultimate closure plan. A properly designed facility also includes facilities for groundwater and surface water monitoring and evaluation. Excavation of soils from the Republic site vicinity would entail backfilling with clean fill, such as washed sand. The excavation would be wet, and the fluid encountered would likely require truck or rail transport to an ultimate disposal site. Excavation would imply the likelihood that workers would be subject to skin and vapor contact with PAH and perhaps other compounds.

A realistic time for the finding of a disposal site for the contaminated material is between five and seven years. Thus, if excavation and landfilling are to proceed, some additional interim measures would be appropriate at the site.

3. Land Spreading

Land spreading, sometimes called land farming, land treatment or soil incorporation, is the controlled disposal of wastes in the surface soil accompanied by continuing monitoring and management of the disposal site. This technique often includes crop cultivation on the disposal site. The land spreading alternative requires excavating the contaminated soil in the Republic site vicinity and transporting it to a designated disposal site.

Land spreading appears to have potential as an effective means of ultimate disposal for PAH-contaminated soils. It is recommended that further information specific to land spreading of PAH-contaminated soils in the Minnesota climatic region be sought. Because several years may be needed to select and acquire a disposal site, interim measures in the Republic site vicinity would also be appropriate.

4. Incineration

Incineration is recognized as a viable disposal technique for organic hazardous wastes. Under controlled conditions, many organic wastes can be incinerated, producing inert ash and stable oxide forms of the major elemental constituents. This alternative entails excavation of the contaminated soils. Plans for a possible municipal refuse incinerator in St. Louis Park could perhaps be modified to accommodate PAH-contaminated soil and fluid disposal in the future.

It appears from preliminary evaluation that incineration may be a viable option. It is recommended that the contaminated soil be tested further to examine its combustibility and evaluate the byproducts of combustion. An incinerator for this purpose would probably not be available for several years. Thus interim measures in the Republic site vicinity would also be appropriate.

C. Discussion

Three of the selected alternatives entail excavating the contaminated soil. As discussed in section V, excavation of contaminated soils by itself would be expected to yield little benefit to groundwater quality. However, excavation coupled with fluid removal from the "source" area and the underlying Middle Drift could significantly reduce the impacts of leakage on groundwater quality in the bedrock aquifers. Fluid removal would require pumpout wells in the Middle Drift and special handling of fluid encountered in the excavation. Disposal of the fluid would probably entail truck or rail transport.

Capping of the wetland "source" area is recommended as an immediate remedial measure. This is because facilities for contaminated soil disposal (secure landfill, land spreading site, or incinerator) and fluid disposal are not available at present. Capping would reduce groundwater quality impacts and would prevent direct human contact with contaminated soils.

In addition, it is recommended that the Minnesota Department of Health, Minnesota Pollution Control Agency and City of St. Louis Park pursue further the feasibility of the three disposal modes for the excavation alternatives. The above agencies should communicate with the Minnesota Waste Management Board, which is responsible for siting and developing design constraints for a secure landfill and hazardous waste processing facility in the State. Land spreading and incineration data specific to the locale and contaminated soil characteristics should also be obtained. A systematic field investigation to determine the extent and degree of contamination of the peat soils at the south of the Republic site is required as part of the implementation of any of the alternatives.

VIII. EXPENSE ESTIMATES

Expense estimates for the gradient control wells, collection and treatment of the well discharge, and contaminated soils management are presented in Tables 8-14. The estimates have been prepared to reflect January 1, 1982 expenses by developing January 1, 1981 estimates and increasing these by a ten percent inflation factor. Expenses have not been estimated for fluid disposal from excavation of the "source" peat or from a pumpout well in the most contaminated area of the Middle Drift aquifer. Legal and administrative expenses are also not included in the estimates presented here. Specific assumptions and unit costs are detailed in Appendices C, "Collection and Treatment of Gradient Control Well Discharge," and E, "Contaminated Soils Management."

A. Detailed Expense Estimates

Table 8 presents annual operation and maintenance expense estimates for the gradient control wells. The following assumptions have been made here:

Normal Pumping Levels (feet)

Mt. Simon-Hinckley	375 feet
Prairie du Chien-Jordan	175 feet
St. Peter	110 feet
Platteville	35 feet
Middle Drift	40 feet

Well Discharge Head - 150 feet

Power Costs - $0.05 per kilowatt-hour

Overall Pump-Motor Efficiency - 70 percent

Labor - $15.00 per hour

The estimates do not include any major maintenance expenses. Labor expenses are based on one-half hour per well per day.

