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Whitefish Bay

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SPEED MEMORANDUM

DATE	:	August 10, 1998
TO	:	Mr. Jim Ibach, Milwaukee Metropolitan Sewerage District
FROM	:	Pratap N. Singh
SUBJECT	:	Summary of Groundwater Quality Test Results for Lincoln Creek Project
COPY TO	:	Dr. Dilip Singh Bret Swenson Project file 4283

The following are groundwater quality results tables for the three landfill areas of the Lincoln Creek project. These are abbreviated tables in that they include only test parameters for which a Preventive Action Limit or Enforcement Standard has been exceeded. The test results are for the latest round of results only, those collected in 1998. A brief summary of parameters of concern follows for each site, along with an interpretation of contaminant migration based on the test results.

Former Whitefish Bay Demolition Landfill

Of the wells sampled, vinyl chloride, trichloroethylene, tetrachloroethylene, benzene, 1,2 dichloroethylene, and 1,1 dichloroethylene were detected at elevated levels. W-MW-5S, W-MW-6, W-MW-C and W-PZ-C had levels of vinyl chloride above the ES. Except for W-MW-6, the wells closest to the creek are not impacted by VOCs at present. However the wells to the center and west side of the site have been impacted somewhat. Groundwater flow for the shallow aquifer is towards the east, suggesting the possibility that the wells closer to the creek may be impacted in the future.

Iron and Manganese, which are indicator parameters, were detected above the ES in several wells at the site. Wells W-MW-6, W-MW-A, W-PZ-A, W-MW-B, W-PZ-B along the creek had the highest concentrations on-site. Arsenic was over the PAL in W-MW-4D, W-MW-5S, W-MW-A, and over the ES in wells W-MW-6 and W-MW-C.

Havenwoods State Forest Landfill

Of the wells sampled, vinyl chloride, trichloroethylene, benzene, and 1, 2 dichloroethylene were detected at elevated levels. Wells H-MW-4, H-MW-6 and the downstream sample H-SW-2 had levels of vinyl chloride above the ES. Historically, vinyl chloride has been detected above the ES in H-MW-6. Levels of trichloroethylene were above the ES in H-MW-4 in this round, and a previous round. Levels of 1, 2 dichloroethylene were above the PAL in H-MW-4 and H-MW-6. Benzene was above the PAL in H-MW-7. Many of the samples taken in the past were not tested for VOCs and so historical data is limited. Wells affected by VOCs are H-MW-4 on the southwest side of the site, H-MW-6 on the south side, and H-MW-7 on the east side by the creek.

Groundwater flow for the site is towards the south and southwest, suggesting the possibility that VOC contamination may be migrating onto the U.S. Army property. Although the upstream surface water sample (SW-1) did not shown any vinyl chloride present, the downstream sample (H-SW-2) had a concentration of 1.5 ppb. Since 1994, concentrations of vinyl chloride have exceeded the ES in H-MW-6, which is located on the southern side of the property along Lincoln Creek. Lincoln Creek turns to the southwest near MW-6, making it very likely that vinyl chloride is migrating into Lincoln Creek, as shown in sample H-SW-2.

Iron and Manganese were found above their respective enforcement standards in wells found throughout the site. Arsenic was found above the ES in H-MW-1S and H-MW-2S, and above the PAL in wells H-MW-4, H-MW-6, and H-MW-7. It was also found in the upstream sample H-SW-1.

United States Army Reserve Complex Landfills

Of the wells sampled, vinyl chloride and trichloroethylene were detected at elevated levels. Wells A-MW-3S, A-MW-4S, A-P102A, A-OW105B, A-P105A and the upstream creek sample had concentrations of vinyl chloride above the ES. The downstream sample has concentrations of vinyl chloride above the PAL. Historically, vinyl chloride has been detected in A-OW-102B, A-P102A, and A-P105A above the ES. Monitoring well A-OW102B had concentrations of trichloroethylene above the ES. Historically, trichloroethylene was detected above the PAL in both A-OW102B and A-P102 in various sampling events.

Iron and Manganese were found above their respective enforcement standards in most of the wells sampled at the site. Arsenic was found above the ES in A-MW5S and above the PAL in wells A-MW-2S, A-OW102B, A-P102A, A-OW105B, A-P105A, A-OW106B, A-P106A, the seep sample (A-SW-3) and the downstream sample (A-SW-2). Historically, arsenic was either not analyzed in samples obtained from wells on-site or below the detection limit. It should be noted, however, that the detection limit for previous samples was higher than the PAL for arsenic.

The higher concentrations of vinyl chloride on the south and southwest side of the western landfill suggest the migration of contaminants in this direction due to groundwater flow. As it flows past the US Army Landfills, Lincoln Creek is a gaining stream, with groundwater flowing towards the creek. Lincoln Creek changes direction from south to southwest in this area, which increases the likelihood of contaminants entering Lincoln Creek. The detection of arsenic in monitoring wells in this area also supports this conclusion. It should be noted that in samples collected from Lincoln Creek both upstream and downstream arsenic and vinyl chloride were present. Levels of arsenic, however, were just above the detection limit. This suggests that at least some of the levels of arsenic found in Lincoln Creek may be from a source upstream. This is also a strong possibility for the levels of vinyl chloride found in the upstream sample. In the army upstream sample vinyl chloride was at 1.4 ppb. In the downstream sample taken at Havenwoods vinyl chloride was at 1.5 ppb.

There is a strong possibility that contaminants from the the south and southwest side of the Havenwoods landfill area may have migrated onto the Army landfill property. Groundwater flow in this area is in a southwesterly direction. Trichloroethylene was detected on Army property only in the monitoring wells closest to Havenwoods. These wells are south of monitoring wells on Havenwoods property which also had elevated levels of trichloroethylene.

Former Whitefish Bay Demolition Landfill Groundwater Quality Test Results for selected parameters

Parameter	Units	PAL	ES	W-MW-1S	W-MW-2S	W-MW-3S	W-MW-4S	W-MW-4D	W-MW-5S	W-MW-6	W-MW-A	W-PZ-A	W-MW-B	W-PZ-B	W-MW-C	W-PZ-C	W-SW-1	W-SW-2
Barium	ug/Liter	400	2,000	< 200	< 200	< 200	350.	300.	< 200	**590.**	**450.**	260.	< 200	< 200	**430.**	< 200	< 200	< 200
Selenium	ug/Liter	10	50	**51**	< 2.6	2.7	0.8	< 2.6	< 2.6	0.6	< 2.6	< 2.6	< 2.6	< 2.6	< 2.6	< 2.6	< 2.6	**20**
Iron	ug/Liter	150	300	< 50.	**220.**	< 50.	< 50.	**480.**	< 50.	**23000**	**5200.**	**670.**	**4500.**	**480.**	**2200.**	< 50.	**370.**	100.
Manganese	ug/Liter	25	50	**260.**	**360.**	**120.**	**270.**	**130.**	**99.**	**320.**	**620.**	**430.**	**250.**	**290.**	**2600.**	18.	**36.**	**38.**
Arsenic	ug/Liter	1.2	6.0	< 1.0	< 1.0	< 1.0	< 1.0	**2.4**	**4**	**15**	**4.4**	< 1.0	< 1.0	< 1.0	**13**	< 1.0	1.1	< 1.0
Chloride	mg/Liter	125.0	250.0	41.	15.	43.	120.	**320.**	**140.**	**230.**	20.	**220.**	**180.**	**190.**	23.	**180.**	**220.**	**270.**
Nitrate	mg/Liter	2.0	10.0	**15.**	0.97	0.11	0.51	**3.6**	0.37	0.030	0.10	0.46	0.21	0.47	0.45	0.050	0.29	0.26
Sulfate	mg/Liter	125.0	250.0	**920.**	82.	110.	**200.**	110.	120.	110.	**160.**	99.	**200.**	94.	82.	**170.**	63.	58.
1,1-Dichloroethylene	ug/Liter	0.7	7.0	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	**0.80**	< 0.47	< 0.47
1,2-Dichloroethylene (Total)	ug/Liter	20.0	100.0	NR	< 0.90	NR	NR	< 0.90	NR	< 0.90	< 0.90	2.7	< 0.90	< 0.90	**51.**	**200.**	< 0.90	2.5
Benzene	ug/Liter	0.5	5.0	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	**0.58**	< 0.44	< 0.44	< 0.44
Tetrachloroethylene	ug/Liter	0.5	5.0	< 0.41	< 0.41	< 0.41	< 0.41	< 0.41	< 0.41	< 0.41	< 0.41	< 0.41	< 0.41	< 0.41	**8.1**	< 0.41	< 0.41	< 0.41
Trichloroethylene	ug/Liter	0.5	5.0	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	**13.**	**16.**	< 0.49	< 0.49
Vinyl chloride	ug/Liter	0.02	0.2	< 0.52	< 0.52	< 0.52	< 0.52	< 0.52	**22.**	**0.99**	< 0.52	< 0.52	< 0.52	< 0.52	**3.1**	**230.**	< 0.52	< 0.52

Wells sampled on 4/21/98 (1)

Boldface type indicates concentrations above the Preventive Action Limit.

Shaded boldface type indicates concentrations above the Enforcement Standard.

