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Wisconsin Groundwater Management Practice Monitoring Project No. 30

GROUNDWATER
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Wisconsin Department of Natural Resources

Report On

Groundwater Contamination

at the Flambeau Paper Corporation

Spent Sulfite Liquor Disposal Site

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I. Executive Summary

The Flambeau Paper Corporation owns and operates a land disposal site located in Sec. 35 of the Town of Eisenstein, along the Flambeau River, which has had multiple purposes. One use of the site was the disposal and storage of spent sulfite liquor, a pulping byproduct, in unlined lagoons. This use, which occurred from 1956 to 1980, has resulted in groundwater contamination over an area of approximately 80 acres. The lagoon system has been abandoned and the site is now being used for wastewater treatment plant sludge landfill cells.

This evaluation of current groundwater quality data from monitoring wells around the site indicates that the site is contaminated. The data, which has some limitations due to differing quality assurance practices, identifies several factors which may be cause for concern about the future of the site.

Further assessment of the site status should be completed including a geologic study and a groundwater monitoring effort along the perimeter of the site. Possible cleanup alternatives should also be evaluated.

II. Introduction

The Flambeau Paper Company operated unlined lagoons for the storage and disposal of spent sulfite liquor, which is a by-product of their wood pulping process. These lagoons were operated between 1956 and 1980 and were abandoned and leveled in 1980. State officials were aware of the practice and discharges from these lagoons were covered by a WPDES permit beginning in 1974 until the lagoons were abandoned. The lagoons are located along the North Fork of the Flambeau River on a 200 acre site which also contains abandoned and active sludge landfills.

Groundwater monitoring associated with landfill construction and operation indicates that operation of the sulfite lagoons has resulted in groundwater contamination. Because the lagoons were unlined and large volumes of spent liquor were stored for extended periods of time, large amounts of liquor seeped into the soil and into the groundwater. Sampling in the area has been ongoing since 1977 and has confirmed the problem. Results have shown contamination at all depths up to 60 feet with COD concentrations up to 41,000 mg/l and conductivities up to 5,200 umhos/cm. Extensive results for parameters such as hardness, alkalinity, chloride, sulfate, and iron also verify contamination. Recent background groundwater quality monitoring around the new sludge landfill had also suggested that elevated levels of heavy metals may also be present. Additionally, seepage of this groundwater out of the bank of the river has resulted in areas of visible vegetation loss where it flows into the river.

The uncertainty about the overall extent and consequences of this groundwater contamination are the reasons for addressing this problem. The requirements of NR140, the groundwater protection code; concern about possible impacts on the river, any nearby wells, and the environment in general; and questions about possible natural attenuation and cleanup versus remedial action are all the specific reasons for evaluating the problem.

This preliminary report addresses these issues by evaluating the literature, historical information, and past and current data. The results, summaries, and discussions will pertain to existing information and provide preliminary recommendations for additional needs.

III. Objectives

The primary objective of this study was to collect and develop information necessary to assess the status of the Flambeau Paper spent sulfite liquor storage lagoon site. The multiple uses of the site and the extended period of time in which the site was used has resulted in a large amount of data and file information which is relevant to this objective. However, this information was dispersed in many files and not in a readily usable form.

Also, current data for the entire site was not available. Although some wells were sampled regularly due to landfill operation requirements, others had not been sampled for eight years.

The activities of this study were designed to consolidate data records, assess the current conditions, and propose a future course of action. Due to the unforeseen size of this project all of these tasks were not accomplished, particularly, proposing solutions or resolutions. However, an objective to identify more specific study needs to further define the current status and propose appropriate solutions was added.

The activities as they were executed are as follows:

Review all department and company file information relevant to the issue and prepare a chronology;

Review and summarize all relevant sampling results;

Conduct a brief literature review and summarize relevant information about the issue;

Collect samples and report results to assess current groundwater quality;

Analyze information and assess current site status;

Identify further study needs;

Prepare summary report.

IV. Chronology of Events

The following chronology was developed through a review of all DNR files, company files and interviews with department and company personnel.

Flambeau Paper Company located in Park Falls, Wisconsin, is a division of Pentair Inc. of St. Paul, Minnesota. It is an integrated paper mill which produces approximately 40,000 tons per year of calcium based bisulfite pulp and consequently about 110 tons of spent sulfite liquor solids per day or 40,000 tons per year. The company sells various grades of lignosulfonate concentrated liquor to end-use markets such as animal feed and road dust control and to other lignosulfonate producers. However, the market is such that additional means for spent sulfite liquor disposal are still necessary from time to time. Since 1950, the roadbinder program has been used as a bonafide disposal method during the summer months.

Another disposal method in place at that time was spraying diluted spent sulfite liquor on the island in the river adjacent to the mill. This liquor contained the wash water from the blow pits and had a solids content of 1-6%. It was hoped through anaeorobic microbiological processes within the soil, that the BOD content of this liquor would be reduced. However, unconfirmed wells reportedly dug in the area were found to be contaminated with spent sulfite liquor. This method also produced strong odor problems. Data on this practice is limited.

According to company officials a third method of disposal involved trucks hauling liquor to land disposal sites away from the mill. The tankers would empty into wooden troughs which emptied onto the ground. Prior to 1956, 2 sites were used for land disposal of liquor. One was located at the intersection of Hwy E and Buckhorn Road and the second on West Maple Ridge Road. The extent and time frame of use of these sites is unknown.

Due to the necessity for a larger disposal site, parts of the 160 acre Town of Eisenstein site in question were also used for land disposal. The site which is along the Flambeau River was purchased in 1949. The exact time when the site was first used is unknown but it was prior to 1956. Liquor was allowed to flow out of tank trucks directly on the ground to be absorbed and treated by the soil before it entered the river. Similar land disposal practices were also used at other mills such as Rothschild and Niagara and was considered an acceptable way to keep the material out of rivers then.

In October of 1956, Walter Sherman of the Flambeau Paper Company toured the Town of Eisenstein disposal site with a state health engineer. The area in use had doubled. Mr. Sherman noticed that liquor was allowed to be discharged on open ground and was distributed over a larger area. It was also noticed that liquor was leaking into the river.

In September of 1959, a fish kill occurred in the Flambeau River. An oxygen deficiency was tested for and confirmed.

By October 1960, the following steps were taken to prevent further fish kills. 1) The total area for soil seepage had been doubled. 2) Total volume for spent sulfite liquor in the disposal areas had been increased about five times. 3) The construction of ridge and furrows along the side slopes had been completed. 4) New storage lagoons had been developed and began to be used sometime between September 1959 and October of 1960. By 1962 a total of 22 lagoons were being used with a total holding capacity of 44,000,000 gallons.

The lagoon system began with two shallow lagoons. Bulldozers were used to construct the lagoons and the dikes between lagoons. Piping and a trough system were constructed on the dikes to connect the lagoons, regulate the depth of liquor, and to prevent washout of the dikes.

In 1965, a six evaporator system called Evapex was installed at the mill to increase the concentration of spent liquor solids. On a rotating basis, one evaporator would be shut down for cleaning. Condensate was used as a wash to dissolve the scale in the evaporator. The condensate would then become contaminated with spent sulfite liquor and either be hauled as roadbinder or disposed of at the lagoon site. The evaporator concentrated material was sold. In 1969 some liquor was still hauled for roadbinder but most was evaporated. At that time wash water from the blow pits was still being sprayed on the island in the river during the summer. The sulfite liquor lagoons were only occasionally being used for liquor during this time-when the evaporator was shut down for wash and repair. Evaporator condensate was tried on the roads with no success. Since it contains little or no spent liquor the binding qualities of the material are not present. Condensate continued to be hauled to the liquor lagoon site.

Apparently in response to questions, in August, 1971 a letter was written from Walter Sherman to Wm. Goetz, Chief Construction Operations Division of the Department of the Army concerning the disposal lagoons of Flambeau Paper Company. Mr. Sherman gave the following synopsis of the liquor lagoon storage facility.

> "We have 120 acres of soil seepage disposal of condensate and any excess sulfite liquor which cannot be evaporated. It is on a granite sub-base which slopes toward the river and the maximum distance from the river bank is about 3/8 of a mile. The flows actually are somewhat longer than this, because of the contours which cause seepage to occur over 1/2 mile on its way toward the river. The seepage through the soil seems to destroy the BOD (Biological Oxygen Demand) and we can operate this total tract of disposal land without allowing the liquid applied to flow above ground into the river during non-feeezing weather. We have checked the D.O. (Dissolved Oxygen) and BOD along the river bank and compared it with the opposite bank where there is no possibility of this material seeping into the water and can find no difference between the two sides. As far as we know the BOD is destroyed before it reaches the river.
>
> We have arranged in some years to drain the storage which now has an available capacity of 35,000,000 gallons in the several ponds in the fall of the year when the river D.O. is high and not upset by this. The drainage is controlled by a valve on each pond which lets the liquid flow out into ditches or ponds at a lower level until at the bottom of each flow path the last valve would allow this material to flow above ground into the river.
>
> Both of these disposal methods were approved by the Committee on Water Pollution many years ago and they had been a part of our order on disposal of BOD materials from our sulfite operations."

Beginning in 1974, concentrated liquor was burned in a loblolly burner. This took place for about a year and a half but was discontinued because of a fly ash problem.

In October of 1974, the Flambeau Paper Company was issued a Wisconsin Pollution Discharge Elimination System Permit No. 0003212 by the DNR for discharges into the North Fork of the Flambeau River. Flambeau Paper's application request for the permit described a total of nine discharge points throughout the entire mill complex. There were two discharge locations authorized in the permit at the lagoon site: outlet 010 as the north disposal discharge drain and outlet 011 as the south disposal discharge drain. The permit placed the following limitations on the discharges at the liquor lagoons. "These discharges shall be further limited by the permittee to periods of high river flow in the cold weather months of October through March and controlled to maintain a minimum of 3 mg/l of D.O. in the river at all times. The permittee should notify the department at least 48 hours ahead of a planned discharge."

In 1975 all evaporator condensate was disposed of at the liquor lagoon disposal site. In the summer of 1976, a condensate chemical recovery plant and wastewater treatment facilities consisting of a blow tank, counter current washer, trickling filter, and primary and secondary clarifiers were put on line. It was hoped that this would eliminate disposal of condensate at the lagoon site. Counter current washers eliminated diluted wash water spraying on the island in the river but the condensate recovery plant had problems and condensate was still hauled to the lagoons.

In the fall of 1976, low flow in the river prevented lagoon drainage and plans were made to empty them in the spring of 1977. Low flow also prevented a spring discharge.

In Feburary of 1977, the Kansas City Star sold the Flambeau Paper Mill to Capitol Cities. This delayed plans for the activated sludge plant to become finalized at that time.

In May of 1977, a file memo stated that the use of the spent sulfite liquor lagoons would be ceased once the new activated sludge treatment plant facilites were completed and the site would be used for emergency standby only. The company's plan was to discontinue discharge from this site after June 30, 1977.

In September of 1977, the company discontinued adding material to the lagoons. Some of the ponds leached out completely while others remained full. On September 19, 1977, a discharge to the river was noted by Ted Smith and Larry Prenn of the Department of Natural Resources while collecting river samples. Wastewaters were observed migrating down the bank and were entering the river at three distinct locations.

Due to problems with excess lagoon contents and permit requirements prohibiting discharge, the contents of all lagoons were pumped to a few lagoons from which they were road spread in the fall of 1977. During this time the district DNR office recommended that the lagoons be emptied and the site permanently abandoned.

During the review of a planned solid waste project in the general lagoon vicinity, in January of 1978, the Bureau of Solid Waste Management and the Bureau of Environmental Impact evaluated data obtained from eight groundwater monitoring wells at distances ranging from 300' - 3000' from the lagoons and found significant groundwater contamination. The Bureau of Solid Waste also recommended that Flambeau Paper Company consider regrading and final abandonment of the inactive lagoons.