TABLE 8

Estimated Annual Operation and Maintenance Expenses for Gradient Control Wells

Aquifer	Plan[2]	Power Expenses Pumping	Energy[1]	Normal Maintenance	Labor	Total
Middle Drift	1	$ 5,800	$1,500	$ 200	$ 8,200	$ 15,700
Platteville	1	$ 6,000	$1,500	$ 200	$ 8,200	$ 15,900
St. Peter	1	$ 9,800	$ 500	$ 300	$ 2,700	$ 13,300
Prairie du Chien-Jordan	1	$157,000	$1,000	$4,800	$14,000	$176,800
	2	$130,000	$1,000	$4,000	$14,000	$149,000
Mt. Simon-Hinckley	1	$ 20,000*	$ 0	$ 600*	$ 2,800*	$ 23,400*
	2	$ 20,000*	$ 500*	$ 600*	$ 5,500*	$ 26,600*
	3	$ 20,000*	$ 500*	$ 600*	$ 2,800*	$ 23,900*

*Dependent on implementation of Mt. Simon-Hinckley remedial measures.

[1] Heating and cooling costs for pump house(s). Existing St. Louis Park wells not included.

[2] Refer to Table 5 for summary of remedial pumping plans.

NOTE: Monitoring, legal and administrative expenses are not included.

Normal maintenance expenses are based on an annual expenditure of 5 percent of the cost of the well pump and motor, which is estimated at $200 per horsepower.

Capital costs for gradient control wells are included in the collection and treatment estimates below.

Tables 9, 10 and 11 present estimated expenses for collection and treatment Schemes A, B and C, respectively. These estimates were developed on the assumption that remedial Plan 1 in the Mt. Simon-Hinckley and remedial Plan 2 in the Prairie du Chien-Jordan would be implemented. The tables show both capital and annual expenses, which are exclusive of the annual expenses in Table 8. It is apparent from Tables 9, 10 and 11 that discharge of gradient control wells into the sanitary sewer incurs substantial expense due to the sewer service charge which would be levied by the Metropolitan Waste Control Commission.

Unit cost estimates for monitoring wells in the Middle Drift, Platteville, St. Peter and Prairie du Chien-Jordan aquifers are listed in Table 12. Cost estimates are provided for both nested and fully penetrating monitoring well types. The estimated expense for monitoring well sampling and analysis is approximately $300 per well.

Table 13 gives expense estimates for managing contaminated soils on and near the former Republic Creosoting site.

B. Summary of Expense Estimates

A summary of expense estimates for remedial measures appears in Table 14. For the selected combination of remedial actions, the total estimated capital expenses are approximately seven

TABLE 9

Collection and Treatment Expense Estimates
Scheme A

Aquifer	Estimated Capital Expense: Treatment Plant	Estimated Capital Expense: Well, Pump, Motor, Force Main, etc.	Annual Operation and Maintenance Expenses (1)	Annual Sewer Service Charge
Middle Drift	0	$ 52,000	$ 13,000	$ 90,000
Platteville	0	$ 46,000	$ 14,000	$ 99,000
St. Peter	0	$123,000	$ 8,500	$107,000
Prairie du Chien-Jordan	$3,000,000	$311,000	$369,000	$588,000
Mt. Simon-Hinckley	$1,550,000*	0	$193,000*	0
TOTAL	$4,550,000	$532,000	$597,500	$884,000

* Dependent on implementation of Mt. Simon-Hinckley remedial measures.

(1) Includes: Pumping costs, heating costs, normal maintenance and labor costs to operate gradient control wells.

NOTE: Monitoring, legal and administrative expenses are not included.

TABLE 10

Collection and Treatment Expense Estimates
Scheme B

Aquifer	Estimated Capital Expense: Treatment Plant	Estimated Capital Expense: Well, Pump, Motor, Force Main, etc.	Annual Operation and Maintenance Expenses(1)	Annual Sewer Service Charge
Middle Drift	0	$ 52,000	$ 13,000	$ 90,000
Platteville	0	$ 79,000	$ 16,000	$ 73,000
St. Peter	0	$ 156,000	$ 10,000	0
Prairie du Chien-Jordan	$3,000,000	$ 843,000	$376,000	0
Mt. Simon-Hinckley	$1,550,000*	0	$193,000*	0
TOTAL	$4,550,000	$1,130,000	$608,000	$163,000

* Dependent on implementation of Mt. Simon-Hinckley remedial measures.

(1) Includes: Pumping costs, heating costs, normal maintenance and labor costs to operate gradient control wells.

NOTE: Monitoring, legal and administrative expenses are not included.