NR indicates parameter not reported by lab

United States Army Reserve Complex Landfills Groundwater Quality Test Results for Selected Parameters

Parameter	Units	PAL	ES	A-MW-1S	A-MW-2S	A-MW-2D	A-MW-3S	A-MW-4S	A-MW-5S	A-MW-5D	A-MW-6S	A-MW-7S	A-MW-8S	A-OW 102B	A-P102 A	A-OW 105B	A-P105A	A-OW 106B	A-P106 A	A-SW-1	A-SW-2	A-SW-3
Barium	ug/Liter	400	2,000	< 200	**540.**	< 200	< 200	< 200	< 200	< 200	**440.**	**430.**	< 200	< 200	< 200	< 200	< 200	< 200	< 200	< 200	< 200	< 200
Lead	ug/Liter	1.5	15	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	**2.5**	< 2.0	< 2.0	**2.7**	< 2.0	< 2.0	< 2.0	**3.0**	< 2.0
Iron	ug/Liter	150	300	< 50.	< 50.	**3400.**	**1200.**	**2600.**	**1000.**	**580.**	< 50.	< 50.	< 50.	< 50.	**2300.**	**2600.**	**4300.**	130.	**200.**	78.	**830.**	**1500.**
Manganese	ug/Liter	25	50	**190.**	**180.**	**89.**	**370.**	**92.**	**110.**	**87.**	**340.**	**470.**	**190.**	**120.**	**61.**	**51.**	**97.**	**28.**	17.	**68.**	**83.**	**380.**
Arsenic	ug/Liter	1.2	6.0	< 1.0	**3**	< 1.0	< 1.0	< 1.0	**6.6**	< 1.0	< 1.0	< 1.0	< 1.0	**3.7**	**2.3**	**2.5**	**2.7**	**2.6**	**4.5**	1.1	**1.9**	**1.9**
Chloride	mg/Liter	125.0	250.0	74.	**360.**	**260.**	27.	58.	37.	73.	17.	39.	12.	< 0.60	59.	**130.**	25.	7.6	2.4	**170.**	**150.**	62.
Sulfate	mg/Liter	125.0	250.0	**170.**	**350.**	**240.**	**290.**	**150.**	58.	100.	**290.**	**810.**	**550.**	85.	**170.**	**150.**	**220.**	110.	58.	72.	87.	**440.**
Trichloroethylene	ug/Liter	0.5	5.0	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	**24.**	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49
Vinyl chloride	ug/Liter	0.02	0.2	< 0.52	< 0.52	< 0.52	**2.4**	**1.5**	< 0.52	< 0.52	< 0.52	< 0.52	< 0.52	< 0.52	**43.**	**35.**	**54.**	< 0.52	< 0.52	**1.4**	**0.96**	< 0.52

Wells sampled on 4/23, 5/13, and 5/14 of 1998

Boldface type indicates concentrations above the Preventive Action Limit.

Shaded boldface type indicates concentrations above the Enforcement Standard.

Havenwoods State Forest Landfill Groundwater Test Results for Selected Parameters

Parameter	Units	PAL	ES	H-MW-1S	H-MW-2S	H-MW-3S	H-MW-4S	H-MW-2	H-MW-4	H-MW-5	H-MW-6	H-MW-7	H-SW-1	H-SW-2
Barium	ug/Liter	400	2,000	**540.**	**510.**	< 200	< 200	< 200	< 200	< 200	< 200	**410.**	< 200	< 200
Lead	ug/Liter	1.5	15	< 2.0	< 2.0	< 2.0	< 2.0	**2.5**	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Iron	ug/Liter	150	300	**610.**	**3700.**	**870.**	< 50.	**560.**	**3700.**	**1800.**	**360.**	**4900.**	55.	**210.**
Manganese	ug/Liter	25	50	**550.**	**400.**	**68.**	**180.**	38.	**98.**	**270.**	**130.**	**190.**	**40.**	**69.**
Arsenic	ug/Liter	1.2	6.0	**9.9**	**11.**	< 1.0	< 1.0	< 1.0	**1.9**	< 1.0	**1.6**	**2.1**	**2.0**	< 1.0
Chloride	mg/Liter	125.0	250.0	45.	76.	7.5	14.	6.0	91.	7.4	**220.**	39.	**270.**	**270.**
Nitrate	mg/Liter	2.0	10.0	0.070	0.060	0.14	0.76	0.19	< 0.02	0.19	**6.5**	1.2	0.32	0.26
Sulfate	mg/Liter	125.0	250.0	79.	28.	**150.**	**160.**	79.	**220.**	**680.**	**280.**	**130.**	63.	70.
1,2-Dichloroethylene (Total)	ug/Liter	20.0	100.0	NR	NR	NR	NR	< 0.90	**20.**	< 0.90	**20.**	< 0.90	4.3	4.4
Benzene	ug/Liter	0.5	5.0	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	**1.0**	< 0.44	< 0.44
Trichloroethylene	ug/Liter	0.5	5.0	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	**15.**	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49
Vinyl chloride	ug/Liter	0.02	0.2	< 0.52	< 0.52	< 0.52	< 0.52	< 0.52	**2.2**	< 0.52	**9.1**	< 0.52	< 0.52	**1.5**

Wells sampled on 4/28, 5/18 of1998

Boldface type indicates concentrations above the Preventive Action Limit.

Shaded boldface type indicates concentrations above the Enforcement Standard.

NR indicates parameter not reported by lab

LINCOLN CREEK FLOOD CONTROL
MANAGEMENT PLAN
Hydrogeological Analysis and Landfill Delineation
of Reach 7 and Reach 9
Milwaukee Metropolitan Sewerage District
Milwaukee, Wisconsin

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SECTION I. EXECUTIVE SUMMARY

This hydrogeologic analysis and landfill delineation report for parts of Reaches 7 and 9 of Lincoln Creek was prepared to assess the potential impact of proposed improvements to Lincoln Creek on the groundwater flow and contaminant transport regimes in the vicinity of former landfills that border the creek. The three landfills are the former Whitefish Bay Demolition Landfill, the Havenwoods State Forest Landfill, and the U.S. Army Reserve Complex (USARC) Landfills. The findings and recommendation of the analysis are to be used in developing design parameters for the deepening and widening of Lincoln Creek.

Project Scope

The scope of this investigation included a review of the existing data for each of the three former landfills. A geophysical survey was conducted to determine landfill boundaries within the survey area identified by the MMSD; landfill areas outside the survey area were not part of the project scope. The survey area included only those portions in the proximity of Lincoln Creek at the Whitefish Bay landfill and the USARC landfills. Based on the findings of the geophysical survey, fifty-four soil borings were conducted to verify the landfill limits within the survey areas.

A hydrogeologic investigation consisting of installation of seventeen monitoring wells and three piezometers was conducted to assist in the determination of groundwater flow characteristics and contaminant transport in groundwater. A sampling and analysis program of selected existing and all new monitoring wells and piezometers was implemented. Two rounds of groundwater quality data were gathered. A characterization of the groundwater flow regime was made and an evaluation of the contaminant migration pathways and potential impact on receptors was determined. Analysis included potential impacts from construction of a meandering Lincoln Creek, using low flow and flood conveyance channels provided by the firm of Camp, Dresser and McKee.

Soil Conditions

Previous site investigations and current field explorations provided data on soil conditions at the former landfills in the proximity of Lincoln Creek. Near surface soils encountered included fill, sandy clay, silty clay, and gravelly sands. In the former Whitefish Bay Demolition landfill sandy gravel is underlain by silty clays, whereas in Havenwoods State Forest landfill and the U.S. Army Reserve Complex landfills sandy clays interbedded with silty clays were found to be more common.

Hydraulic conductivities, on the order of 10^{-3} to 10^{-6} cm/sec, were found, with the higher conductivity found in the sandy gravel formations surrounding the piezometer wells of the former Whitefish Bay Demolition landfill and the lower conductivities in the piezometers installed in the bedrock of the Havenwoods State Forest landfill.

Elevations and Groundwater Directions

Flow directions of the shallow aquifer at the former Whitefish Bay Demolition Landfill vary. During the wet and dry seasons, the flow on both sides of Lincoln Creek are towards the landfill. The shallow groundwater flow away from the creek appears to be towards the creek. Groundwater flow for the deeper aquifer appears to be towards the south central area of the western side of the landfill. The shallow aquifer at Havenwoods State Forest Landfill has a groundwater flow direction to the southwest, with groundwater of the deeper, bedrock aquifer flowing to the east. Groundwater flow at the U.S. Army Reserve Complex is toward the west as determined from both the shallow and deep wells for the eastern landfill, and to the south for both the shallow and deep wells of the western landfill. During the wet season, the shallow groundwater flow near the creek, both at Havenwoods Landfill and USARC Landfills, appear to be towards the creek. During the dry season, as the groundwater elevation drops, the shallow groundwater flow appears to be towards the landfill.

Surface and Groundwater Quality

A contamination assessment of the groundwater quality of each landfill area was conducted. Dissolved iron and manganese, which are landfill indicator parameters, were detected at elevated levels at all three landfill areas. At the former Whitefish Bay Demolition landfill other parameters of concern include vinyl chloride and arsenic, which were both detected above their respective Enforcement Standards. Monitoring wells closest to the creek, however, do not appear to be impacted by VOC contaminants. Contaminants of concern at Havenwoods State Forest Landfill include vinyl chloride, which was found at elevated levels in wells on the south and southwest sides of the site and in the downstream creek sample. At the USARC landfills vinyl chloride and arsenic were detected at elevated levels in monitoring wells along the western side of Lincoln Creek and to the south of the western landfill. Trichloroethylene was also detected in monitoring wells that border the Havenwoods landfill property. Of further concern is the potential for contamination due to excavating into or close to the landfill boundaries due to construction of revised creek channels.