In June of 1978, the Flambeau Paper Company started burning spent sulfite liquor again in the boilers because of no storage facilites or sellable markets. Also in June, lagoon number 2 was lined with bentonite at the rate of 1 lb./sq. ft. The lining was complete in July. Lagoons 3 and 17, were also lined with bentonite. The ponds were full of liquor at the time the bentonite was layed down so it was difficult to get uniform coverage throughout the pond. These lagoons would be used for emergency storage of Evapex feed liquor as needed.

On November 7, 1978 the Flambeau Paper Company was sold to Pentair. It was Pentair's intent to increase production of the Flambeau Paper Mill so the plans for the secondary activated sludge treatment plant were modified to handle the increased production.

In January of 1979, plans for a synthetically lined five million gallon reservoir designed as a temporary storage terminal for sulfite liquor were submitted. When the hypalon lined lagoon was finished, liquor from the bentonite lined lagoons was to be transferred to the new lagoon or put on the roads.

On July 11, 1980, Flambeau Paper advised Northwest District personnel that a number of the lagoons had been emptied but had not been restored to their natural state.

By July 15, 1980 all old condensate lagoons at the disposal area had been emptied and by September, 1980 all the lagoons were leveled and the ground surface was restored.

In May of 1981, DNR Solid Waste staff in Madison concluded that the past disposal of spent sulfite liquor in the site area had contaminated the groundwater and depleted the marginal attenuative capacity of the predominately on-site sandy soils. The contamination also made groundwater monitoring at the new landfill site difficult. It was noted that data from wells number 1-4, located east of the disposal site, suggested that the COD contributed by sulfite disposal had decreased significantly since 1977 though the values still remained at high levels.

In August of 1985, a DNR warden noticed seepage into the river near the old sulfite liquor lagoons. DNR personnel inspected the sight and confirmed the wardens findings. This inspection prompted a heightened interest in a study into the nature of the problem.

V. Description and Characteristics of Spent Sulfite Liquor

The following information presents a brief summary of the chemical and physical characteristics of wood, lignins, and lignosulfonates, and sulfite liquor.

A. Composition of Wood:

	Average %
Cellulose	45
Lignin	28
Hemicellulose	25
Extractives	2

Cellulose - Polymer of glucose units
Lignin - Polymer of Phenyl Propyl units
Hemicellulose - Polymer of mixed Hexose & Pentose units

B. Chemistry of lignin and lignosulfonate:

Lignosulfonates are complex polymeric materials obtained as by-products of wood pulping. The term "lignosulfonate" is a mixture of sulfonated lignin, sugars, sugar acids, resins, and inorganic chemicals. This complex and variable mixture is water-soluble and anionic, with certain surface-active characteristics.

In the sulfite pulping process, wood is debarked, chipped, and cooked in a digestor. Under heat and pressure in a solution of sulfurous acid and either calcium, magnesium, sodium or ammonium bisulfite, the wood is transformed into pulp. During cooking the wood lignin is partially sulfonated. The sulfonation usually occurs on a carbon atom next to the ring structure:

Composition of Spent Sulfite Liquor Solids

	% Range	
	Softwood	Hardwood
Lignosulfonates	55	42
Hexose sugars	14	5
Pentose sugars	6	20
Miscellaneous:		
Hemicellulose, sugar acids and residues	12	20
Resins and extractives	3	3
Ash	10	10

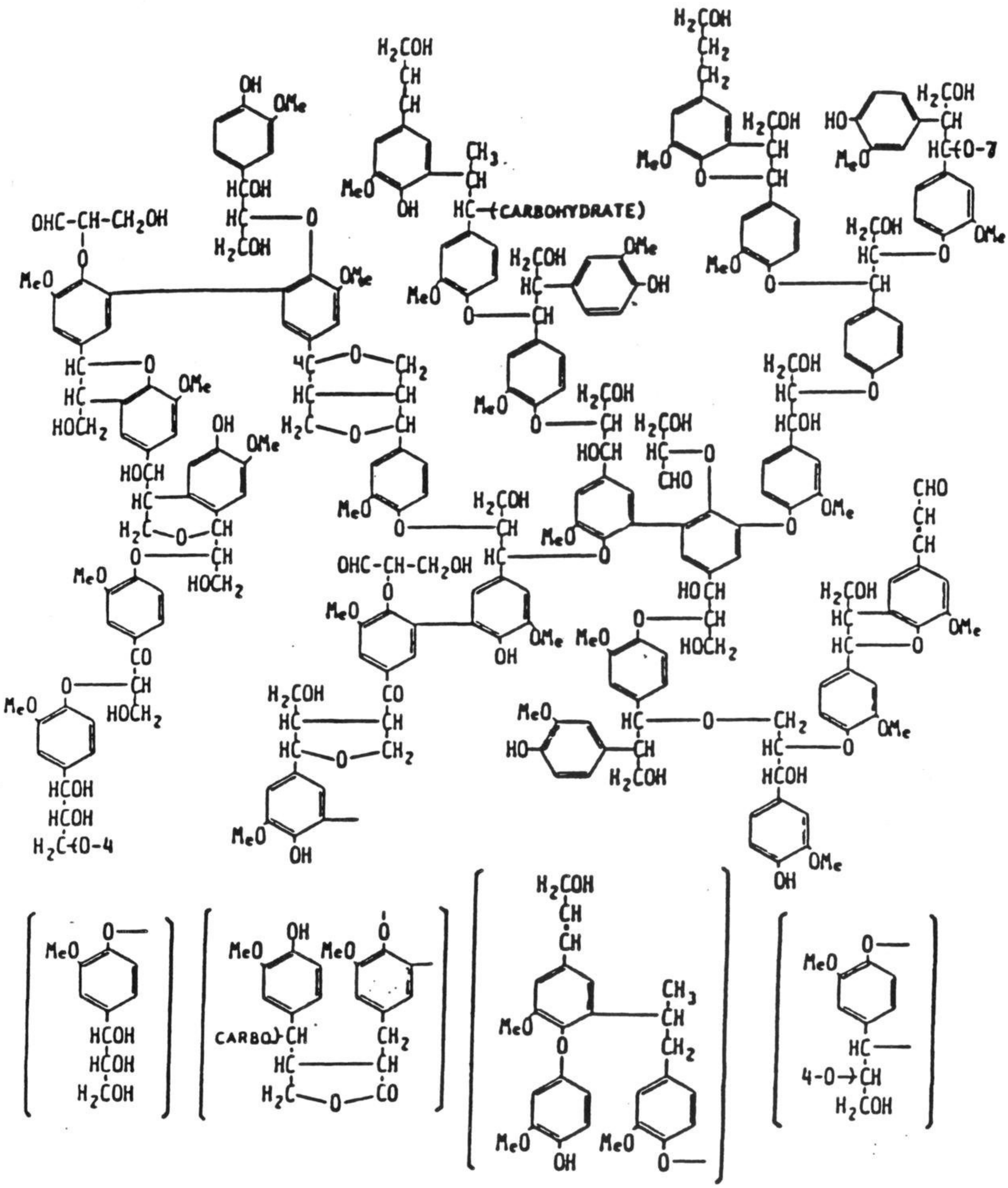
The lignins are quite variable in compositon, depending on the tree species, location within the tree, geographic area, climatic conditions, age of the tree, and time of cutting. In general terms, the lignin is a hetergeneous ether polymer with several different aromatic components and numerous O_2 - containing functional groups.

The prominent aromatic constituents of lignins are guaiacyl, p-hydroxphenyl and syringyl units. See Figure 1, 2, 3.

C. Physical features of Flambeau Paper Company Spent Sulfite Liquor

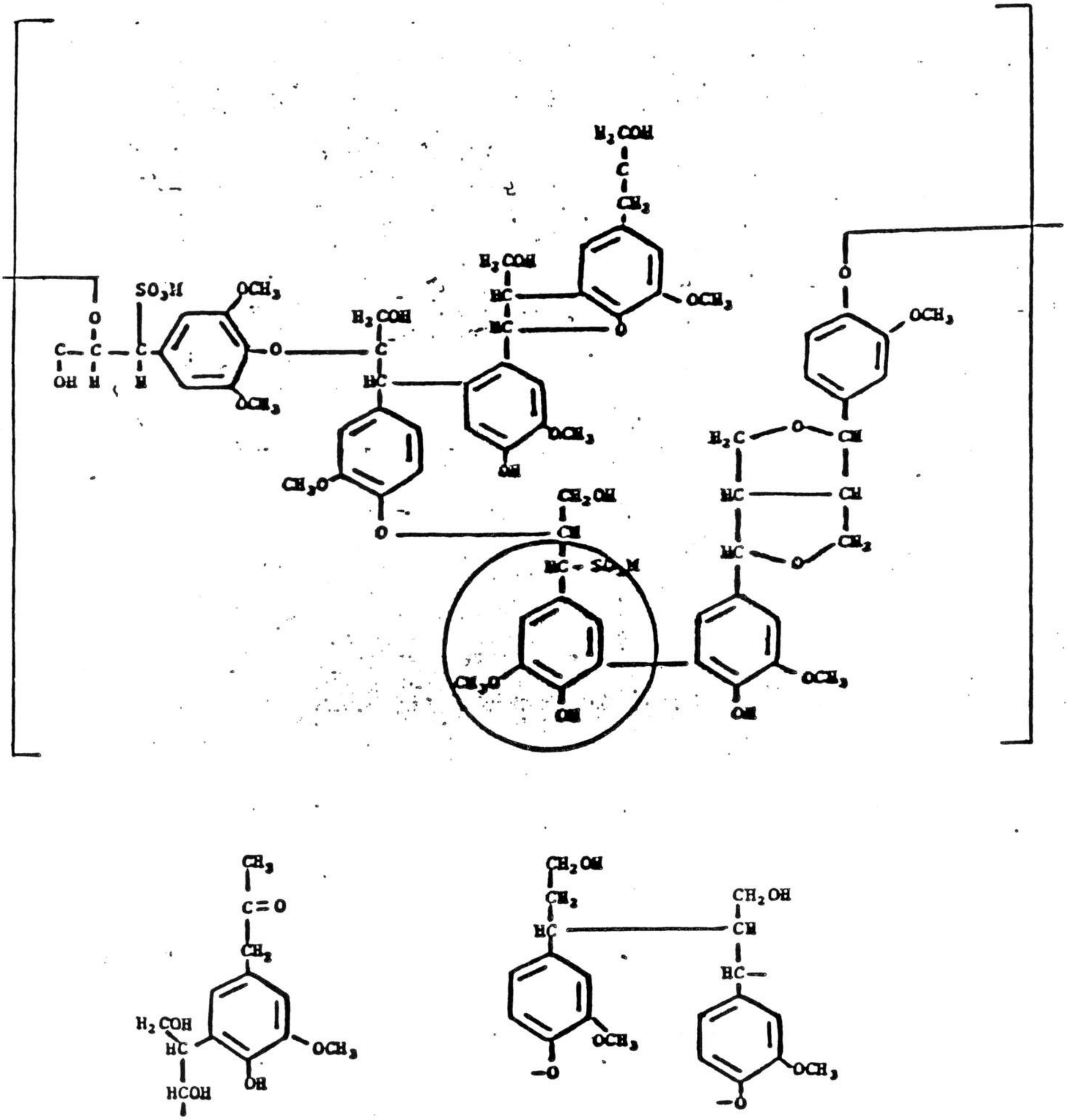
1. Dilute (from digestor blow tanks)
   Color = yellow to brown solution
   Odor = sharp, sulfer dioxide
   Concentration = 8-15% (usually 10-14%)
   ph = 3 to 4
   Viscosity = 10 to 50 cps at 25°C
   Specific gravity = 1.02-1.08 g/cc at 25°C
   lbs. solids/U.S. gal. = approx. 1.2

2. Concentrated (Plant evaporation)
   Concentration = 50%
   Color = Dark Brown
   Odor = Burnt coffee
   ph = 3 to 4
   Viscosity = approx. .450 cps at 25°C
   Specific gravity 1.255 g/cc at 25°C
   lbs. solids/U.S. gal. = 5.3



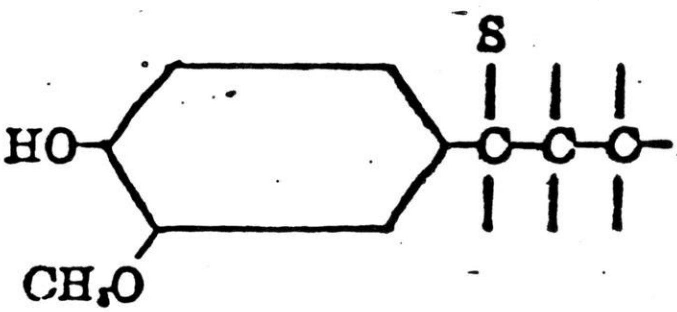
A structural model of softwood lignin.