TABLE 11

Collection and Treatment Expense Estimates
Scheme C

	Estimated apital xpense			
Aquifer	Treatment Plant	Well, Pump, Motor, Force Main, etc.	Annual Operation(1) and Maintenance Expenses	Annual Sewer Service Charge
Middle Drift	0		$ 18,000	—
Platteville	0		$ 19,000	0
St. Peter	0	$4,600,000	$ 14,000	0
Prairie du Chien-Jordan	0		$182,000	0
Mt. Simon-Hinckley	0		$ 26,000*	0
TOTAL	0	$4,600,000	$259,000	0

*Dependent on implementation of Mt. Simon-Hinckley remedial measures.

(1) Includes: Pumping costs, heating costs, normal maintenance and labor costs to operate gradient control wells.

NOTE: Monitoring, legal and administrative expenses are not included.

TABLE 12

Monitoring Well Unit Cost Estimates

Aquifer	Approximate Nested Well Cost* Upper	Approximate Nested Well Cost* Lower	Approximate Fully Penetrating Well Cost†
Middle Drift	$1700 - 2,200	$ 2,400 - 3,400	$ 3,400 - 4,400
Platteville	$2500 - 3,600	$ 3,200 - 4,800	$ 4,800 - 6,200
St. Peter	$3300 - 4,900	$ 6,200 - 9,600	$ 9,600 - 12,500
Prairie du Chien-Jordan	$8100 - 12,500	$13,600 - 22,100	$22,100 - 28,700

*Upper and lower denote nested well screened adjacent to upper and lower five feet of aquifer, respectively.

†Fully penetrating well screened over 80 percent of aquifer thickness.

TABLE 13

Soil Management Expense Estimates

Alternative	Itemized Expense	Total Expense
1. Capping		$ 1,500,000
2. Secure Landfill (Germantown, Wisconsin Site)		$18,100,000(3)
a. Excavation(1)	$ 2,100,000	
b. Backfill(2)	$ 4,000,000	
c. Transportation to Site	$12,000,000	
Secure Landfill (New Site)		$15,100,000
a. Excavation(1)	$ 2,100,000	
b. Backfill(2)	$ 4,000,000	
c. Landfill Construction and Transportation	$ 9,000,000	
3. Land Spreading		$12,000,000
a. Land Purchase	$ 1,500,000	
b. Excavation(1)	$ 2,100,000	
c. Backfill(2)	$ 4,000,000	
d. Transportation	$ 3,700,000	
e. Cultivation	$ 700,000	
4. Incineration		$56,100,000
a. Excavation(1)	$ 2,100,000	
b. Backfill(2)	$ 4,000,000	
c. Incinerator	$25,000,000	
d. Operation and Maintenance	$20,000,000	

(1) Excavation of contaminated soil at former Republic Creosoting site, including $1,060,000 for soil excavation and $1,040,000 for dewatering.

(2) Backfilling of (1) above.

(3) Does not include landfill fee which would be charged to disposer.

NOTE: Monitoring, legal and administrative expenses are not included.

TABLE 14

Selected Remedial Measures Expense Summary*

	Capital Expense	Annual Expense
Gradient Control Wells Operation and Maintenance (with Plan 1 in Mt. Simon-Hinckley and Plan 2 in Prairie du Chien-Jordan)	0	$217,000
Collection and Treatment (Scheme B)	$5,680,000	$771,000
Contaminated Soil Management (Interim Capping)	$1,500,000	0
TOTAL	$7,180,000	$988,000

*Total expenses would differ for combinations of remedial actions other than those shown here. Not included here are removal of the "source" fluid in the Middle Drift and excavation of the overlying peat and associated fluid.

NOTE: Monitoring, legal and administrative expenses are not included.

million dollars, with additional annual expenses of one million dollars. Other combinations yield different totals. In particular, removal of contaminated soils (alternatives 2, 3 or 4) would incur substantially greater expense than is reflected in Table 14.

IX. CONCLUSIONS

The following conclusions have been developed from this study.

Description of Problem

1. Polynuclear aromatic hydrocarbons (PAH) are present in St. Louis Park groundwater in all aquifers from the surficial glacial drift to the Ironton-Galesville. The presence of PAH in the Mt. Simon-Hinckley aquifer at a depth of approximately 1,000 feet is inferred from available hydrogeologic information.

2. The concentrations of PAH observed in groundwater samples exceed the proposed criteria for potable use in at least one well in each aquifer, except for the Mt. Simon-Hinckley aquifer, which has not been extensively tested.

3. Twelve specific PAH compounds are known to be carcinogenic, and of these, seven have been identified in St. Louis Park groundwater.

4. The City of St. Louis Park now has a water shortage because of well closures due to elevated PAH concentrations in the well water.