Design Impacts

In order to protect the surface water in Lincoln Creek from the toxic substances entering from the landfills, various conceptual designs for isolating the creek from the landfills have been evaluated. It may be also desirable to isolate the creek from the landfill in order to minimize the leachate generation within the landfill. Based on constructability considerations and economic evaluations, a conceptual design has been recommended. The recommended design consists of a multiple-layered lining approach. First, the creek bed and lower sideslope of the creek would be lined with sand sprayed with bentonite and the upper sideslope with compacted clay. The second layer would consist of a geomembrane liner which would underlie a layer of vegetative surface down to the dry season water level in the creek and along with rounded stone on the lower sideslope and in the creek bed. The thickness of the rounded stone layer would be adequate to prevent uplift of the membrane. In the implementation of this design, the removal and/or management of soil or solid waste may require an NR 500.8 exemption.

Vinyl chloride is the only toxic compound which has been identified in concentrations high enough to potentially impact surface water in the creek. The areas which need to be protected from vinyl chloride contamination have been identified in this report. It is recommended that these areas be isolated from the landfill using the proposed liner. Based on the concentration of the indicator parameters of dissolved iron and dissolved manganese, the areas have been identified where there appears to be interaction between landfill and the creek have been identified. For greater protection of the creek, these areas may also need to be lined using the recommended methodology.

SECTION II. INTRODUCTION

2.1 General

The Milwaukee Metropolitan Sewerage District (MMSD) has retained K. Singh & Associates (Singh) to provide a Hydrogeological Analysis and Landfill Delineation of Reach 7 and 9 of Lincoln Creek in order to assess the potential impact of flood control improvements on Lincoln Creek in relation to groundwater flow and contaminant transport characteristics in the vicinity of landfills that border the creek. The flood control improvement plan calls for the deepening, widening, and modifying the channel of Lincoln Creek between W. Good Hope Road and W. Silver Spring Drive. A topographic map showing the study area, taken from the USGS 7.5 minute quadrangle map, is included in Figure 2.1.

2.2 Project Background

Lincoln Creek is a tributary of the Milwaukee River. The Lincoln Creek watershed is located almost entirely within the City of Milwaukee. Small portions of the watershed are also located in the Village of Brown Deer and City of Glendale. The Lincoln Creek watershed drains an area of approximately 19.26 square miles. Lincoln Creek originates in the northwestern part of the City of Milwaukee near N. 76th Street and W. Good Hope Road. From its originating point, Lincoln Creek flows in a southeasterly direction approximately nine miles to the Milwaukee River. Just north of W. Silver Spring Drive, Lincoln Creek starts to be underlain by a concrete spillway. Lincoln Creek has been designated "Reach 7" between W. Silver Spring Drive and W. Mill Road by the MMSD and "Reach 9" between W. Green Tree Road and W. Good Hope Road by the MMSD.

During the course of its run, Lincoln Creek flows past a number of landfills. Between W. Good Hope Road and W. Silver Spring Drive, Lincoln Creek flows past the former Village of Whitefish Bay Demolition Landfill, the Havenwoods State Forest Landfill, and two landfills at the U. S. Army Reserve Complex (USARC). None of these landfills are presently active. All are closed. The locations of the landfills in relation to Lincoln Creek are shown in Figure 2.1.

In the area between W. Good Hope Road and W. Silver Spring Drive, Lincoln Creek commonly has a surface elevation between 666 and 693 feet, MSL. The depth of water in Lincoln Creek is generally 1.5 to 3 feet. Water in Lincoln Creek has a relatively mild gradient between W. Good Hope Road and W. Mill Road and a steeper gradient between W. Mill Road and W. Silver Spring Drive. A series of weirs and other control structures have local effects on the water levels in Lincoln Creek.

2.2.1 Former Whitefish Bay Demolition Landfill

The former Whitefish Bay Demolition Landfill property occupies approximately 14 acres of land at 5201 W. Good Hope Road in the City of Milwaukee. The property is divided by Lincoln Creek and includes a small triangular portion located east of Lincoln Creek and a larger rectangular portion located west of Lincoln Creek.

The property was purchased by the Village of Whitefish Bay in 1960 and was used for the disposal of incinerator ash and demolition wastes from approximately 1962 to 1972. Reportedly, landfill operations only occurred on land located on the west side of Lincoln Creek. However, the limits of the landfilling operations were not well defined, and recent investigations show evidence of demolition material on both the east and west portions. In 1980, the western portion of the landfill was capped with 1 to 2 feet of compacted clay, covered with topsoil, and seeded with grass, trees, and shrubs (9). The site is currently inactive.

Soil and groundwater contamination was discovered at the property in approximately 1987. Since the discovery of contamination, various geologic and hydrogeologic investigations have been performed. Discussion of these investigations is included in Chapters III and V.

2.2.2 Havenwoods State Forest Landfill

The former landfill property occupies approximately 240 acres of land bounded by United States Army Reserve property to the south, Sherman Boulevard to the east, the Chicago & Northwestern Railroad Line to the north, and 60th and 64th Streets to the west. The U. S. Government owned the property from 1945 until 1974. In 1974 the U. S. Government turned the property over to Milwaukee County, the General Services Administration, and the Milwaukee Area Vocational Technical School. Since 1974, the Wisconsin Department of Natural Resources (WDNR) has managed the property as the Havenwoods Nature Reserve.

From 1957 to 1966 a portion of the property located on the west side of Lincoln Creek was used as a landfill. Approximately 100,000 tons of solid wastes were disposed of at the landfill during its operating life. Reportedly, no putrescible materials, industrial, or hazardous wastes were disposed of at the landfill. Refuse depths reportedly varied between 6 to 14 feet. The location of the landfill in relation to Lincoln Creek is shown on Figure 2.1. The limits of the landfilling operations are not well defined. The landfill was reportedly capped with 1 to 2 feet of clay material, although soil borings indicate that the cap may not be continuous over the fill area. In particular, there are concerns with the integrity of the cap near Lincoln Creek. Also, there is some evidence of soil and groundwater impacts at the site.

Various geologic and hydrogeologic investigations have been performed at the site since 1986. Discussion of the investigations is included in Chapters III and VI.

2.2.3 United States Army Complex (USARC) Landfills

The USARC is comprised of several administrative and maintenance buildings located on approximately 60 acres of land. The study area is bounded by the Chicago, Milwaukee, St. Paul and Pacific Railroad right-of-way and the Havenwoods Nature Center to the northeast, W. Silver Spring Drive to the south, and residential and light commercial properties to the west along North 55th Street. The entire facility is fenced and access to the site is restricted. The southwest portion of the USARC is located within the 100 year floodplain of Lincoln Creek. The locations of the landfills in relation to Lincoln Creek are shown on Figure 2.1.

Prior land use information suggests that from 1957 through 1966, the Milwaukee Sanitation Department utilized two landfill areas in the northern portion of the site, one on each side of the creek. The landfill east of the creek is approximately 18 acres in area and the western landfill is approximately 24 acres in area. Lincoln Creek flow south between the landfills then turns to the southwest after it passes the landfill areas and exits USARC. property. During the period of operation, approximately 500,000 cubic yards of solid waste were disposed of at the site. The solid waste was comprised of furniture, appliances, street sweepings, leaves, tin cans, bottles, ashes, cinder and sewer pipe. Reportedly, no newspaper, garbage, industrial or hazardous wastes were accepted at the facility. During landfilling operations, earth berms were constructed to minimize the potential for migration of contaminants into Lincoln Creek.

The limits of the landfilling operations are not well defined. In 1987, it was determined that the thickness of the landfill cap did not meet the landfill closure guidelines specified in the Wisconsin Administrative Code. In 1994, corrective actions were taken to properly cap both landfills located at the site. In addition, a passive gas venting system was installed at the site. Questions remain regarding the boundaries of the landfill caps adjacent to Lincoln Creek.

Various geologic and hydrogeologic investigations have been performed at the site since 1984. Groundwater impacts have been confirmed on the northern portion of the property, upgradient from USARC. landfills. Discussion of the investigations is included in Chapters III and VII.

2.3 Purpose and Scope

The purpose of this report is to assess the potential impact of proposed improvements to Lincoln Creek on the groundwater flow and contaminant regimes in the vicinity of landfills that border the area. Singh conducted a hydrogeologic investigation of part of Reach 7 and Reach 9 of Lincoln Creek to determine hydrogologic conditions and contaminant transport in these areas. Additionally, a landfill delineation study was conducted to determine the boundaries along Lincoln Creek for the USARC landfills and the Village of Whitefish Bay Landfill. Information on the landfill limits is required so that dimensional modifications to Lincoln Creek will avoid encroachment of the landfill boundaries.

The specific scope of this study included:

1) Review of existing reports and data concerning environmental conditions of the study area landfills including groundwater conditions and any groundwater testing results.

2) Perform a geophysical survey of areas along the length of Lincoln Creek in both the former Whitefish Bay Demolition Landfill and the United States Army Reserve Complex Landfills to determine the boundaries of the former landfill areas.