FIGURE 1

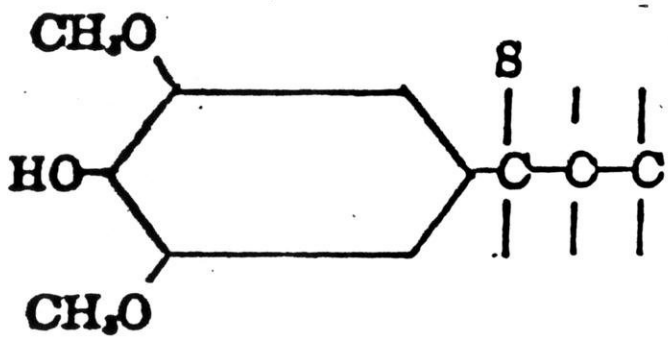


LIGNOSULFONATE

FIGURE 2



Guaiacyl Unit



Syringyl Unit

FIGURE 3

VI. Description and Characteristics of the Sulfite Liquor Disposal Site

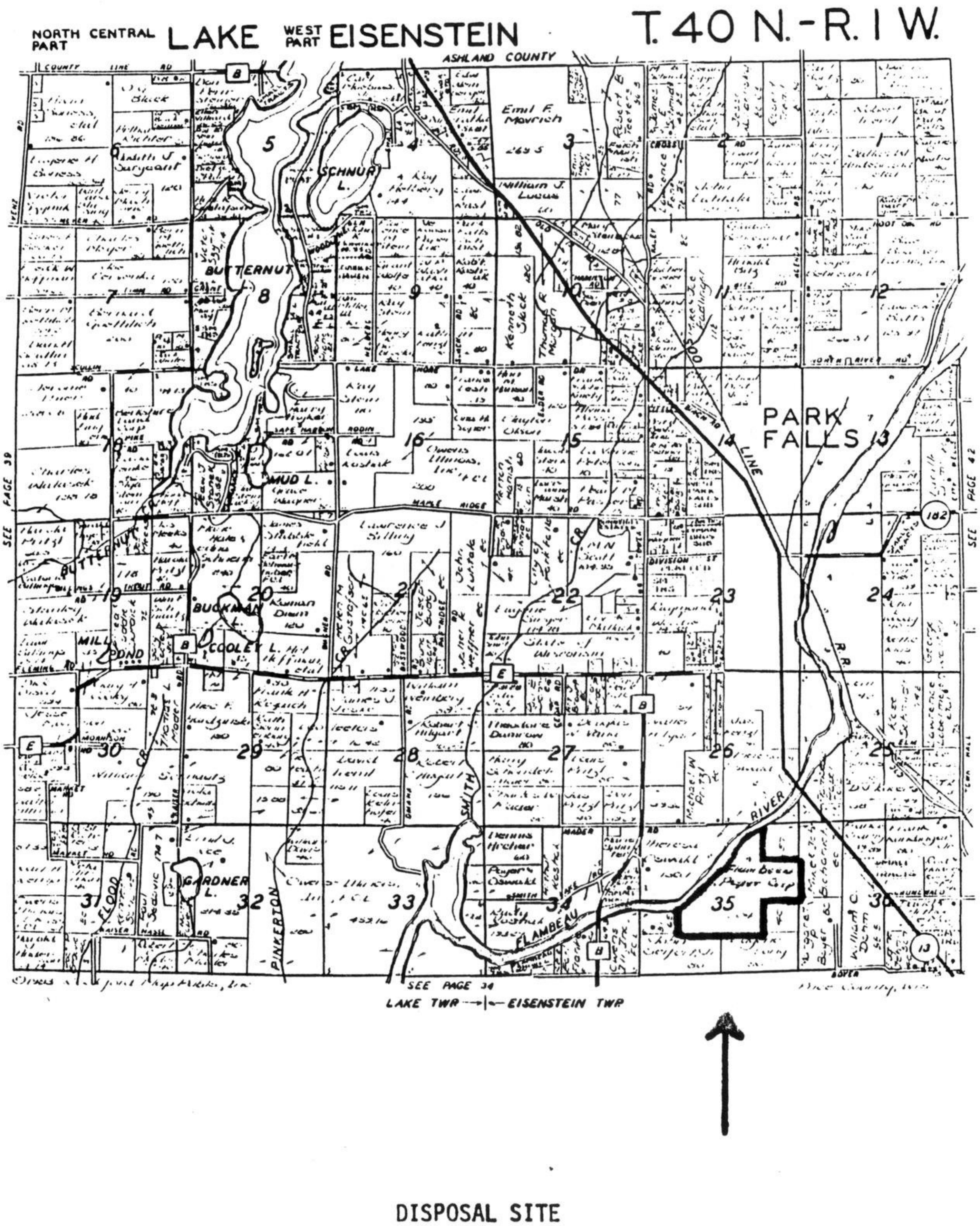
The sulfite liquor disposal area in question is located on a 200 acre site owned by Flambeau Paper in Price County, Town of Eisenstein (T40N - R1W), Sec. 35 (see Figure 4). A portion of this site is currently being used for a synthetically lined landfill which is planned for 5 cells covering 32 acres. A closed 5 acre primary sludge landfill, a closed 13 acre primary and secondary sludge landfill, an active hypalon lined sulfite liquor storage pond, and two closed emergency sludge disposal cells are also on the site.

The sulfite liquor lagoons, which existed between 1956 and 1980 numbered 22 with a total volume of 44,000,000 gallons. The lagoons were located along the river and encompassed an area of about 80 acres. The closest lagoon was approximately 100 feet from the edge of the river while the furthest lagoon back was approximately 1,500 feet from the river (see Figure 6).

The soils on the site are typical of glacial till consisting of unconsolidated deposits of silty fine to course sand with traces of gravel, cobbles, and boulders. The soils are unstratified although generally the finer materials are found closer to the surface with the more course materials at greater depths. Soil hydraulic conductivities are variable, ranging from 10^{-6} cm/sec to 10^{-3} cm/sec, and soil conditions have been affected by site use. The soils are underlain by Pre-Cambrian meta-volcanic, meta-sedimentary bedrock at depths of 65 to 70 feet.

The land surface elevations at the site range from 57 feet above the river to 32 feet above the river at the top of the river bank. The bank then recedes down to the river with slopes of 9 to 13 percent. The river elevation along the site is about 1,458 feet MSL (see Figure 7).

The groundwater elevations range from 1,510 feet MSL to 1,485 feet MSL with average depths to groundwater of 5 to 15 feet. Regionally, groundwater flow is to the northwest (see Figure 8).