5. Substantial amounts of PAH have migrated beyond the property boundary of the former Republic Creosoting site.

6. Sorption in the glacial drift and leakage through confining beds will probably cause substantial PAH contamination to persist in the shallow aquifers for thousands of years, even with implementation of remedial measures.

7. Leakage into the Prairie du Chien-Jordan aquifer, the major aquifer in the Twin Cities area, will probably cause significant PAH contamination to persist in this aquifer for at least a century, even with remedial measures.

8. The Middle Drift and Platteville aquifers exhibit zones of PAH contamination north and east of the site which cannot be explained with existing knowledge of groundwater transport from the site and require further investigation.

9. If groundwater movement is not controlled in the Prairie du Chien-Jordan and shallower aquifers, the generally eastward groundwater flow will eventually carry PAH to the Mississippi River or other tributary surface waters, which can be expected to preclude future potable use (without treatment) of groundwater in the affected area.

<u>Gradient Control Well System</u>

10. Effective control of groundwater PAH contamination requires gradient control wells in all aquifers with the possible exception of the Mt. Simon-Hinckley.

11. An effective gradient control well system is feasible, including the ultimate disposition of water discharged from the wells.

12. Treatment of gradient control well discharge for potable use would address the present water supply shortage of the City of St. Louis Park and at the same time provide a means for removing PAH from the environment.

13. Granular activated carbon appears to be the best available treatment method for PAH removal from gradient control well discharge.

14. Operation of the gradient control well system needs to be flexible and will require extensive groundwater monitoring in order to accommodate present data deficiencies and future changes in groundwater withdrawal.

15. Operation of the gradient control well system may cause contamination of aquifer areas not presently known to be contaminated.

16. The gradient control well system would need to operate for an indefinite period in some aquifers.

<u>Major Contaminant "Source" Area</u>

17. The finding of PAH concentrations above reported solubilities in water suggests that a distinct fluid zone with a predominantly hydrocarbon character exists in the Middle Drift aquifer at the south of the former Republic Creosoting site.

18. Indirect evidence suggests that peat deposits at the south of the site will probably act as a continuing source of groundwater contamination in the Middle Drift.

19. Removal of the "source" fluid in the Middle Drift and excavation of the overlying peat and associated fluid could significantly reduce the impacts of leakage on groundwater quality in the underlying bedrock aquifers.

20. Disposal of "source" fluid removed from the Middle Drift and the overlying peat would probably entail truck or rail transport because the extremely high PAH concentrations preclude local treatment and disposal at the present time.

21. As an interim measure, capping the "source" peat deposits with clay or other low-permeability material would reduce groundwater quality impacts and would prevent direct human contact with contaminated soils.

Information Deficiencies

22. PAH measurements in the parts per trillion (nanogram per liter or nanogram per kilogram) range are variable and difficult to interpret. More reliable methods for quantifying PAH at low concentrations are needed.

23. Available data do not define the full extent of PAH contamination in any one of the aquifers.

24. Available data do not define the nature and full extent of the major contaminant "source" area at the south of the former Republic Creosoting site, including fluid in the Middle Drift and overlying peat deposits and associated fluid. A disposal plan and cost estimates cannot be formulated for the fluid until more detailed information is available on the quantity and quality of the "source" material and resulting disposal techniques.

X. RECOMMENDATIONS

The following recommendations have resulted from the present study.

Immediate Actions

1. St. Louis Park municipal wells 4, 10 and 15 in the Prairie du Chien-Jordan aquifer should be returned to service as soon as possible, with discharge of the water to the sanitary sewer system.

2. The "source" peat deposits should be capped with low-permeability material and graded to maximize surface runoff, as an interim measure.

3. The City of St. Louis Park should continue to investigate alternative water sources.

4. All groundwater usage in the St. Louis Park vicinity should be inventoried, controlled and monitored.

Ultimate Solutions

5. The State of Minnesota should define criteria for polynuclear aromatic hydrocarbons (PAH) in potable water and ambient ground and surface water. The adopted criteria will have statewide impacts, including in particular storm runoff and cooling water discharges into Minnehaha Creek.

6. A gradient control well system should be implemented in order to protect downgradient groundwater.

7. A pumpout well or wells should be implemented in the Middle Drift "source" fluid zone at the south of the site when appropriate means of disposal are available.

8. The data deficiencies should be investigated whether the gradient control well system is implemented or not.

9. After determination of the extent and nature of "source" peat deposits, excavation of the peat and removal of the associated fluid should be re-evaluated. New data on PAH sorption in the glacial drift should also be taken into account when available.

10. One unit of government should have overall responsibility for managing the groundwater in the St. Louis Park vicinity, with successful operation of the gradient control well system as its primary function.

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