3) Perform geoprobe and hand auger soil borings in selected areas to verify data developed during the geophysical survey and make recommendations to MMSD regarding the boundary of the landfills in relation to Lincoln Creek.

4) Perform soil borings and install monitoring wells parallel to Lincoln Creek in proximity to the creek at each landfill.

5) Perform an engineering survey to determine the elevation and location of all on-site soil borings and monitoring wells.

6) Develop and sample all newly installed monitoring wells. Selected existing monitoring wells to be sampled. Two rounds of groundwater sampling to determine contaminant concentrations in monitoring wells within the study area were conducted.

7) Use of groundwater transport models to interpret the hydrogeological characteristics of surface and groundwater flow regimes of the landfills and their effect on Lincoln Creek.

8) Use of contaminant transport models to determine the impact of contaminants to the surface and groundwater quality in the proximity of the creek at each landfill.

9) Use of a conceptual model to analyze the effects on the groundwater flow regime of the proposed deepening and widening of the creek and the potential for contaminant migration from the landfills to the creek.

2.4 Report Organization

This report is organized into thirteen sections. Sections I and II include an executive summary and introduction for the report, respectively. Section III briefly discusses the current investigation procedures. Section IV provides a regional characterization, including geology and hydrogeology of the area. Sections V, VI, and VII provide a discussion on hydrogeologic conditions and contamination assessment of each landfill area. Sections VIII includes a discussion on conceptual design suggested for mitigation of contaminant migration. Sections IX includes conclusions and recommendations. Sections X, XI, XII, and XIII include references, tables, figures, and appendices, respectively.

SECTION III. SITE INVESTIGATION

3.1 General

A hydrogeological analysis was performed for each landfill. Activities included review of available data for each site, performing soil borings, installing monitoring wells, conducting groundwater sampling for each site, and determining groundwater flow and contaminant transport characteristics for each site. A review of previous investigations and description of the procedures employed during this investigation is included in this section. Please note that the term"monitoring well" has been used in this discussion to include monitoring wells (MW), observation wells (OW), and piezometers (P) for clarity purposes.

3.2 Previous Site Investigations

At the former Whitefish Bay Demolition Landfill over 30 monitoring wells and piezometers were installed between 1988 and 1997, although some have been damaged and are no longer usable (9, 16). The locations of the monitoring wells are shown on Figure 3.1. Wells were placed throughout the southern two-thirds of the western portion of the site. No wells were installed on the eastern portion of the landfill. Nomenclature, screen lengths, and depths for the wells are summarized in Table 3.1. All of the monitoring wells and piezometers were reportedly constructed and developed in accordance with Wisconsin Administrative Code (WAC) NR 141.

Five monitoring wells and four piezometers were installed at the Havenwoods State Forest Landfill site between 1986 and 1994 (11, 18). The locations of the monitoring wells are shown on Figure 3.2. Wells were placed throughout the western side of the property. No wells were placed on the portion of the property to the east of Lincoln Creek. Nomenclature, screen lengths, and depths for the wells are summarized in Table 3.2. The monitoring wells and piezometers were reportedly constructed and developed in accordance with WAC NR 141.

Thirteen monitoring wells and thirteen piezometers were installed as well nests at the USARC. Landfills site between 1984 and 1989 (12, 13, 14, 19). One well nest (OW-103B, P-103A) had been abandoned. The locations of the monitoring wells are shown on Figure 3.3. Monitoring wells were placed surrounding the landfills. No monitoring wells were placed between the landfills and Lincoln Creek. Nomenclature, screen lengths, and depths for the wells are summarized in Table 3.3. All of the monitoring wells and piezometers were reportedly constructed and developed in accordance with WAC NR 141.

3.3 Monitoring Well Installation and Development

Additional monitoring wells were installed by Singh at the former landfill areas to give a more accurate understanding of the hydrogeologic conditions encountered along Lincoln Creek and to assist in the assessment of contaminant concentrations in both surface and groundwater near the creek. Nomenclature for the new wells and previously installed wells include a letter prefix to differentiate any duplicate wells names throughout the three study areas. A "W" was used for the former Whitefish Bay Demolition Landfill, an "H" for the former Havenwoods State Forest Landfill, and an "A" for the U.S. Army Reserve Complex Landfills.

At the former Whitefish Bay Demolition Landfill five water table observation wells were installed with depths ranging 13 to 15 feet below grade. A piezometer well was also installed which has a depth of 20 feet below grade. Wells installed include: W-MW-1S,W-MW-2S,W-MW-3S,W-MW-4S,W-MW-4D (piezometer), and W-MW-5S. Nomenclature for the wells is summarized in Table 3.1. The locations of the wells are shown in Figure 3.1.

At Havenwoods State Forest Landfill four water table observation wells were installed with depths ranging 14 to 20 feet below grade. Wells installed include: H-MW-1S, H-MW-2S, H-MW-3S, and H-MW-4S. Nomenclature for the wells is summarized in Table 3.2. The locations of the wells are shown in Figure 3.2.

At the United States Army Reserve Complex Landfills eight water table observation wells were installed with depths ranging 13 to 15 feet below grade. Two piezometer wells were also installed, both with a depth of 28 feet below grade. Wells installed include: A-MW-1S, A-MW-2S, A-MW-2D, A-MW-3S, A-MW-4S, A-MW-5S, A-MW-5D, A-MW-6S, A-MW-7S, and A-MW-8S. Nomenclature for the wells is summarized in Table 3.3. The locations of the wells are shown in Figure 3.3.

The wells were installed by Briohn Environmental Contractors of Pewaukee, Wisconsin in accordance with WAC NR 141 (1). General conditions for data collection are included on Appendix A. Monitoring wells at the United States Army Reserve Complex Landfills were installed on April 21, May 12, and May 13, 1998. Monitoring wells at Havenwoods State Forest Landfill were installed on May 14, 1998. Monitoring wells at the former Whitefish Bay Demolition Landfill were installed on May 1, May 11 and May 12, 1998.

Development of the monitoring wells was conducted using a bailer or a submersible pump. The pump was a Well Wizard Submersible 921. The submersible pump was used on wells with rapid recharge rates. Depth to water was measured prior to and following well development. Monitoring wells at the United States Army Reserve Complex Landfills were developed on April 23, May 13, and May 14, 1998. Monitoring wells at Havenwoods State Forest Landfill were developed on May 18, 1998. Monitoring wells at the former Whitefish Bay Demolition Landfill were developed on May 12 and May 13, 1998.

The total volume of water discharged from each well was measured. Soil borings, well installation and development details for each facility are included in Appendices B, C, and D.

3.4 Hydraulic Conductivity Testing

Limited in-situ hydraulic conductivity testing was planned to determine the transport characteristics of the porous medium at each of the three sites. The baildown tests were conducted for monitoring wells A-OW102-B, A-P105-A, A-MW-2D, A-MW-3S, A-MW-5D, and A-MW-8S at the United States Army Reserve Complex Landfills on July 28, 29, and 30, 1998. Monitoring wells H-MW-2, H-MW-5, H-MW-6, and H-MW-3S at Havenwoods State Forest Landfill were tested on July 22, 1998. Monitoring wells W-MW-6, W-PZ-B, W-PZ-C, W-MW-3S, W-MW-4S, W-MW-4D, and W-MW-5S at the former Whitefish Bay Demolition Landfill were tested on July 16, 1998.

Testing of hydraulic conductivity consisted of purging water from the well using a bailer or pump, and measuring the rise of the water level in the well with respect to time. Based on the data obtained, Hvorslev's method (2) was used to estimate the hydraulic conductivity of water bearing soils at the site. Estimations of hydraulic conductivities using Hvorslev's method for the tested wells are summarized in Tables 5.2, 6.2, and 7.2 and are discussed further in Appendix E.

3.5 Surface Water Quality Testing

Surface water sampling of Lincoln Creek was conducted during two rounds at each of the three sites at upgradient and downgradient locations at each site. The upstream samples were designated as "SW-1" and the downstream samples were designated as "SW-2" for each of the three study areas. An additional sample was collected from the groundwater seep at the United States Army Reserve Complex Landfills site and designated as "SW-3". The seep is located approximately 100 feet north of A-MW-3S on the eastern side of Lincoln Creek. Sample locations are shown in Figures 3.1 to 3.3. Samples were collected at the United States Army Reserve Complex Landfills on April 23 and July 30, 1998, at Havenwoods State Forest Landfill on April 27 and July 22, 1998, and at the former Whitefish Bay Demolition Landfill on April 28 and July 15, 1998. All samples were collected according to WDNR site assessment guidelines (3). After collection samples were then delivered to the MMSD laboratory using chain of custody records.

Samples were tested for volatile organic compounds (VOCs) and RCRA metals using EPA Methods 8021 and 6010. These parameters include: Barium Calcium, Chromium, Iron, Magnesium, Manganese, Zinc, and Hardness (calculated). Parameters tested using the EPA Method 4-79-020 include: Alkalinity, Chloride, Ammonia Nitrogen, Sulfate, Nitrate, Nitrite. Other parameters tested include: Silver and Lead (EPA Method 7761), Arsenic and Selenium (EPA Method 7740), Cadmium (EPA Method 7000 series), Mercury (EPA Method 7471), BOD (SM 19 5210B), and COD (SM 19 5210B). Chain of Custody records and test results for each facility are included in Appendices F, G, and H.