DISPOSAL SITE

TOWN OF EISENSTEIN

FIGURE 4

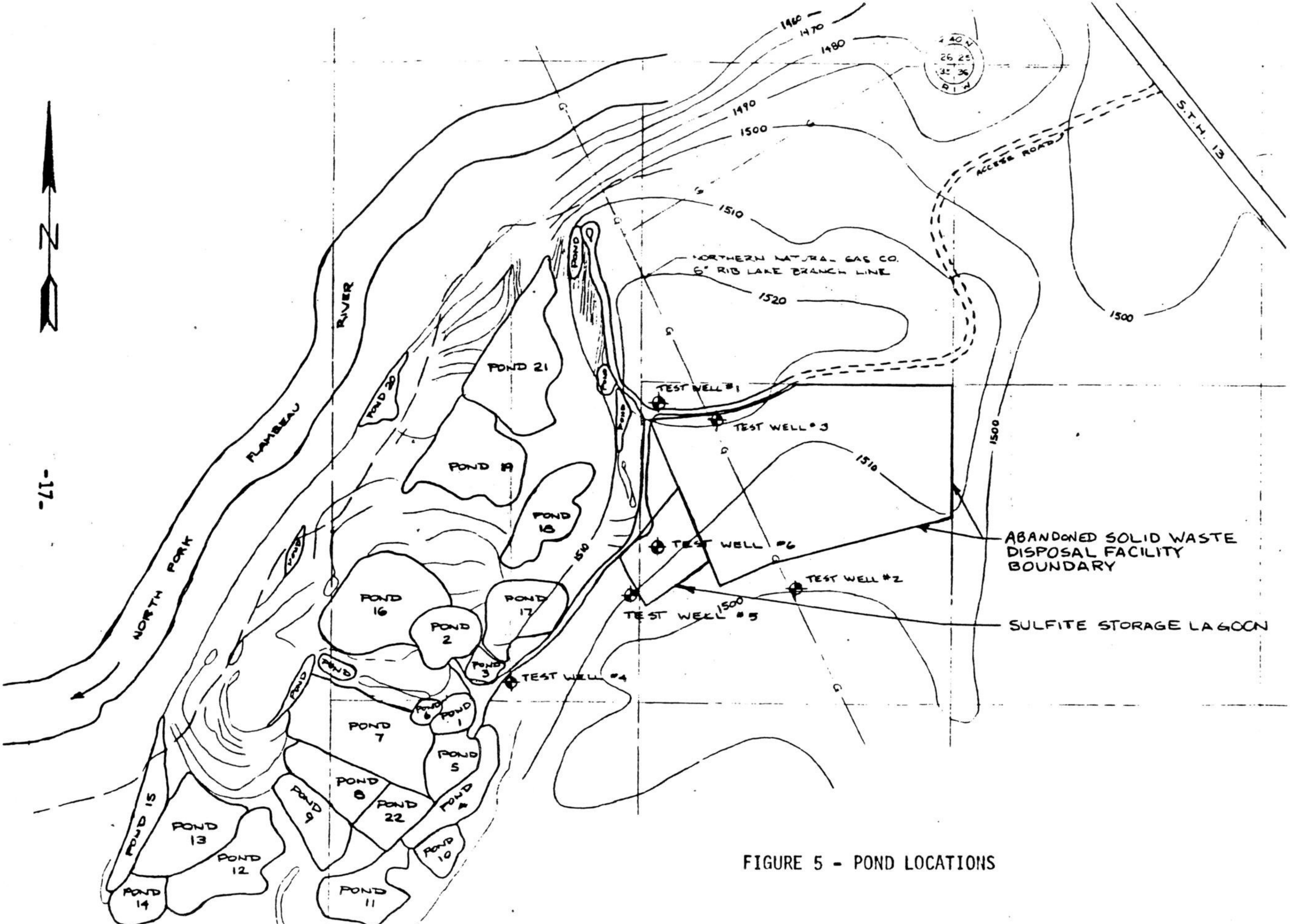


FIGURE 5 - POND LOCATIONS

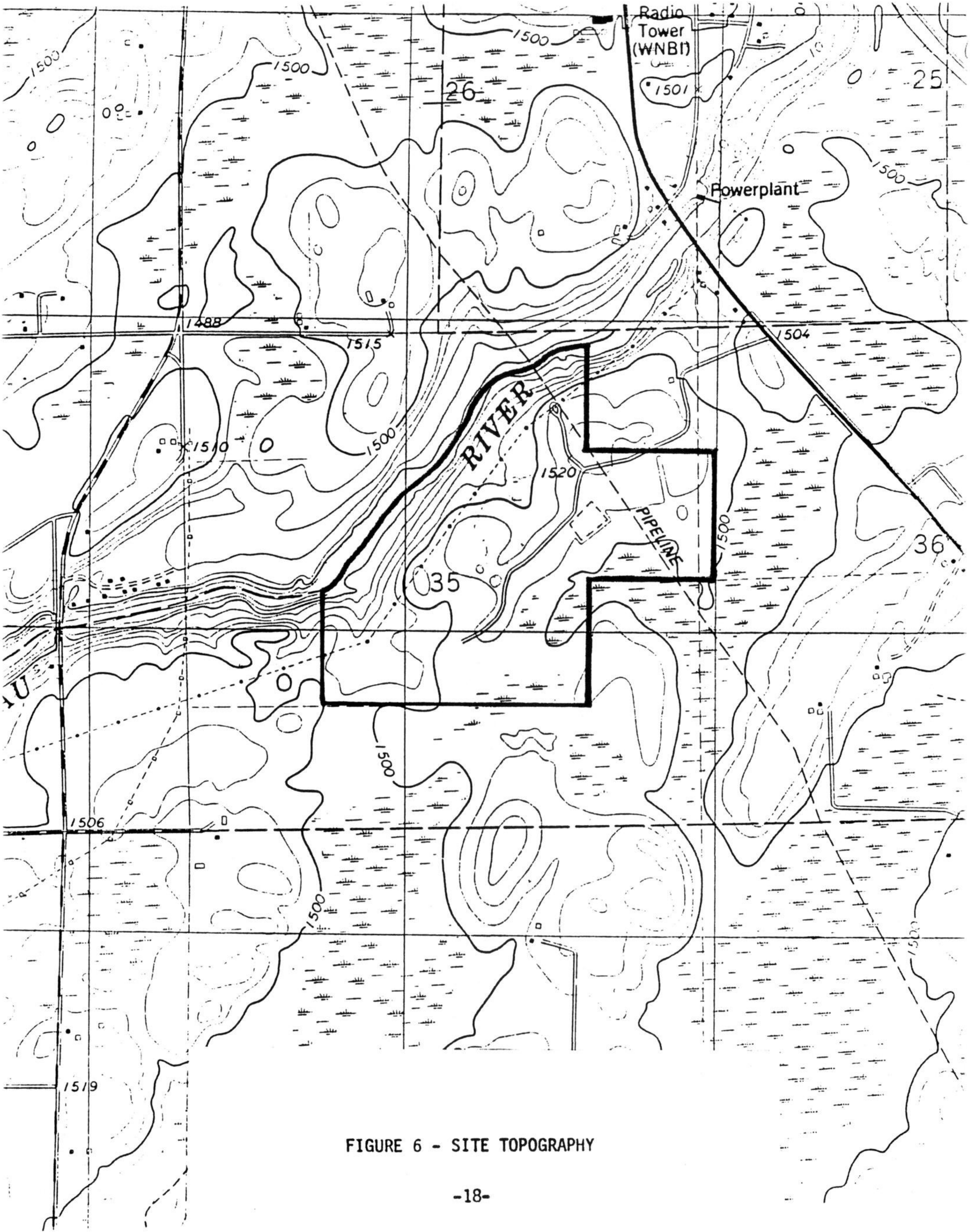


FIGURE 6 - SITE TOPOGRAPHY

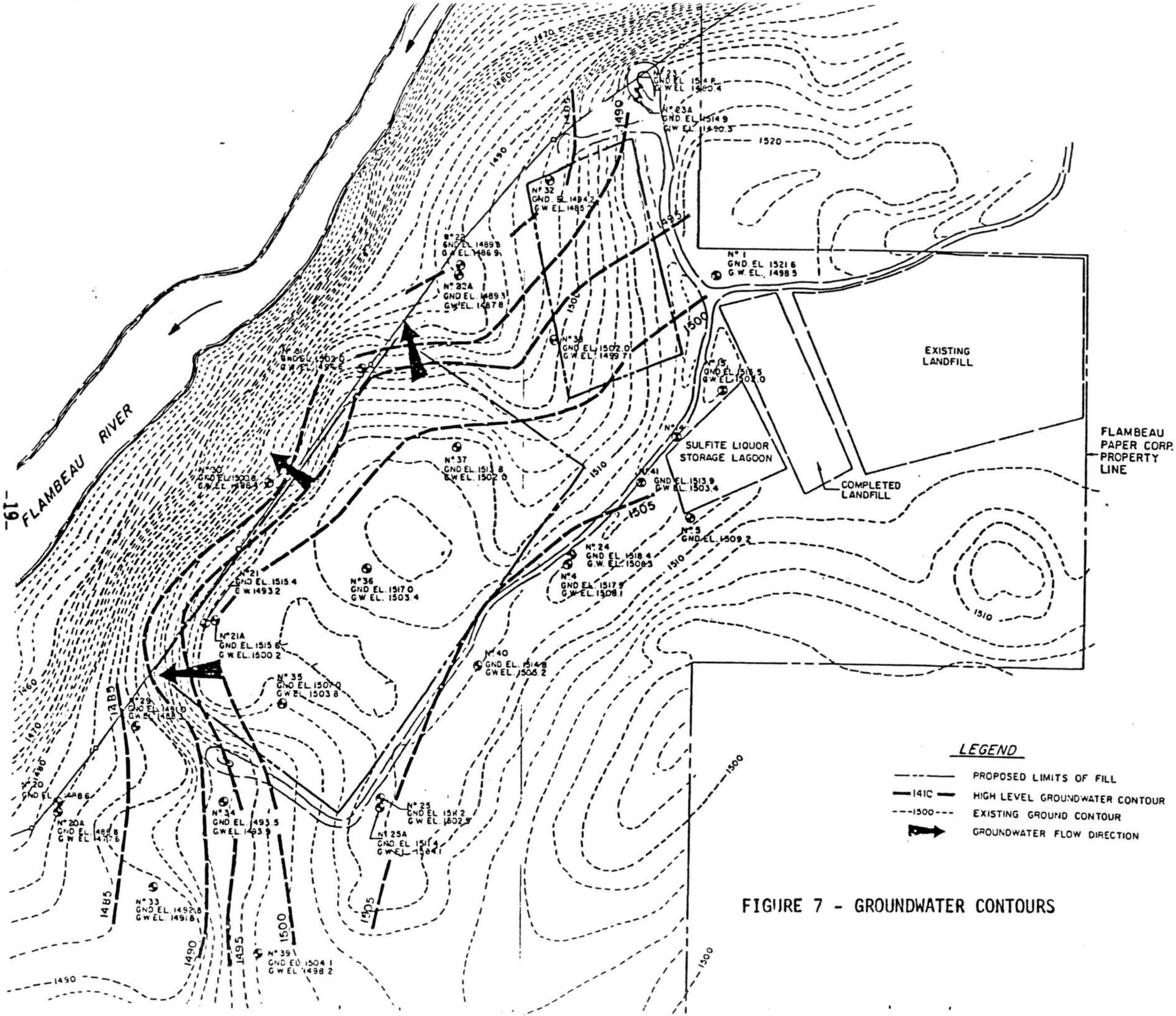


FIGURE 7 - GROUNDWATER CONTOURS

VII. Data

Due to the long term and varied use of the site, a significant amount of data has been collected by the paper company and the DNR. All the available data including that which was generated as a result of this effort are presented here.

Approximately 75 groundwater monitoring wells have been installed and sampled since 1977. Some of these have been abandoned due to landfill expansions, some have been sampled a few times, some have been sampled routinely and some are still being sampled due to landfill operation requirements. Figure 9 is a map of monitoring wells.

As part of this study, 60 existing wells which were accessible and not damaged were sampled once for conductivity, pH, temperature, chemical oxygen demand (COD), and elevation. Bailers and a pneumatic pump were used for sampling and DNR quality control procedures for sample collection, washing, filtration, and preservation were followed when possible. Where very low recharge rates or other limitations were present, variations in procedure were used. The results are presented in Table 1. This data is also included with a summary of all other available groundwater monitoring data in Table 2. Some past river sampling data and bank seepage data has also been collected. Due to the limited amount of surface water data its significance is unclear at this time. That data is included with all groundwater data in Appendix D.

It should be noted that the quality assurance procedures and sampling practices and conditions may have varied with the various sources of data.