3.6 Groundwater Quality Testing

Groundwater samples were collected from all of the newly installed monitoring wells (W-MW-1S,W-MW-2S,W-MW-3S,W-MW-4S,W-MW-4D, and W-MW-5S) and selected existing monitoring wells at each site for two rounds. Existing monitoring wells sampled in the two rounds for the former Whitefish Bay Demolition Landfill include: W-MW-6, W-MW-A, W-PZ-A, W-MW-B, W-PZ-B, W-MW-C, and W-PZ-C. The second round also included previously installed wells W-MW-10, W-MW-11, W-MW-26, W-MW-D, and W-PZ-D. Samples were collected at the former Whitefish Bay Demolition Landfill on May 12 and 13, 1998 for the first round and July 15 and 16, 1998 for the second round.

Samples were collected at Havenwoods State Forest Landfill on May 18, 1998 for the first round and July 21 and 22, 1998 for the second round. Sampling included the newly installed monitoring wells (H-MW-1S, H-MW-2S, H-MW-3S, and H-MW-4S) and previously installed wells H-MW-2, H-MW-4, H-MW-5, H-MW-6, and H-MW-7.

Samples were collected at the United States Army Reserve Complex Landfills on April 23, May 13, and 14, 1998 for the first round and July 28, 29 and 30, 1998 for the second round. Sampling included the newly installed monitoring wells (A-MW-1S, A-MW-2S, A-MW-2D, A-MW-3S, A-MW-4S, A-MW-5S, A-MW-5D, A-MW-6S, A-MW-7S, and A-MW-8S) and previously installed wells A-OW102B, A-P102A, A-OW105B, A-P105A, A-OW106B, and A-P106A.

All samples were collected according to WDNR site assessment guidelines (3). After collection samples were then delivered to the MMSD laboratory using chain of custody records. All groundwater samples were collected after the wells were purged in accordance with WDNR guidelines (4).

Groundwater samples were tested for the same parameters as the surface water samples as listed in Section 3.4 along with their respective analytical methods. Samples collected during the second round were analyzed only for VOCs and any parameters of concern which were detected during the first round. Chain of Custody records and test results are included in Appendices F, G, and H.

3.7 Geophysical Survey

A geophysical survey survey was conducted by Fromm Applied Technology, of Mequon, Wisconsin. The purpose of the survey was to determine landfill boundaries near the creek using geophysical methods at the United States Army Reserve Complex Landfills and former Whitefish Bay Demolition Landfill. A copy of the Fromm's survey report is included in Appendix I.

3.8 Soil Test Borings

Thirty-one soil test borings were conducted at the former Whitefish Bay Demolition Landfill to supplement and verify results of the geophysical surveys performed. These included seventeen geoprobe soil borings performed by Briohn Environmental Contractors of Pewaukee, WI and fourteen hand auger borings performed by Singh staff. Depth of soil borings ranged from 2 to 11 feet below grade. Soil boring logs are included in Appendix B.

Twenty-three soil test borings were conducted at the United States Army Reserve Complex Landfills. These included fourteen geoprobe soil borings performed by ESP Enterprises of West Bend, WI and nine hand auger borings performed by Singh staff. Depth of soil borings ranged from 3 to 15 feet below grade. Soil boring logs are included in Appendix D. Geoprobe soil borings were abandoned with granular bentonite after their completion. Locations of soil borings are shown in Appendix I. General conditions for test boring data collection are included in Appendix A.

3.9 Engineering Survey

An engineering survey was conducted by Singh staff. The purpose of the survey was to prepare a base map showing the State Plane Coordinates of newly installed monitoring wells and previously installed monitoring wells, any buildings or structures, creek location, and other pertinent topographic features of each site. Also included was the area covered by the geophysical survey of Linclon Creek at both the Whitefish Bay landfill and the U.S. Army landfills. A base map of each landfill is shown in Figures 3.1 to 3.3.

The engineering survey also determined the ground elevation of soil borings and PVC pipe elevation for the monitoring wells and the creek at the project sites. Tables 3.1 to 3.3 show the nomenclature of test borings, corresponding wells, if any, and PVC pipe elevation.

SECTION IV. REGIONAL CHARACTERIZATION

4.1 Demography

The City of Milwaukee is located in Milwaukee County. The population of the city is approximately 630,000. The potable water supply needs of the City of Milwaukee are met by Lake Michigan.

4.2 Climate and Meteorology

Climate and meteorology data were taken from the Midwest Climatological Center records for the City of Milwaukee. The average annual precipitation is approximately 32.93 inches with a slight seasonal influence on monthly precipitation. Average monthly precipitation ranges from 1.45 inches in February to 3.53 inches in September. Average annual snowfall is 50.1 inches with a monthly variation of zero in summer to 12.9 inches in winter.

The mean monthly temperature is 46.1°F with a monthly temperature range from 18.9 °F in January to 70.9°F in July. The lowest recorded temperature was 26 °F below zero in February 1996. The highest recorded temperature was 103 °F in July of 1995.

The prevailing wind direction of the region is from the southwest. The information on temperature and precipitation was obtained from the Midwest Climatological Center (5).

4.3 Regional Geology

The materials that control the movement and storage of groundwater in the Milwaukee area range from basement rocks of Precambrian age to the unconsolidated glacial deposits, alluvium, and soils of Pleistocene and Holocene ages. Bedrock is overlain by glacial drift throughout the county. The bedrock, from oldest to youngest, includes Precambrian crystalline rocks, Cambrian sandstone, Ordovician dolomite, sandstone, and shale, and Silurian dolomite. A description of the bedrock (consolidated) and quaternary (unconsolidated) geology is included in Table 4.1 (6).

The Precambrian rocks are impermeable crystalline rocks encountered between 2,500 and 4,000 feet below land surface and form the foundation for the water bearing rocks. The depth to the crystalline rocks, therefore, is the greatest possible depth of available groundwater.

Cambrian rocks in Milwaukee County are mostly sandstone and interbedded shale, siltstone and dolomite. They are separated from bottom to top into the Mount Simon Sandstone, the Eau Claire Sandstone, the Galesville and Franconia Sandstones undifferentiated, and the Trempealeau Formation. Cambrian rocks include the most consistently productive water bearing zones in the area and are tapped by wells for industrial and public water supplies. The thickness of the Cambrian rocks is estimated to range from 2,000 to 3,500 feet in Milwaukee County (7).

Ordovician sedimentary rocks include the Prairie du Chien Group, St. Peter Sandstone, the Platteville and Decorah Formations, Galena Dolomite, and Maquoketa Shale. The St. Peter Sandstone is mostly sandstone, although it also contains a variety of rock types ranging from conglomerate to shale. The St. Peter Sandstone is the only Ordovician rock that yields water in significant amounts in the area. However, it is less productive than the sandstones of Cambrian age. The maximum thickness of St. Peter Sandstone is 80 to 357 feet.

Silurian rocks are the youngest rock unit and consist mostly of dolomite and have a maximum thickness of 325 feet. Silurian dolomite forms the bedrock surface in most of the area, the Maquoketa Shale forms this surface when dolomite is absent. Silurian rocks yield small to large amounts of water and are the principal source of water for domestic wells.

4.3.1 Geology of Consolidated Sediments

The oldest rocks in the Milwaukee area are igneous and metamorphic rocks of the Precambrian basement complex. Outcrops in northern and central Wisconsin indicate that the basement complex includes granite and quartzite. The upper surface of the Precambrian basement complex is an erosion surface on which the Cambrian formations were deposited.

The regional Paleozoic formations include dolomite, limestone, shale and sandstone, ranging from the Cambrian Period to the Devonian period. The sediments are composed of sand, silt and clay transported from adjacent land areas and formed by chemical and biological activity in the sea.

4.3.2 Geology of Unconsolidated Sediments

The region was covered by four major continental ice sheets which advanced into the Great Lakes area during the Pleistocene Epoch. The predominant lithology is an unsorted mixture ranging in size from clay to large boulders, called till. The tills were deposited beneath the ice sheets and are classified as lodgement tills. The outwash and lacustrine sediments were deposited in proglacial lakes. The general features of the soil units are summarized in Table 4.2 in terms of density/ consistency, color, grain size permeability, and unique characteristics.

4.4 Regional Hydrogeology

The source of all underground water in southeastern Wisconsin is precipitation that falls upon the land surface in the area. The Drift - Bedrock province is characterized by glacial deposits of the Quaternary System and sedimentary rocks of the Devonian, Silurian, Ordovician and Cambrian System (7). The shale and crystalline rock yield very little water except where the rocks are fractured. Dolomite, ordinarily dense and impervious, yields water where it is creviced. Sand, gravel, and sandstone are relatively permeable and generally yield water to wells.

4.4.1 Hydrogeology of Consolidated Sediments

The Devonian aquifer is a carbonate rock aquifer similar to the underlying Silurian aquifer. Recharge is mostly by downward vertical seepage from the overlying glacial drift.

The Cambrian-Ordovician System consists of the Maquoketa Group and the sandstone aquifer. The Maquoketa Shale is a dolomitic shale approximately 160 feet thick containing layers of interbedded dolomite. It works as an aquitard and yields very little water to wells.

The St. Peter Sandstone is a fine to medium-grained fairly well consolidated dolomitic sandstone. In the Milwaukee area it is an important source of water to wells. The sandstone aquifer lies between the base of the Maquoketa Group and the top of the Precambrian basement.

The aquifer is recharged:

1) By direct precipitation and movement of water through the aquifer of the Maquoketa Group outcrop;

2) From downward movement of groundwater across the Maquoketa Group; and

3) Through wells open to the overlying dolomite and the sandstone aquifer.

The Silurian aquifer overlies the Maquoketa Group and includes all formations of the Silurian System. The aquifer is recharged by vertical seepage of surface waters and precipitation through surficial deposits.

The groundwater in the sandstone aquifer is under confined conditions and its potentiometric surface is above the confining Maquoketa Group. The potentiometric surface of the aquifer slopes towards Lake Michigan at an approximate gradient of 4.50 feet / mile. The storage coefficient of the sandstone aquifer is about 0.0004 (unitless).

4.4.2 Hydrogeology of Unconsolidated Sediments

Precipitation in the Lake Michigan Basin area accounts for nearly all the water entering the area. Seasonal change in the amount of water storage of surface and groundwater resevoirs occurs within the basin but on the average is not significant. The general groundwater flow direction is from the west to the east towards Lake Michigan.

The Pleistocene glacial and Holocene alluvial deposits of the Quaternary System contain sands and gravel which can locally be important sources of groundwater.

The primary source of groundwater recharge to the sand and gravel aquifer is downward percolation of precipitation (6,7) and downward percolation of surface water from streams. Recharge in the Milwaukee County area is generally between 48,000 and 191,00 gallons per day per square mile.

4.5 Near-Surface Soil Conditions

Information concerning soils of the site was obtained from the Milwaukee County soil survey (8). Undisturbed near surface native soils on-site are classified as being part of the Ozaukee-Morley-Mequon Association. This association is found in glaciated uplands where the soils formed a thin layer of loess and the underlying glacial till. The association extends westward from Lake Michigan. It consists of a narrow beach sand and intermittent clay bluffs and of gently sloping to rolling morainic ridges that roughly parallel the shoreline. The ridges rise progressively higher toward the western edge of the association. Members of the association found on-site include the Ozaukee and Mequon silt loams and Askum silty clay loam. The Ozaukee and Mequon silt loams developed in the topographical highs of the property, whereas the Askum silty clay loam developed within the flood plain deposits along Lincoln Creek.

The Ozaukee soil series consists of well-drained and moderately well drained silty soils that have a silty clay loam and silty clay subsoil underlain by calcareous silty clay loam glacial till. The tills are described in Table 4.2. These soils occupy the convex side slopes of glacial moraines in the northern half of Milwaukee County. The Ozaukee soils have moderately slow permeability and high available water capacity. The Mequon soil series are somewhat poorly drained silty soils that have a sitly clay subsoil underlain by calcareous silty clay loam glacial till. These soils are on the concave side slopes of drainageways and in slight depressions in the northern part of Milwaukee County. The Mequon soils have moderately slow permeability and high available water capacity. The Ashkum series includes poorly drained, silty soils underlain by calcareous silty clay loam glacial till in drainageways and depressions. These soils are on ground moraines in Milwaukee County. The Ashkum series soils have moderately slow permeability and high available water capacity. These soils occur with well drained or moderately well drained Morley and Ozaukee soils.

SECTION V. FORMER WHITEFISH BAY DEMOLITION LANDFILL

5.1 Site Description

This former landfill property occupies approximately 14 acres of land at 5201 West Good Hope Road in the City of Milwaukee. The property is divided by Lincoln Creek and includes a small triangular portion located east of Lincoln Creek and a larger rectangular portion located west of Lincoln Creek. The property locations is described as being in part of the NE 1/4 of the NW 1/4 of Section 23, Township 8 North, Range 21 East, City of Milwaukee, Milwaukee County, Wisconsin. The site is bordered by West Good Hope Road to the north, Presidio Apartments to the west, Webster Middle School property to the south, and the former Superior Irrigation property to the east. This property is for sale and is surrounded by a chain link fence with buildings to the north along Good Hope Road and large lot to the south which is mostly empty (Figure 3.1).

5.2 Project Background

The subject property was purchased by the Village of Whitefish Bay in 1960 and was used for the disposal of incinerator ash and demolition wastes from approximately 1962 to 1972. Reportedly, landfill operations only occurred on land located on the west side of Lincoln Creek. However, the limits of the landfilling operations were not well defined and recent investigations show evidence of demolition material on both sides of the creek. In 1980, the landfill was capped with 1 to 2 feet of compacted clay, covered with topsoil, and seeded with grass, trees, and shrubs. The site is currently unoccupied.

STS Consultants, Ltd. (STS) was retained by the Village of Whitefish Bay to perform a site assessment of the property for potential environmental contamination (9). Between 1986 and 1995 STS performed soil borings and installed monitoring wells MW-4 through MW-27 at and around the landfill property. The results of their investigation indicated chlorinated and petroleum VOCs were present in some portions of the soil at the site. Groundwater was impacted with these contaminants in some areas with the highest concentrations in the southwest corner of the site (9, 16). Sigma Environmental Services installed well nests MW-A/PZ-A through D and monitoring well MW-E on-site in 1997. Soil and groundwater quality test results were generally similar to previous results (16).

5.3 Topography and Surface Water Drainage

The landscape consists of glacial landforms left by the advance and retreat of glaciers. Moderate relief and a gently undulating surface is typical of ground moraine. The topography of the western portion of the site is relatively flat to the north and generally slopes to the southeast, with a rise in the elevation on the south central portion of the landfill. Berms constructed for flood control parallel Lincoln Creek in the center of the property. Ground surface on the eastern side of the property slopes to the southwest towards the creek. Topographic relief across the site has been affected, to varying degrees, by human activities. Elevation at the project site is in the range of 700 feet, MSL. The stream elevation of Lincoln Creek is approximately 687 feet, MSL. Surface water drainage appears to be towards Lincoln Creek from both portions of the site. Stream levels in Lincoln Creek itself can fluctuate on the order of several feet throughout the year, depending upon the severity of rainfall events in the Lincoln Creek recharge basin.

5.4 Site Geology

The geology of the site is described using geologic data gathered from previous site investigations and soil borings performed at the site in May of 1998. Locations of geologic cross sections A-A' to E-E' are shown in Figure 5.1 and described in Figures 5.2 to 5.6.

In review of data gathered during various investigations since 1986 and examination of geologic cross-sections of the site, it appears that five stratigraphic units have been identified at the referenced site (9). The five stratigraphic units consist of fill material, fluvial deposits, glaciofluvial deposits, glacial till, and bedrock. A brief description of each unit is described in descending order below.

5.5 Soil Stratigraphy

Due to berm construction and the prior use of the property as a demolition landfill, fill material has greatly altered the topography across the site. In the far western portion of the property, numerous exposed piles of broken concrete and asphalt debris were noted during a visual inspection of the site. The remainder of the landfilled portion of the property appears to be covered with fill material composed of a mixture of silty clay, topsoil, and gravel. Numerous borings performed within the landfilled areas east and west of the creek (especially cross-sections D-D' and E-E') document the extensive presence of colored broken glass, plastic, wood, and construction/demolition material within the silty clay fill matrix. Visual observation indicates the suspected presence of fill material east of the creek also. The western portion of the fill material ranges in thickness from two to approximately ten feet below grade.

Information concerning soils of the site was obtained from the Milwaukee County soil survey (8). Undisturbed near surface native soils on-site are classified as being part of the Ozaukee-Morley-Mequon Association. Members of the association found on-site include the Ozaukee and Mequon silt loams and Askum silty clay loam. These soils consist of well-drained to poorly drained silty soils that have a silty clay loam and silty clay subsoil underlain by calcareous silty clay loam glacial till.

The near surface soils at the site are underlain by the Oak Creek Formation. The Oak Creek Formation consists of silty clay till and glaciofluvial sand and gravel deposited in front of the Lake Michigan Lobe during late Wisconsinan time.

In soil borings performed west of Lincoln Creek, fluvial deposits consisting of clayey silts / silty clays with trace sand, gravel and organics were found to extend to approximately six foot below grade (cross-section C-C'). These deposits are attributed to recent fluvial deposits from Lincoln Creek (9).

Underlying the fill material and the fluvial deposits is a widespread layer of glaciofluvial deposits (cross-sections A-A' and B-B'). The glaciofluvial deposits are composed of various layers of silty sand and clay with interbedded seams of sandy gravel. Thickness of this stratigraphic unit ranges from zero feet east of Lincoln Creek to greater than twenty feet west of the creek channel. This unit appears to be the major unstratified groundwater bearing unit present at the site. These deposits are interpreted as the glaciofluvial deposits of the Oak Creek Formation.

Glacial till of the Oak Creek Formation was found underlying the glaciofluvial deposits across the site. The till consists of brown to gray, silty clay underlain by silty, gravelly sand. This unit was encountered at approximately eight feet below grade on the eastern portion of the Whitefish Bay property and at a depth of greater than forty feet in the western portion in soil boring B-22. The overlying silty clay seem to act as a confining layer for the more porous gravelly sand. Towards the western border of the site and beyond this confining layer appears to become discontinuous and the upper and lower aqifers are joined, as evidenced by groundwater elevations of monitoring wells in this area. Based on the findings of soil boring B-22, performed by STS consultants, dolomitic limestone bedrock of the Niagara Formation is found underlying the unconsolidated formations at approximately 640 feet MSL.