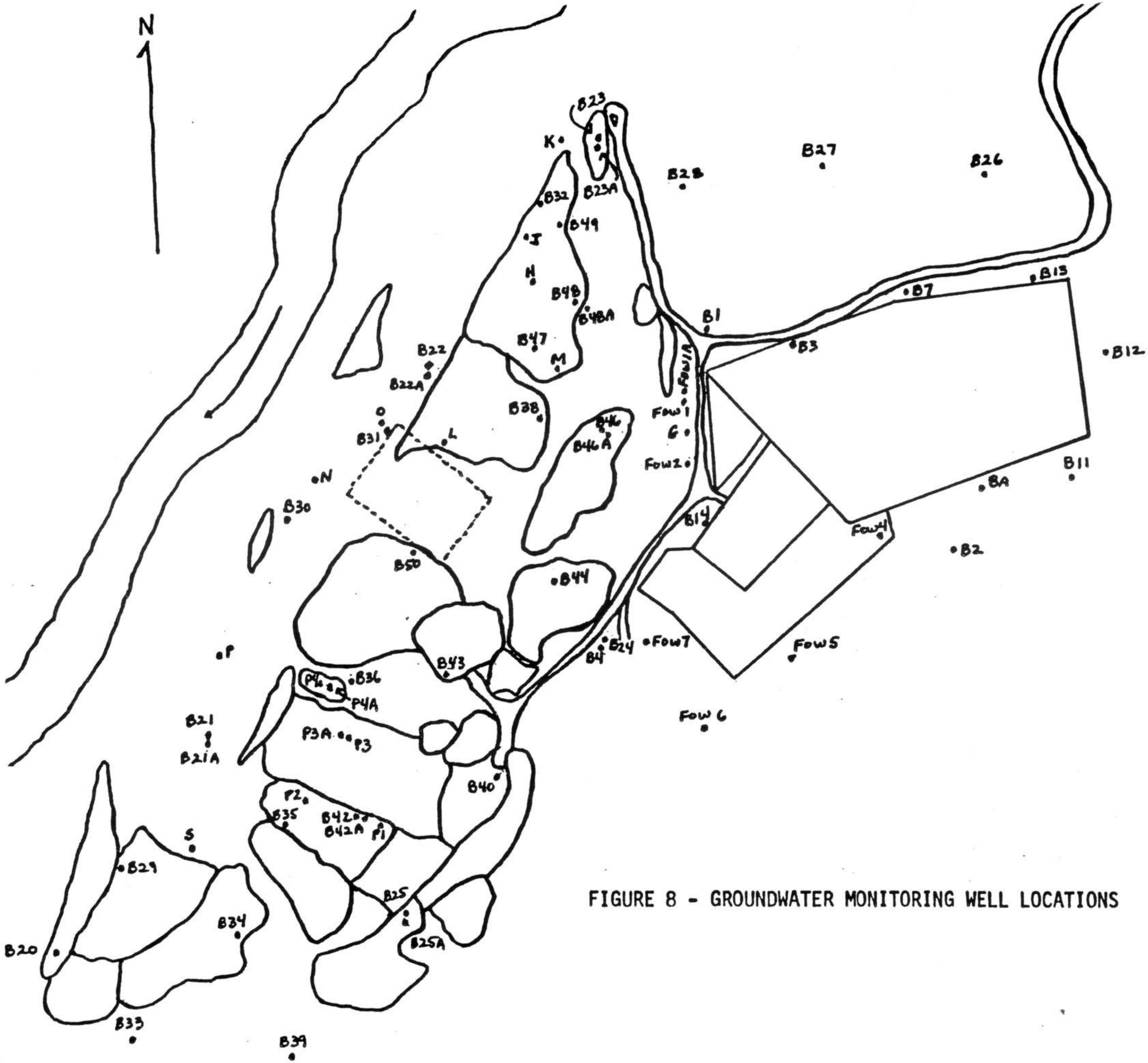


FIGURE 8 - GROUNDWATER MONITORING WELL LOCATIONS

TABLE 1 - JULY 1986 MONITORING DATA

Number	Number of Previous Samplings	Time Period of Sampling	COD (mg/1) July 1986 Sampling	COD (mg/1) Previous Samplings Range	Conductivity (umhos/cm) July 1986 Sampling	Conductivity (umhos/cm) Previous Samplings Range	Well Still Exists
B1	34	1977-1985	-	2000-34375	2250	2300-8000	Yes
B2	34	1977-1985	14	1-178	750	160-801	Yes
B3	2	1978-1979	-	63-1547	-	310-2600	*
B4	37	1977-1985	200	125-19731	1150	210-2700	Yes
B5	3	1977-1979	-	36-55	-	210-280	No
B6	2	1977-1978	-	52-106	-	210-260	No
B7	30	1977-1985	220	13-13300	2625	160-4900	Yes
B8A	22	1979-1985	16	1-1639	675	170-650	Yes
B9	1	1979	-	207	-	600	No
B10	1	1979	-	355	-	480	No
B11	26	1979-1985	<5	0-699	230	120-410	Yes
B12	25	1979-1985	<5	12-785	750	150-3800	Yes
B13	26	1979-1985	200	15-5729	1550	190-4700	Yes
B14	4	1979-1984	79	112-1200	675	100-920	Yes
B15	4	1980-1983	-	12-167	-	220-340	No
B20	-	-	14000	-	3150	-	Yes
B20A	-	-	1200	-	1250	-	Yes
B21	8	1982-1985	-	19600-29934	-	2300-7200	Yes*
B21A	6	1983-1985	350	340-500	468	430-700	Yes
B22	8	1982-1985	6000	12400-13300	3150	1640-2600	Yes
B22A	2	1982-1983	8200	7404-8950	2450	1800	Yes
B23	3	1982-1983	19000	25960-36300	4800	3800-5000	Yes
B23A	-	-	-	-	-	-	Yes*
B24	2	1982-1983	5400	270-394	2000	270	Yes

*Difficult or impossible to sample.

Number	Number of Previous Samplings	Time Period of Sampling	COD (mg/l) July 1986 Sampling	COD (mg/l) Previous Samplings Range	Conductivity (umhos/cm) July 1986 Sampling	Conductivity (umhos/cm) Previous Samplings Range	Well Still Exists
B25	2	1982-1983	15000	4712-21400	2150	3000	Yes
B25A	2	1982-1983	460	3570-5481	900	1200	Yes
B26	-	-	7	-	345	-	Yes
B27	-	-	<5	-	280	-	Yes
B29	2	1982-1983	510	1860-2212	485	840	Yes
B30	7	1982-1985	4800	11200-14800	1825	960-3000	Yes
B31	7	1982-1985	840	1260-8365	1000	820-1400	Yes
B32	6	1983-1985	4000	2500-8365	1625	1340-2400	Yes
B33	-	-	6800	-	2300	-	Yes
B34	1	1983	38000	41400	4550	3800	Yes
B35	1	1983	23000	-	3850	4800	Yes
B36	1	1983	350	19400	625	2200	Yes
B37	1	1983	-	168	-	400	No?
B38	2	1983	820	1170-1465	1050	950	Yes
B39	2	1983	3800	740-6290	1650	2700	Yes
B40	7	1983-1985	40000	848-37200	7200	3500-9400	Yes
B41	2	1983	-	140-192	-	340	No
B42	1	1983	1100	770	590	760	Yes
B42A	1	1983	8300	9285	2200	3400	Yes
B43	1	1983	-	9285	-	3200	Yes*
B44	1	1983	7300	18570	1900	4000	Yes
B45	1	1983	-	29	-	370	No
B46	1	1983	42	29	210	310	Yes
B46A	1	1983	-	3428	1275	1880	Yes*

*Difficult or impossible to sample.

Number	Number of Previous Samplings	Time Period of Sampling	COD (mg/l) July 1986 Sampling	COD (mg/l) Previous Samplings Range	Conductivity (umhos/cm) July 1986 Sampling	Conductivity (umhos/cm) Previous Samplings Range	Well Still Exists
B47	1	1983	190	114	448	940	Yes
B48	1	1983	-	400	700	530	Yes*
B48A	1	1983	850	4857	900	1200	Yes
B49	1	1983	-	1143	-	1400	Yes*
B50	1	1983	580	514	470	950	Yes
P1	1	1983	4300	7140	1500	2200	Yes
P2	1	1983	1900	4000	550	980	Yes
P3	1	1983	-	300	-	260	Yes*
P3A	1	1983	420	943	650	1050	Yes
P4	1	1983	-	3860	675	820	Yes
P4A	-	-	-	-	-	-	Yes*
FOW-1	5	1984-1985	360	470-2150	900	100-1200	Yes
FOW-1A	5	1984-1985	1100	750-2000	1200	1095-1600	Yes
FOW-2	6	1984-1985	160	1250-1900	700	750-1130	Yes
FOW-3	1	1984	-	20	11	240	No
FOW-4	1	1984	-	0	-	230	Yes*
FOW-5	4	1985	<5	20-40	69	75-200	Yes
FOW-6	5	1984-1985	20	20-100	340	92-200	Yes
FOW-7	5	1984-1985	96	110-330	400	250-1020	Yes
G	3	1985	730	200-2800	890	1130-1360	Yes
H	3	1985	2000	100-2400	1100	1100-1430	Yes
J	3	1985	3100	3400-4000	1450	1340-2100	Yes
K	3	1985	3900	2000-2800	1275	700-1500	Yes
L	3	1985	5000	3750-4500	2450	1220-2800	Yes

*Difficult or impossible to sample.

Number	Number of Previous Samplings	Time Period of Sampling	COD (mg/1) July 1986 Sampling	COD (mg/1) Previous Samplings Range	Conductivity (umhos/cm) July 1986 Sampling	Conductivity (umhos/cm) Previous Samplings Range	Well Still Exists
M	3	1985	240	130-155	650	590-1300	Yes
N	3	1985	95	30-120	950	250-380	Yes
O	3	1985	520	30-420	400	240-500	Yes
P	3	1985	120	80-170	295	360-400	Yes
S	3	1985	120	140-230	140	270-400	Yes

COMMENTS:

B22 COD below and Cond. above previous ranges?

B24 Questionable, but look at B4 results.

B25A COD seems low.

B36 Big difference, but COD and Cond. agree.

TABLE 2a - GROUNDWATER MONITORING DATA SUMMARY

(ELEVATION, CONDUCTIVITY, COD, SULFATE)

WELL NUMBER	WELL DEPTH (feet)	NUMBER OF SAMPLING EVENTS	PERIOD OF SAMPLING EVENTS	GROUNDWATER ELEVATION RANGE OF RESULTS (MSL - Feet)	CONDUCTIVITY RANGE OF RESULTS (umhos/cm)	COD RANGE OF RESULTS (mg/l)	SULFATE RANGE OF RESULTS (mg/l)
B1	66	28	1977 - 1985	1493.0 - 1498.3	2300.0 - 8000.0	2000.0 - 34375.0	5.0 - 2300.0
B2	20	29	1977 - 1985	1498.8 - 1501.8	160 - 801	1 - 178	1.6 - 37
B3	-	2	1978 - 1979	-	310 - 2600	63 - 1547	4.3 - 14
B4	30	28	1977 - 1985	1501.6 - 1510.9	210 - 2700	125 - 19731	13.7 - 1160
B5	-	3	1977 - 1979	-	210 - 280	36 - 55	26 - 106
B6	-	2	1977 - 1978	-	210 - 260	52 - 106	3.6 - 7.9
B7	31	28	1977 - 1985	1491.8 - 1499.1	160 - 4900	13 - 13300	1.0 - 775
B8A	27	22	1979 - 1985	1497.6 - 1499.5	170 - 650	1 - 1639	1.0 - 115
B9	-	1	1979	-	600	207	406
B10	-	1	1979	-	480	355	396
B11	25	26	1979 - 1985	1496.0 - 1498.8	120 - 410	0 - 699	7.4 - 134
B12	27	26	1979 - 1985	1495.5 - 1501.8	150 - 3800	12 - 784	4.8 - 548
B13	24	26	1979 - 1985	1495.3 - 1498.6	190 - 4700	15 - 5729	3.7 - 270
B14	26	4	1979 - 1984	1500.0 - 1502.4	100 - 920	112 - 1200	230 - 440
B15	-	4	1979 - 1984	1502.3	220 - 340	12 - 167	20 - 165
B20	41						

Table 2a.

WELL NUMBER	WELL DEPTH (feet)	NUMBER OF SAMPLING EVENTS	PERIOD OF SAMPLING EVENTS	GROUNDWATER ELEVATION RANGE OF RESULTS (MSL - Feet)	CONDUCTIVITY RANGE OF RESULTS (umhos/cm)	COD RANGE OF RESULTS (mg/1)	SULFATE RANGE OF RESULTS (mg/1)
B20A	20						
B21	64	8	1982 - 1985	1466.1 - 1492.1	2300 - 7200	19600 - 29934	68 - 4200
B21A	26	6	1982 - 1985	-	430 - 700	340 - 500	20 - 252
B22	41	8	1982 - 1985	-	1640 - 2600	12400 - 13300	19.5 - 1005
B22A	21	2	1982 - 1983	-	1800	7404 - 8950	420.0 - 750
B23	71	3	1982 - 1983	-	3800 - 5000	25960 - 36300	155 - 2350
B23A	26						
B24	61	2	1982 - 1983	-	270	270 - 394	420 - 440
B25	61	2	1982 - 1983	-	3000	4712 - 21400	200 - 3700
B25A	25	2	1982 - 1983	-	1200	3570 - 5481	160 - 4800
B26	54						
B27	53						
B29	17	2	1982 - 1983	-	840	1860 - 2212	270 - 6200
B30	27	6	1982 - 1985	-	960 - 3000	11200 - 14800	29 - 880
B31	26	6	1982 - 1985	-	820 - 1400	1260 - 8356	280 - 313
B32	21	6	1982 - 1985	-	1340 - 2400	2500 - 8356	20 - 2300
B33	10						
B34	19	1	1983	-	3800	41,400	1070

Table 2a.

WELL NUMBER	WELL DEPTH (feet)	NUMBER OF SAMPLING EVENTS	PERIOD OF SAMPLING EVENTS	GROUNDWATER ELEVATION RANGE OF RESULTS (MSL - Feet)	CONDUCTIVITY RANGE OF RESULTS (umhos/cm)	COD RANGE OF RESULTS (mg/l)	SULFATE RANGE OF RESULTS (mg/l)
B35	22	1	1983	-	4800	-	990
B36	24	1	1983	-	2200	19,400	650
B37	-	1	1983	-	400	168	242
B38	19	2	1983	-	950	1170 - 1465	1400.0 - 2000
B39	18	2	1983	-	2700	740 - 6290	880 - 8200
B40	29	7	1983 - 1985	1492.5 - 1505.5	3500 - 9400	848 - 37200	20 - 1400
B41	-	2	1983	-	340	140 - 192	42 - 600
B42	9	1	1983	-	760	770	380
B42A	20	1	1983	-	3400	9285	940
B43	-	1	1983	-	3200	9285	850
B44	19	1	1983	-	4000	18,570	798
B45	-	1	1983	-	370	29	181
B46	20	1	1983	-	310	29	190
B46A	20	1	1983	-	1880	3428	138
B47	19	1	1983	-	940	114	42
B48	18	1	1983	-	530	400	430
B48A	21	1	1983	-	1200	4857	160
B49	19	1	1983	-	1400	1143	138

Table 2a.