5.6 Site Hydrogeology

Hydrogeology of the site is assessed in view of geologic data gathered from March through July of 1998.

The first round of groundwater elevations of the monitoring wells on-site were taken on March 27, 1998. Measurements were taken for all of the on-site wells with the exception of MW-24S and MW-24D of which keys were not available. These wells are far to the west of the former landfill area and were not considered important for the interpretation of groundwater flow in the vicinity of Lincoln Creek. Groundwater measurements were also taken when selected on-site wells were sampled (April 29-30, 1998). Groundwater elevation contours are shown in Figures 5.7 and 5.8. A round of groundwater mesurements was also taken on May 15, 1998 for the newly installed monitoring wells. The latest round of groundwater elevation measurements was taken on July 15, 1998 and are contoured in Figures 5.9 and 5.10. The several rounds of data provide information about fluctuations in groundwater levels during a wet season (March-May), and during a dry season (July). It should be noted that some of the recent wells were not installed until after the first round of elevation data was taken, and therefore are not shown in the wet season figure.

Through the interpretation of groundwater elevation data and soil profiles it appears that groundwater at the site is divided into a shallow, near surface shallow and deep aquifers. The two aquifers are separated by a confining layer throughout most of the site. The average depth of groundwater in the shallow aquifer during the wet season is 9 feet below grade. During the dry season it is approximately 13 feet. The average depth of groundwater in the deep aquifer during the wet season is 15 feet below grade. During the dry season it is approximately 17 feet. The average seasonal change in elevation for wells in the shallow aquifer was 3.6 feet, with the largest drop in W-MW-2S (6.48 feet), and the smallest drop in W-MW-4S (1.56 feet). The average seasonal change in elevation for wells in the deep aquifer was 1.8 feet, with the largest drop in W-MW-18 (2.92 feet), and the smallest drop in W-MW-25 (1.44 feet).

Groundwater elevation data are included in Table 5.1 Groundwater data collected on March 27 and July 15, 1998 were used to plot the groundwater contours for both aquifers in each season and are included in Figures 5.7 through 5.10.

The data taken from the monitoring wells intersecting the shallow aquifer indicate that the groundwater surface at the site is generally sloping in an eastern direction towards Lincoln Creek. On the eastern part of the site in proximity to the creek the flow is west towards the creek. During the dry season a groundwater elevation low was in the area of W-MW-C, with groundwater flowing from the east and the west to this low. With the average elevation of the creek being 687 feet, MSL, and the groundwater contour in this area being several feet lower, it appears that Lincoln Creek in the area of the former Whitefish Bay Demolition Landfill is a losing stream. The recharge of the groundwaterfrom this area may result in increase in leachate generation. The recharge of the landfill is an environmental concern that may need to be addressed during design.

It does not appear, however, that the amount of stream water which infiltrates has any noticible effect on the groundwater table of the area. Of the wells installed as piezometer wells, groundwater flow is indicated as sloping towards the southern center of the site, in the area of W-MW-11 and W-MW-C. The gradient from the south and east is relatively gentle, from the north moderate, and from the west steep. Groundwater elevations (7/15/98) at the site range from 690.83 feet in monitoring well MW-E to 680.86 feet in W-PZ-B.

The hydraulic gradient of the shallow aquifer in the direction of predominant groundwater flow toward the creek is approximately 0.016 feet/foot. Using a hydraulic gradient of 0.016, an effective porosity of 0.2 and an average hydraulic conductivity of 6.5×10^{-6} ft/second, the velocity of groundwater flow in an eastern direction is approximately 16 feet per year.

The hydraulic gradient of the deep aquifer in the direction of predominant groundwater flow is approximately 0.002 feet / foot. Using a hydraulic gradient of 0.002, an effective porosity of 0.3 and an average hydraulic conductivity of 9.7×10^{-5} ft/second, the velocity of groundwater flow to the south central part of the site is approximately 20 feet per year.

Vertical movement of groundwater was also determined. The vertical gradient used was the difference in hydraulic head of a well nest divided by the distance between the centers of the well screens. The hydraulic conductivity of the confining layer (1×10^{-7} ft/sec) was used as well as an effective porosity of 0.2. The average velocity of groundwater flow in a vertical direction is one foot per year. It should be noted that the confining layer is not continuous and vertical recharge is anticipated to be much higher.

5.7 Groundwater Quality Assessment

A summary of the test results of the groundwater samples taken during wet and dry periods in 1998 is included in Table 5.3 along with selected 1996 and 1997 historical data for the parameters found in 1998. Because of limited nature of data, site specific ES and PAL could not be established. The default ES and PAL were used for interpreting the test results. The recent test results indicate detection in one or more of the wells of iron, manganese, arsenic, chloride, nitrate, sulfate, 1,2-dichlorethelene, tetrachloroethylene and vinyl chloride in levels that exceeded the respective Enforcement Standard (ES). Also the test results indicated the presence of barium, selenium, 1,1-dichloroethylene, benzene and trichloroethylene above their respective Preventive Action Limit (PAL). These elevated levels of chemical constituents in the groundwater and their interrelation with the surface water quality in the Lincoln Creek is discussed below.

Near Surface Groundwater Quality

The monitoring wells in the shallow zone (with screen length of 10 feet and screened between 3 to 15 feet bgs) include W-MW-1S, W-MW-2S, W-MW-3S, W-MW-4S, W-MW-5S, W-MW-A, W-MW-B, W-MW-C. Of these, W-MW-A, W-MW-B, W-MW-1S, W-MW-3S and W-MW-4S are located within 200 feet of the center line of Lincoln Creek and in our opinion, may therefore have more impact on Lincoln Creek water quality than wells further away. Each of these wells are impacted by one or more of the indicator parameters. A maximum iron concentration of 23,000 µg/L was documented in W-MW-6 in the wet season sampling. Manganese at 2600 µg/L was recorded in W-MW-C. Highest level of vinyl chloride was noted in W-PZ-C. Historically, very high levels of vinyl chloride (8700 µg/L in W-MW-27) was also documented in the Western side of the landfill.

During wet season testing in April and May, the following wells were found to have levels higher than ES or PAL:

W-MW-A	Iron and manganese (ES); barium and arsenic (PAL)
W-MW-B	Iron and manganese (ES); chloride and sulfate (PAL)
W-MW-1S	Manganese, nitrate and sulfate (ES); selenium (PAL);
W-MW-3S	Manganese (ES)
W-MW-4S	Manganese (ES); sulfate (PAL)

During the dry season testing in July, ES and PAL levels were exceeded in the following wells:

W-MW-A	This well was not sampled
W-MW-B	Manganese (ES); iron was the only other listed parameter tested
W-MW-1S	This well was not tested for these parameters
W-MW-3S	Manganese (PAL); this well was not tested for the other parameters listed
W-MW-4S	Manganese (ES); this well was not tested for the other parameters listed

The historic data for the two shallow wells that existed at that time (W-MW-A and W-MW-B) close to the creek shows that vinyl chloride levels were below the detection limit of <0.23 μg/L in June 1997.

None of these wells had vinyl chloride above detection limits during either the wet season or dry season sampling. It may be noted that the detection limit of 0.52 μg/L for vinyl chloride is higher than the ES of 0.2 μg/L set forth in WAC NR 140.

Among the wells located at more than 200 feet away from the center line of the creek, W-MW-5S, and W-MW-C had vinyl chloride above the ES of 0.2 μg/L. Among the wells sampled, the highest level (22 μg/L) of vinyl chloride was noted in the monitoring well MW-5S in the wet season (April 1998) sampling round. These wells are also impacted by one or more of indicator parameters. Reportedly, remediation of groundwater in the western portion of the landfill is planned (16).

Groundwater Quality in Deeper Zone

The piezometers in the deeper zone (with screen length of 5 feet and screened between 15 to 30 feet bgs) include W-MW-4D, W-MW-6, W-PZ-A , W-PZ-B and W-PZ-C. Of these, W-PZ-A, W-PZ-B, W-MW-4D, and W-MW-6, located within 200 feet from the center line of Linoln Creek, may have more impact on Lincoln Creek water quality than the wells further away. Each of these wells are impacted by one or more of the indicator parameters.

During the wet season testing in April, ES and PAL levels were exceeded in the following wells:

W-PZ-A	Iron, manganese (ES); chloride, benzene (PAL)
W-PZ-B	Iron, manganese (ES); chloride (PAL)
W-MW-4D	Iron, manganese, chloride (ES); arsenic, nitrate (PAL)
W-MW-6	Iron, manganese, arsenic, vinyl chloride (ES); barium, chloride (PAL)

During dry season testing, the following wells were found to have levels of contaminants higher than ES and PAL:

W-PZ-A	Iron, manganese (ES); Other parameters were not analyzed
W-PZ-B	Manganese (ES); iron below detection limit. Other parameters not analyzed
W-MW-4D	Manganese, chloride (ES); barium, selenium, arsenic, nitrate, sulfate not analyzed. Other parameters are below detection limits or PAL
W-MW-6	Manganese, vinyl chloride (ES); iron (PAL); barium, selenium, arsenic, chloride, nitrate, sulfate not analyzed. Other parameters are below detection limits.