WELL NUMBER	WELL DEPTH (feet)	NUMBER OF SAMPLING EVENTS	PERIOD OF SAMPLING EVENTS	GROUNDWATER ELEVATION RANGE OF RESULTS (MSL - Feet)	CONDUCTIVITY RANGE OF RESULTS (umhos/cm)	COD RANGE OF RESULTS (mg/1)	SULFATE RANGE OF RESULTS (mg/1)
B50	22	1	1983	-	950	514	190
P1	8	1	1983	-	2200	7140	240
P2	8	1	1983	-	980	4000	210
P3	8	1	1983	-	260	300	270
P3A	23	1	1983	-	1050	943	150
P4	8	1	1983	-	820	3860	164
P4A	13						
FOW-A	31	5	1984 - 1985	1497.2 - 1500.0	1000 - 1200	470 - 2150	160 - 650
FOW-1A	39	5	1984 - 1985	1493.1 - 1499.7	1095 - 1600	750 - 2000	20 - 420
FOW-2	29	6	1984 - 1985	1484.9 - 1496.5	750 - 1130	1250 - 1900	68 - 350
FOW-3	-	1	1984	1500.4	240	20	115
FOW-4	-	1	1984	1500.6	230	0	103
FOW-5	14	4	1985	1501.7 - 1502.3	75 - 200	20 - 40	10 - 190
FOW-6	16	5	1984 - 1985	1501.5 - 1503.0	92 - 200	20 - 100	10 - 40
FOW-7	24	5	1984 - 1985	1502.9 - 1505.8	250 - 1020	110 - 330	3 - 83

Table 2a.

WELL NUMBER	WELL DEPTH (feet)	NUMBER OF SAMPLING EVENTS	PERIOD OF SAMPLING EVENTS	GROUNDWATER ELEVATION RANGE OF RESULTS (MSL - Feet)	CONDUCTIVITY RANGE OF RESULTS (umhos/cm)	COD RANGE OF RESULTS (mg/1)	SULFATE RANGE OF RESULTS (mg/1)
G	32	3	1985	-	1130 - 1360	200 - 2800	147 - 410
H	14	3	1985	-	1100 - 1430	100 - 2400	938 - 1055
J	19	3	1985	-	1340 - 2100	3400 - 4000	558 - 870
K	30	3	1985	-	700 - 1500	2000 - 2800	49 - 343
L	22	3	1985	-	1220 - 2800	3750 - 4500	205 - 234
M	15	3	1985	-	590 - 1300	130 - 155	254 - 870
N	24	3	1985	-	250 - 380	30 - 120	70 - 180
O	21	3	1985	-	240 - 500	30 - 420	74 - 191
P	24	3	1985	-	360 - 400	80 - 170	113 - 242
S	24	3	1985	-	270 - 400	140 - 230	102 - 184

TABLE 2b - GROUNDWATER MONITORING DATA SUMMARY

(CHLORIDE, ALKALINITY, HARDNESS, DISSOLVED IRON, pH)

WELL NUMBER	WELL DEPTH (feet)	NUMBER OF SAMPLING EVENTS	TIME PERIOD OF SAMPLING EVENTS	CHLORIDE RANGE OF RESULTS (MSL - Feet)	ALKALINITY RANGE OF RESULTS (umhos/cm)	HARDNESS RANGE OF RESULTS (mg/l)	DISSOLVED IRON RANGE OF RESULTS (mg/l)	pH RANGE OF RESULTS (S.U.)
B1	66	28	1977 - 1985	2.0 - 580.0	1950.0 - 4500.0	2500 - 10000	0.30 - 215.6	6.0 - 7.2
B2	20	29	1977 - 1985	0.5 - 23.5	70 - 340	88 - 394	0.02 - 1.42	6.7 - 7.8
B3	-	2	1978 - 1979	4 - 180	147 - 1410	5 - 150	0.23	6.4 - 7.7
B4	30	28	1977 - 1985	0.5 - 24.0	64 - 425	105 - 2500	0.48 - 64.2	4.7 - 7.7
B5	-	3	1977 - 1979	3 - 40	21 - 38	1 - 1	2.5	6.4 - 7.0
B6	-	2	1977 - 1978	1 - 3	80 - 88	94 - 120	0	7.2 - 7.4
B7	31	28	1977 - 1985	0.5 - 610	27 - 4000	0 - 2220	0.02 - 69.7	6.2 - 7.2
B8A	27	22	1979 - 1985	1.0 - 10.5	35 - 236	3 - 236	0.01 - 19.7	6.6 - 7.8
B9	-	1	1979	20	34	1	2.5	6.1
B10	-	1	1979	5	2480	1	1.39	6.7
B11	25	26	1979 - 1985	0.5 - 5.5	46 - 182	1 - 190	0.02 - 17.1	6.7 - 8.0
B12	27	26	1979 - 1985	1.0 - 227.5	6.5 - 2180	1 - 3250	0.02 - 139.0	6.4 - 7.7
B13	24	26	1979 - 1985	0.5 - 180	75 - 2550	1 - 3300	0.01 - 253.3	6.1 - 7.5
B14	26	4	1979 - 1984	0.5 - 15.0	170 - 620	25 - 900	0.48 - 91.0	6.5 - 6.8
B15	-	4	1979 - 1984	2.0 - 17.5	65 - 180	86 - 202	0.02 - 2.8	6.2 - 7.0
B20	41							
B20A	20							

TABLE 2b - GROUNDWATER MONITORING DATA SUMMARY

(CHLORIDE, ALKALINITY, HARDNESS, DISSOLVED IRON, pH)

WELL NUMBER	WELL DEPTH (feet)	NUMBER OF SAMPLING EVENTS	TIME PERIOD OF SAMPLING EVENTS	CHLORIDE RANGE OF RESULTS (MSL - Feet)	ALKALINITY RANGE OF RESULTS (umhos/cm)	HARDNESS RANGE OF RESULTS (mg/1)	DISSOLVED IRON RANGE OF RESULTS (mg/1)	pH RANGE OF RESULTS (S.U.)
B21	64	8	1982 - 1985	25 - 200	2400 - 4000	4900 - 9200	868 - 1355	5.6 - 5.8
B21A	26	6	1982 - 1985	5.0 - 13.3	300 - 358	310 - 375	13.3 - 239	6.7 - 6.9
B22	41	8	1982 - 1985	20 - 150	1675 - 18600	2525 - 3100	29.7 - 222	6.5 - 6.7
B22A	21	2	1982 - 1983	35.0 - 62.5	1600 - 1860	2250 - 2900	142.6	6.5
B23	71	3	1982 - 1983	60 - 200	2150 - 3140	5900 - 7000	941.2 - 1200	6.0 - 6.4
B23A	26							
B24	61	2	1982 - 1983	5 - 35	112 - 130	155 - 1700	77.9	5.9 - 6.0
B25	61	2	1982 - 1983	35 - 125	900 - 2300	470 - 1700	170.6	6.2 - 6.8
B25A	25	2	1982 - 1983	5.0 - 37.5	220 - 230	600 - 1200	136.8	5.3 - 5.4
B26	54							
B27	53							
B29	17	2	1982 - 1983	20 - 25	327 - 355	550 -1000	232.23	6.4 - 6.5
B30	27	6	1982 - 1985	15 - 30	1400 - 1450	2500 - 3100	30.6 - 390	6.2 - 6.8
B31	26	6	1982 - 1985	3.5 - 15.0	500 - 580	600 - 1650	28.6 - 210	6.4 - 6.7
B32	21	6	1982 - 1985	18.8 - 29.0	960 - 1100	1550 - 1800	29.4 - 264.7	6.2 - 6.5
B33	10							
B34	19	1	1983	100	3600	8000	1158	6.2

TABLE 2b - GROUNDWATER MONITORING DATA SUMMARY

(CHLORIDE, ALKALINITY, HARDNESS, DISSOLVED IRON, pH)

WELL NUMBER	WELL DEPTH (feet)	NUMBER OF SAMPLING EVENTS	TIME PERIOD OF SAMPLING EVENTS	CHLORIDE RANGE OF RESULTS (MSL - Feet)	ALKALINITY RANGE OF RESULTS (umhos/cm)	HARDNESS RANGE OF RESULTS (mg/l)	DISSOLVED IRON RANGE OF RESULTS (mg/l)	pH RANGE OF RESULTS (S.U.)
B35	22	1	1983	100	1030	4200	1470.6	5.2
B36	24	1	1983	25	1310	4300	550	6.0
B37	-	1	1983	2.0	68	260	11.62	6.3
B38	19	2	1983	10 - 100	740 - 750	860 - 1020	134.8	6.4
B39	18	2	1983	25 - 60	920 - 1540	2150 - 2500	900	6.2 - 6.7
B40	29	7	1983 - 1985	10 - 200	250 - 4700	1700 - 7000	33.2 - 1688.2	5.7 - 6.1
B41	-	2	1983	1.0 - 5.0	160 - 250	200 - 266	3.1	6.5 - 6.8
B42	9	1	1983	3.0	20	220	154.4	5.4
B42A	20	1	1983	30	930	1650	485.3	5.4
B43	-	1	1983	30	900	950	785.3	5.3
B44	19	1	1983	30	560	2400	755.9	4.8
B45	-	1	1983	1.5	40	11	3.09	6.3
B46	20	1	1983	1.5	6.0	134	6.76	5.2
B46A	20	1	1983	20	952	1100	88.2	6.6
B47	19	1	1983	2.0	60	430	55.9	5.9
B48	18	1	1983	10	16	240	51.5	6.0
B48A	21	1	1983	15	548	540	76.5	6.7

TABLE 2b - GROUNDWATER MONITORING DATA SUMMARY

(CHLORIDE, ALKALINITY, HARDNESS, DISSOLVED IRON, pH)

WELL NUMBER	WELL DEPTH (feet)	NUMBER OF SAMPLING EVENTS	TIME PERIOD OF SAMPLING EVENTS	CHLORIDE RANGE OF RESULTS (MSL - Feet)	ALKALINITY RANGE OF RESULTS (umhos/cm)	HARDNESS RANGE OF RESULTS (mg/1)	DISSOLVED IRON RANGE OF RESULTS (mg/1)	pH RANGE OF RESULTS (S.U.)
B49	19	1	1983	15	58	880	182.4	5.9
B50	22	1	1983	10	218	420	39.7	7.0
P1	8	1	1983	25	610	500	120.6	5.6
P2	8	1	1983	20	190	575	173.5	5.0
P3	8	1	1983	4.5	10	120	18.9	5.1
P3A	23	1	1983	10	492	500	110.3	6.5
P4	8	1	1983	30	340	700	302.9	6.2
P4A	13							
FOW-1	31	5	1984 - 1985	5.3 - 10.0	470 - 920	650 - 880	62.2 - 134.0	6.5 - 6.9
FOW-1A	39	5	1984 - 1985	5.8 - 20.0	970 - 1080	1060 - 1200	22.3 - 152.0	6.4 - 6.8
FOW-2	29	6	1984 - 1985	10 - 30	160 - 370	440 - 560	18 - 208	6.2 - 7.4
FOW-3	-	1	1984	5.5	37	88	0.16	6.4
FOW-4	-	1	1984	1.0	38	92	0.23	7.2
FOW-5	14	4	1985	0.9 - 1.5	16 - 60	34 - 52	0.07 - 110.0	5.9 - 6.5
FOW-6	16	5	1984 - 1985	1.0 - 1.8	28 - 72	34 - 96	0.03 - 0.42	5.8 - 7.4
FOW-7	24	5	1984 - 1985	10 - 50.5	78 - 296	112 - 400	1.1 - 59.8	6.3 - 6.7

TABLE 2b - GROUNDWATER MONITORING DATA SUMMARY

(CHLORIDE, ALKALINITY, HARDNESS, DISSOLVED IRON, pH)

WELL NUMBER	WELL DEPTH (feet)	NUMBER OF SAMPLING EVENTS	TIME PERIOD OF SAMPLING EVENTS	CHLORIDE RANGE OF RESULTS (MSL - Feet)	ALKALINITY RANGE OF RESULTS (umhos/cm)	HARDNESS RANGE OF RESULTS (mg/l)	DISSOLVED IRON RANGE OF RESULTS (mg/l)	pH RANGE OF RESULTS (S.U.)
G	32	3	1985	7.5 - 12.5	500 - 570	740 - 1150	27.7 - 123.0	6.3 - 6.4
H	14	3	1985	10 - 25	8.0 - 16.0	660 - 880	29 - 262	6.1 - 6.5
J	19	3	1985	25 - 40	270 - 490	1000 - 2000	31.6 - 600	6.1 - 6.3
K	30	3	1985	10 - 20	300 - 515	560 - 900	24.2 - 30.6	6.4
L	22	3	1985	1.5 - 12.5	1720 - 1800	2080 - 2180	29.2 - 149.0	6.5 - 6.7
M	15	3	1985	5.0 - 28.0	4.0 - 16.0	310 - 615	16.6 - 25.9	5.5 - 5.8
N	24	3	1985	0.5 - 1.0	61 - 149	114 - 232	1.1 - 160	6.3 - 6.8
O	21	3	1985	1.0 - 58.0	24 - 172	94 - 284	4.4 - 110	6.3 - 6.6
P	24	3	1985	7.0 - 42.0	7.0 - 8.0	125 - 158	22.7 - 1760	6.1 - 6.3
S	24	3	1985	2.0 - 5.0	70 - 98	148 - 168	10.2 - 198	6.3 - 6.5

VIII. Data Summary

The data which has been collected provides valuable information for assessing the status of groundwater at the site.

Generally, the quality assurance of the July, 1986 data is known to be good. Table 1 lists those results next to the ranges of values from previous samples. There seems to be good correlation. Since the July, 1986 values, and in some cases previous sample values, are single data sets, comparisons are limited to qualitative assessments.

The July, 1986 data confirms that the groundwater at the site is still contaminated. The indicator parameters of COD and conductivity are almost all in excess of acceptable values. High COD values of 40,000 mg/l and high conductivities of 7,200 umhos/cm were found. This information supports previous data indicating contamination.

To attempt to evaluate any trends, graphs of COD, conductivity and sulfate data from wells with a number of data sets were made. Some of these graphs, which are shown in Appendix C, are constructed with relatively few points while a few have more than 30. Observations about the graphs are listed in Table 3.

Finally, the data was evaluated in light of well location, construction, and, particularly, well depth. July, 1986 data (a few former values are also plotted) is plotted against well depth in Figure 10. This figure and the assessments listed in Table 4 indicate that well depth affects the results as does well construction which prevents the entry of perched water. With a couple exceptions, deep wells appear to be the most contaminated. Well location also affects results. Comparing data points in Figure 10 with the well locations shown in Figure 9 shows that wells located near or directly under lagoon sites or located near to and directly in the path of groundwater flow are most contaminated.

The effects of location, construction, and depth can also be seen by reviewing Figure 11 which is a map of the site with the July, 1986 sample results listed adjacent to the corresponding wells.

The figure shows that concentration contours are not easily drawn, are incomplete, and point out seemingly contradictory data points. The difficulties are due to the fact that differences in well construction and depth, in addition to the probable impacts of groundwater mounding, liquid density gradients, and soil inconsistencies, result in varying data. This data is not erroneous but, rather, indicative of actual variability caused by the physical system.

The extensive number of wells does provide for duplication; for future sampling efforts not all of the wells would need to be sampled. Figure 12 identifies the wells which, based on the July, 1986 results, would seem to provide an accurate assessment of the situation.

A more thorough evaluation may lead to other conclusions about the quality of the data or its implications. The trends and conclusions drawn in this report are not the result of an exhaustive hydrogeological evaluation and can only be considered possibilities, and then only of a general nature.

Table 3. Summary of Trends for Wells with Several Samples

B1	Conductivity,	decreasing, other side of landfill from B2
	COD,	some trend, from 35,000 down to 10,000, rate of decrease slowing
	SO_4,	highly variable, maybe a decreasing trend?
B2	Conductivity,	increase due to landfill, southeast of landfill
	COD,	shows variability but not much change
	SO_4,	highly variable, slight upward trend
B21	Conductivity,	data too erratic
	COD,	somewhat decreasing, very high values
	SO_4,	very erratic
B31	Conductivity,	fairly constant
	COD,	data not significant, this test value may bee too high
	SO_4,	data agrees with Conductivity and COD
B22	Conductivity,	slightly increasing
	COD,	slightly decreasing
	SO_4,	too erratic
B30	Conductivity,	fairly constant
	COD,	slight decrease
	SO_4,	too erratic
B21A	Conductivity,	fairly constant
	COD,	fairly constant
	SO_4,	too erratic
B32	Conductivity,	constant
	COD,	constant
	SO_4,	too erratic
B4	Conductivity,	decreasing until 1985, then increasing significantly
	COD,	slightly decreasing til 83, then slightly increasing
	SO_4,	decreasingtil 83, then erratic
B11	Conductivity,	good data, slightly increasing, due to landfill? low values relatively speaking
	COD,	somewhat erratic, slight decreasing trend
	SO_4,	good data slightly decreasing
B13	Conductivity,	2 sets of ranges 81/82 , 82 and after higher due to landfill now very slight decrease
	COD,	erratic, data not good
	SO_4,	erratic

B7	Conductivity,	very good data since 80, constant, well near landfill
	COD,	COD decreasing from 80-82, now constant
	SO_4,	erratic but decreasing
B8A	Conductivity,	good data, increasing
	COD,	some variability, fairly constant
	SO_4,	increasing since 82
B2	Conductivity,	slight decrease
	COD,	decreasing
	SO_4,	decreasing

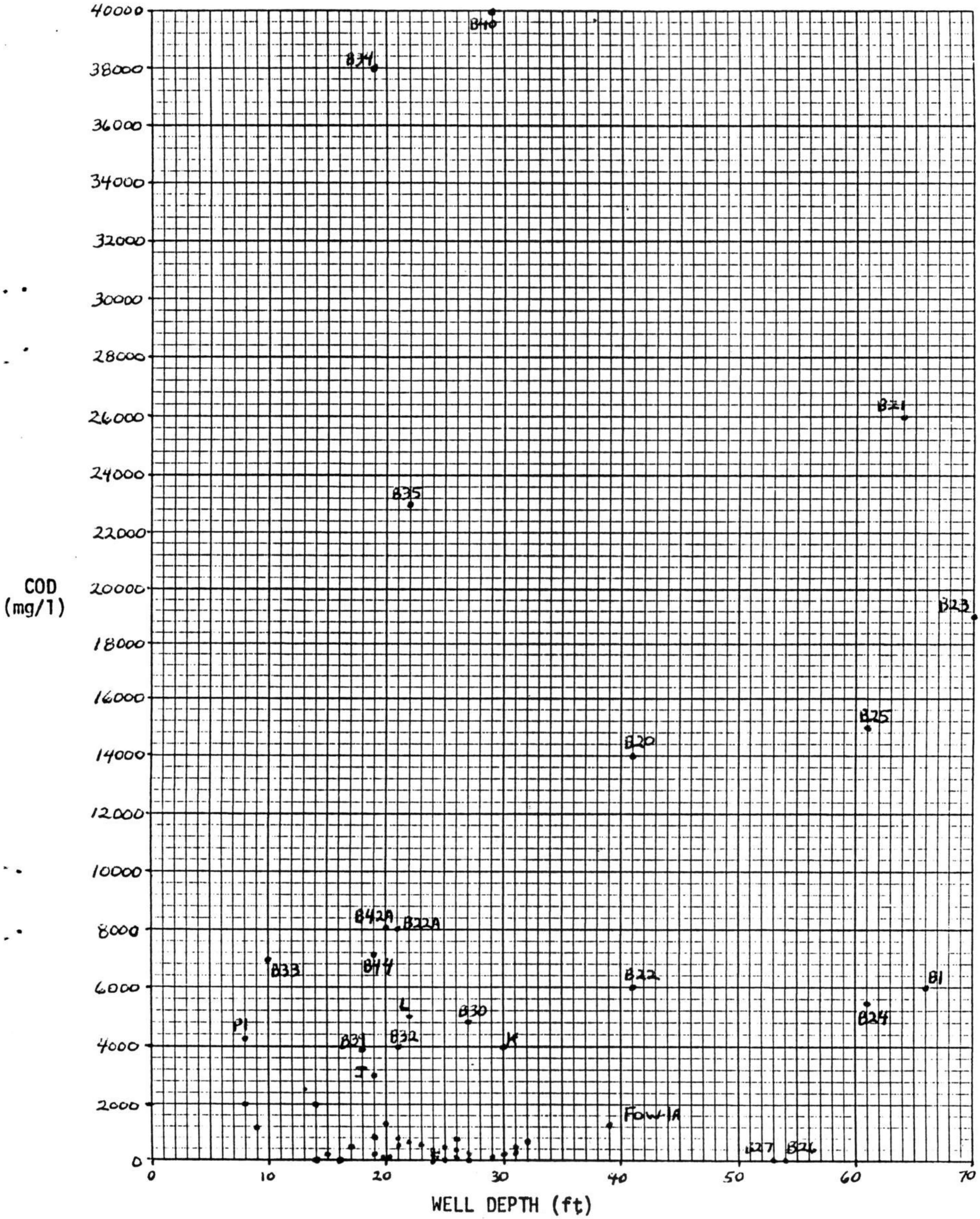


FIGURE 9 - COD CONCENTRATION VS. WELL DEPTH

Table 4. Possible Causes of High Monitoring Data Depicted in Figure 9.

a = a deep well
b = located directly on a lagoon site
c = well constructed to prevent perched water entry
d = affected by groundwater flow
e = off site, not affected by groundwater flow

B 23 - a,b,c
B 21 - a,b,c
B 25 - a,b,c
B 1 - a,b,c
B 24 - a,b,c
B 26 - e
B 27 - e
B 20 - a, b
B 22 - a, b
B 40 - b
B 35 - b
B 34 - b
B 42A- b
B 22A- b
B 33 - b? d?
B 44 - b
P 1 - b
B 39 - b? d?
J - b
B 32 - b
L - d
B 30 - d?
K - b
FOW1A- ?

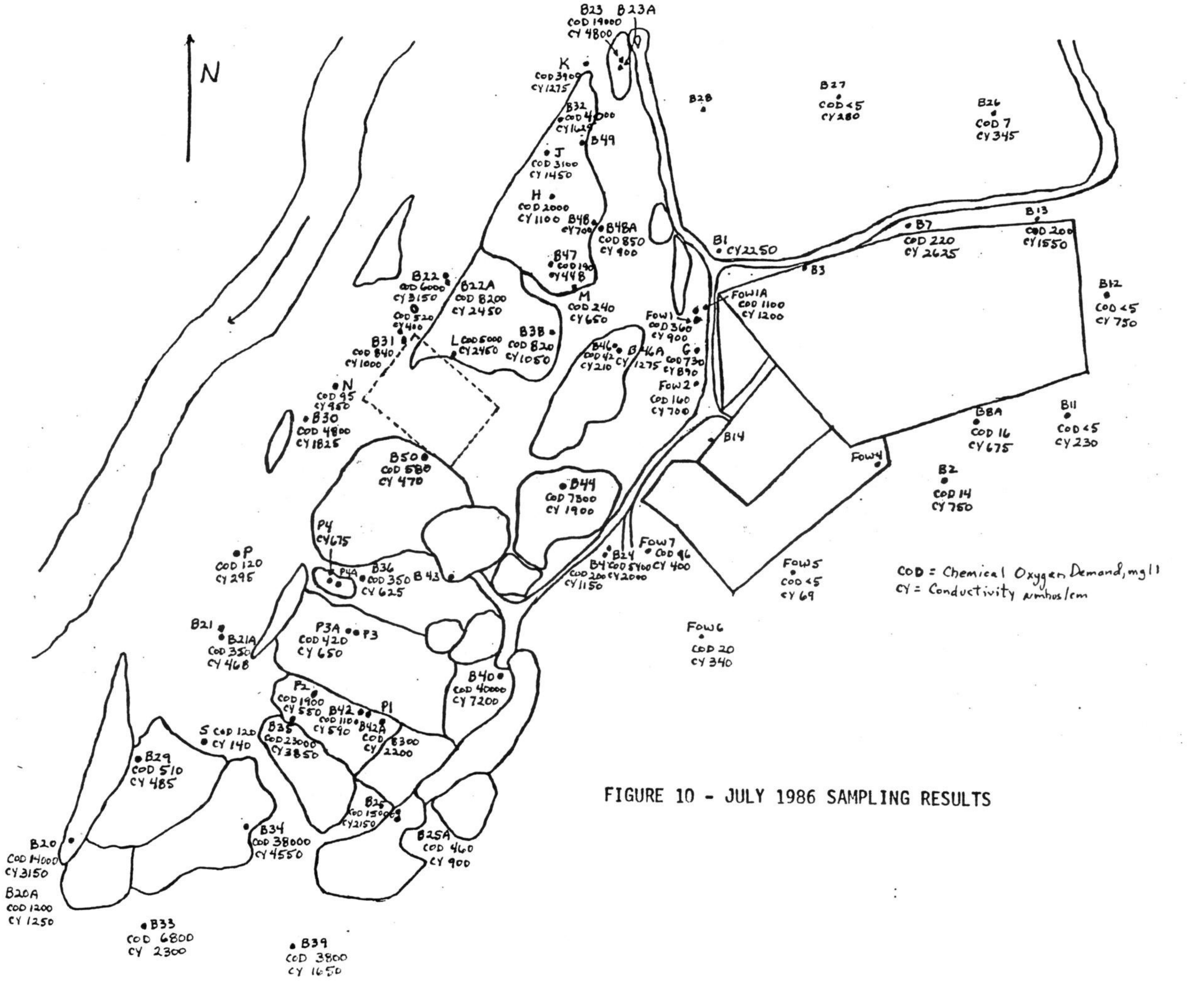


FIGURE 10 - JULY 1986 SAMPLING RESULTS

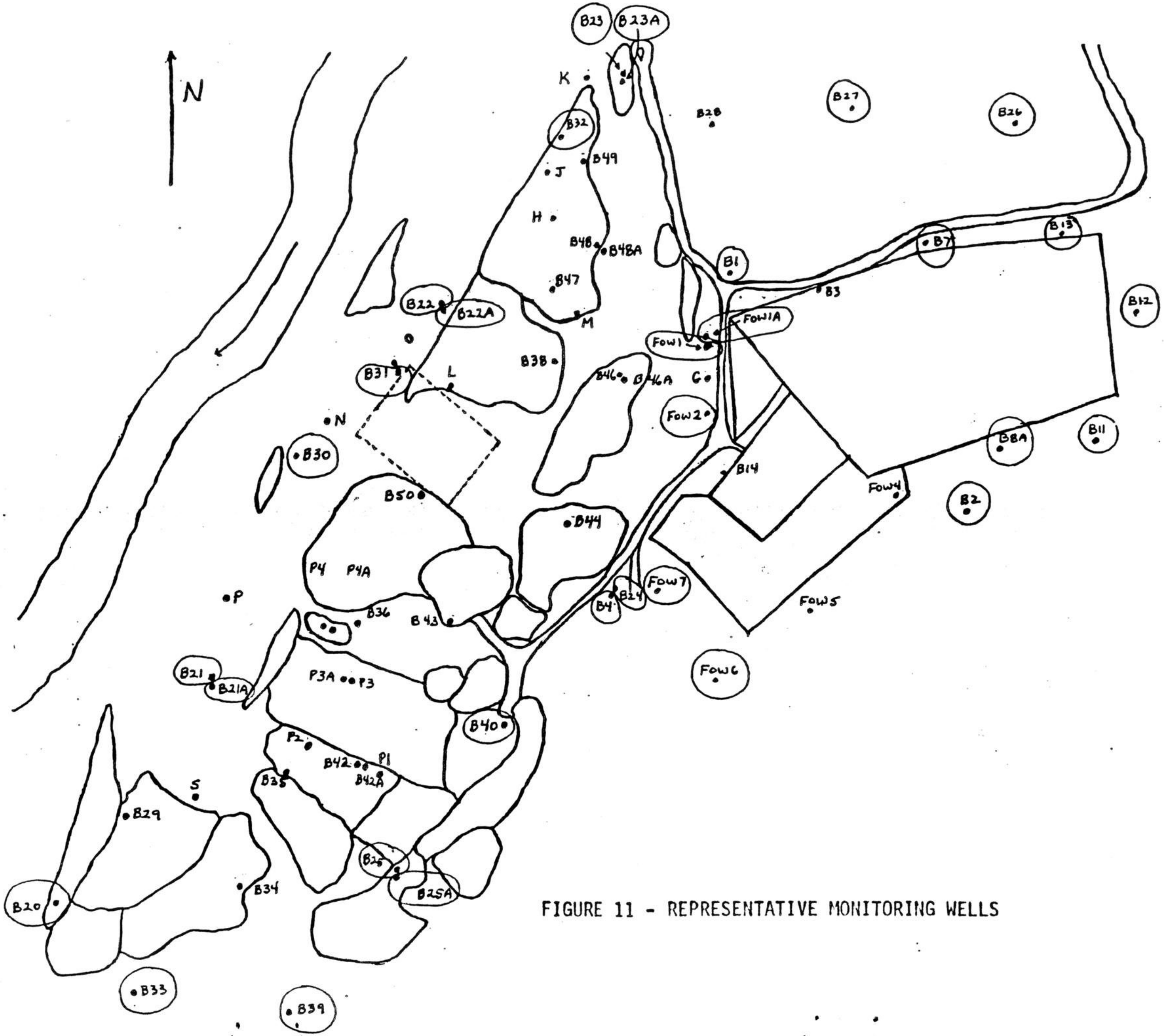


FIGURE 11 - REPRESENTATIVE MONITORING WELLS

IX. Discussion of Findings

The sulfite liquor disposal area was used for about 24 years and encompassed an area of about 80 acres. The system which was originally used to land dispose of small amounts of liquor was eventually developed into a 22 lagoon system with a volume of 44,000,000 gallons for storing and disposing of liquor products. The available information suggests that over the 24 years of operation a large amount of sulfite liquor and evaporator condensate were disposed of at the site.

The original concept of land disposal involved treatment of the liquid as it passed through the soil and into the river. Cation exchange, absorption, and biological degradation were all probably expected to have a cleansing effect and probably did when site loading first began. However, application of liquor depleted the physical attenuative capacities and inhibited the biological capabilities of the soil. This theory has been documented in other studies (Wisniewski, 1956 and Wright, 1957) and appears to be the case here. It also appears that due to loading rates the mechanism of dilution by groundwater was not sufficient to prevent contamination.

The result of this long term use of the site for liquor disposal is groundwater contamination. The monitoring data which has been collected since 1977 and which is discussed in the Data Summary Section verifies this.

Several other observations can also be made about the data. First, the contamination in many of the shallower monitoring wells appears to be decreasing. The rate is not rapid and varies depending on the location of the well. Some wells located directly on the site of an old lagoon have fairly constant results. Contaminant concentrations from wells located between the lagoons and the river are also either staying constant or decreasing slowly. These observations seem to indicate that groundwater flow, which is towards the river, is accounting for some of the gradual but slow cleanup of the shallow groundwater.

Second, concentrations in a number of deep wells remain unchanged or are increasing. Of the deep wells that appear to have been impacted by the lagoons, all have high sample concentrations. Furthermore, those wells which were constructed to eliminate the affect of shallow groundwater have seen noticeably less improvement than nearby wells which are affected by shallow groundwater. These results as well as other research works and case studies indicate that the high specific gravity (1.25) of the liquor may allow it to pass through the soil regardless of groundwater flow. It appears that the results in the deep wells support this theory. The problem with this is that natural attenuation by groundwater flow may not occur. In fact, depending on the nature of the bedrock the most highly concentrated liquid may be moving in an unknown direction, even possibly away from the river.

If these descriptions provide an accurate assessment of what is happening at the site, the problem may not be getting smaller. In fact, if highly contaminated water is moving along the bedrock away from the site, the problem may be getting worse. Furthermore, even if the areal extent of the problem is not increasing, the gradual natural cleanup rate may be governed more by diffusion than groundwater flow due to the high density of the contaminants.

These observations suggest but certainly do not confirm several possible scenarios of what might happen at the site. First, if the bedrock configuration is such that the area of contamination is not expanding, then a natural cleanup process may occur. The ongoing dilution of groundwater will continue at shallower depths and will eventually have effects at greater depths as the more contaminated areas diffuse and become diluted and as the liquor desorbs from the soil. This process could easily take hundreds of years before groundwater at the site is acceptable. The available 10 years worth of data seem to support the idea of a long time for natural attenuation.

A second possibility as mentioned above is that the deep material is moving away from the site. This would mean that the area of contamination would be increasing. The natural attenuative process would again be dependent on the rate of dilution and diffusion that the material underwent as it migrated. This scenario could also result in pockets of contamination setting in low spots in the bedrock indefinitely.

The third scenario can only generally be described as an intervention alternative. Withdrawal of contamination, supplementing groundwater flow, or some other active method of counteracting the slow natural attenuation and the possible expansion of the contaminated area.

Each of these scenarios, which are certainly not exhaustive of the possibilities, might also result in impacts on the river and river bank. The ongoing seepage out of the bank and into the river does impact the shoreline vegetation and surface characteristics as well as the river. The impacts on the river are not fully known but have been accounted for in the calibration of past river models. However, localized impacts as a result of variable amounts of seepage are unknown. The effects of a more active cleanup effort are, of course, unknown.

X. Conclusions

The groundwater contamination resulting from the long term practice of disposal and storage of spent sulfite liquor at the Flambeau Paper Company land disposal site needs further study. The data and natural mechanisms discussed in this evaluation suggest the possibility that the problem may be worsening and that the natural cleanup process could take a long time.

The situation needs to be evaluated further and the concerns about a worsening of the problem necessitate haste. The specific issues which need to be addressed are:

- A groundwater study of the sulfite liquor disposal sites used prior to 1956. This will provide additional data on the long term degradation and attenuation of spent sulfite liquor in the soil.

- Geologic study of the bedrock at and near the lagoon site to determine its nature and topography. This information will assist in determining if the problem will expand, persist indefinitely, or improve.

- Placement of a groundwater monitoring network around the perimeter of the site to provide for long term monitoring. The network should include clustered wells with wells at bedrock and should include a perimeter of unaffected wells so that an expanding problem can be detected.

- An evaluation of specific action alternatives to prevent the problem from worsening and to shorten the cleanup period.

- Conduct a thorough evaluation of river impacts by sampling and modeling.

- Continue to sample selected on site wells to monitor the site status.

These issues and activities are extensive but the environmental impacts may be significant for a long period of time. Additionally, this problem must be addressed in light of ongoing solid waste activities at the site, possible contamination by toxic materials, and NR 140 and its mandated groundwater protection requirements.