The historic data for the parameters detected in deeper wells in 1998 is limited. Groundwater samples were analyzed for vinyl chloride from W-PZ-A and W-PZ-B only. The data shows that vinyl chloride level exceeded the ES in W-PZ-A. Vinyl chloride was not detected in W-PZ-B.

Of the piezometers sampled, W-PZ-C was the only deep well located at more than 200 feet away from the center line of the creek. During wet season sampling in April 1998, 1,2-dichloroethylene, trichloroethylene and vinyl chloride were detected at levels exceeding the respective ES. The levels of Chloride, sulfate, and 1,1-dichloroethylene exceeded the respective PAL. Barium, selenium, iron, maganesearsenic, chloride, benzene and tetrachloroethylene were either not detected or were below the respective PAL.

During dry season sampling in July 1998, barium, selenium, iron, manganese, arsenic, nitrate, sulfate, were not analyzed. Of the parameters tested, 1,1-dichloroethylene, benzene, and tetrachloroethylene were not detected. 1,2-dichloroethylene and vinyl chloride levels exceeded the ES. Trichloroethylene exceeded the PAL. Historical data for this well included the test result for vinyl chloride only for the groundwater sample collected in June 1997. The level of vinyl chloride was 150 µg/L.

Groundwater Contamination Assessment

For studying the nature of vertical movement of contaminants in the study area, test results of the shallow and deep well combinations, W-MW-A and W-PZ-A, W-MW-4S and W-MW-4D, W-MW-B, W-PZ-B and W-MW-C and W-PZ-C were compared. The shallow and deep wells in each nest are located close to each other.

For the wet season samples from W-MW-A and W-PZ-A, which are in the well nest closest to Lincoln Creek, the concentrations of barium, iron, manganese, and sulfate were lower in the deeper well than in the shallow well. However, the concentrations of chloride and 1,2-dichloroethylene were relatively higher in the deeper well. Other parameters were not detected in both the shallow and deep wells or were below PAL. Wet season test results for W-MW-4S and W-MW-4D, W-MW-B and W-PZ-B, and W-MW-C and W-PZ-C, further from Lincoln Creek, also indicate the same trend. Test results of dry season sampling are not available for similar comparison. These wet season trends of low concentrations in deeper wells in relation to the shallow wells at the same location need to be verified with the corresponding trend in the dry season, with future testing.

Groundwater flow in this area is generally towards the creek. The possibility was investigated that the wells closer to the creek may be impacted by the contamination prevailing in the landfill area, which in turn may impact the water quality in Lincoln Creek. However, as it approaches the creek, the groundwater appears to be recharged under both the wet and dry season conditions, as is shown schematically on Figure 5.14. This will essentially mitigate the migration of contaminants from the landfill to the creek. It appears that the shallow groundwater recharges the lower aquifer and the overall groundwater flow in the landfill area is to the south.

Dissolved iron (23000 µg/L in W-MW-6) and manganese (2600 µg/L in W-MW-C), which are indicator parameters, were detected above the ES in several wells at the site. Concentrations for these parameters were higher during the wet season than the dry season. Although dissolved iron and manganese do not pose a health risk, the elevated levels detected do suggest that the landfill has affected an area close to and in some sections within the proposed flow width of Lincoln Creek.

Groundwater contamination contours were drawn for vinyl chloride (Figure 5.11), iron (Figure 5.12) and manganese (Figure 5.13) on the basis of the test results of the April 1998 groundwater sampling. The maximum concentration of vinyl chloride of 230 μg/L was observed in W-PZ-C. The maximum concentration of iron of 23,000 μg/L was noted in W-MW-6. As stated above, maximum concentration of 2600 μg/L for manganese was noticed in W-MW-C. Among these constituents, the migration of vinyl chloride with a PAL of 0.02 μg/L and ES of 0.2 μg/L and its likely impact on the creek was considered most critical. Therefore, vinyl chloride was chosen for contaminant transport modeling.

5.8 Surface Water Quality Assessment

A summary of surface water quality test results of Lincoln Creek as it passes through the former landfill property from samplings performed in 1998 is included in Table 5.3. Sampling of the creek as it enters the property (W-SW-1) and as it exits the property (W-SW-2) was done in April and July of 1998.

Dissolved iron, manganese and chloride were detected in W-SW-1 and W-SW-2 during the first round of sampling performed in the wet season of April 1998. The concentration levels, however, were very much lower than those encountered in the monitoring wells near the creek. The concentration of iron in the upstream sample (370 μg/L) was higher than the ES of 300 μg/L. The chloride levels in both the upstream and downstream samples exceeded the PAL of 125 μg/L during April 1998 round of sampling. In the second round performed in July 1998 (dry season), manganese and iron were analyzed with iron concentrations being less than the detection limit. Manganese was above the PAL for both the first and second rounds. Chloride was not analyzed in the July 1998 round of sampling.

Only one VOC was detected for upstream and downstream samples collected in both rounds. 1,2 dichloroethylene was detected below the PAL in the downstream sample for both rounds of sampling.

Based on the test results, which show the incoming creek water containing higher levels of most contaminants than outgoing creek water, it does not appear that the landfill has any effect on the surface water the quality of the creek within the study area of the Whitefish Bay Demolition Landfill. The detection of elevated level of iron and manganese in the upgradient direction indicates that other sources upgradient of the study area may have contributed to the surface water contamination. As the surface water quality was much improved during the dry season sampling, the source of contamination couldalso be surface water run-off. This observation may have to be verified by additional sampling.

5.9 Landfill Delineation

Based on information obtained during the visual inspections, previous investigations, geophysical survey and geoprobe borings, the following observations are made concerning the limits of the landfill areas. The full report, along with figures, is included in Appendix I.

The landfill limits appear to extend into the existing flood conveyance channel between station 502+00 and station 507+00 on the west side of Lincoln Creek. Singh believes that the removal and/or management of soil/solid waste will require a WAC NR 500.08 exemption.

There may be a need for development and implementation of environmental repair program consisting of placement of cap on the exposed waste as per WAC NR 500 requirements.

The landfill limits appear to approach within 50 feet of the Lincoln Creek centerline between station 502+00 and station 504+00 on the east side of Lincoln Creek. The management of soil/solid waste may require WAC NR 500.08 exemption. There may be a need for development and implementation of an environmental repair program consisting of placement of a clay cap on the exposed waste as per WAC NR 500 requirements.

No evidence was found that the landfill limits approach within 100 feet of the center of the creek between stations 498+00 and 502+00, on either side of the creek. It does not appear that the management of soil/solid waste within this reach would require an NR 500.08 exemption.

Based on visual inspection, geophysical survey data, soil borings and discussions with a representative of the former Superior Irrigation property, Singh believes that potential landfill encroachment exists north of the study area on both sides of the creek. A study similar to the current one is recommended to extend to station 511+00 on both sides of Lincoln Creek.

The proximity of landfilled material to the Lincoln Creek flood channel has had some impact on soil and groundwater quality in this area. Elevated levels of dissolved iron and manganese are indicative of an environment affected by landfilled material. There may be a need for development and implementation of an environmental repair program to manage any affected areas along Lincoln Creek.

5.10 Groundwater Modeling

The presence of vinyl chloride above the ES level set forth in WAC NR 140 in the monitoring wells W-MW-5S, W-MW-6, W-MW-C and W-PZ-C is considered critical for its impact on the water quality of the creek. An assessment of the migration potential of the contamination was, therefore, performed using BIOSCREEN model (Appendix J). Based on the vinyl chloride concentration contours (Figure 5.11), two contaminant plumes of 200 µg/L and 10 µg/L were considered for analysis. Distances from the leading edges of these plumes to the point of concern, chosen at the highwater level of the creek, were measured along the groundwater flow path. The concentrations of vinyl chloride at different times were computed using the the BIOSCREEN model. The concentrations resulting from both the contamination plumes were added to obtain the combined effect of both the plumes.

For contaminant transport modeling, a constant source has been used in the original BIOSCREEN model. However, as there is no ongoing release of contaminant into sub-surface environment, the source has been modeled as a declining one. The source receives contaminant from the unsaturated zone as the contaminants from the soil mix with water as it percolates through the soil matrix during groundwater recharge. The source attenuation model is described in Attachment A-1 of Appendix J. The results of source attenuation analysis for the two contaminant plumes of the model are described in Figures 1 and 2 of Attachment A-1. The parameters for the source attenuation analysis are listed in Tables 1 and 2 of Attachment A-1. The source can be approximated as an exponentially decaying source. The source attenuation rates for vinyl chloride were 0.537 and 0.520 per year, for 200 µg/L and 10 µg/L plumes, respectively.

The transport processes for vinyl chloride in the groundwater have been modeled using a modified BIOSCREEN model. The model is described in more detail in Attachment A-2 of Appendix J. The contaminant transport model for the saturated zone is developed assuming the first order biodegradation rate constant to be zero. A first order rate constant of 0.00024 per day is normally used for the degradation of vinyl chloride. The zero value for the rate constant is assumed for worst case scenario.

The results of the modeling are included in Table 5 and Figure 3 of Attachment A-2. The parameters used in the modeling are summarized in Tables 3 and 4 of Attachment A-2. Based on the first order reaction rate model, a maximum concentration of 0.06 μg/L for vinyl chloride was reached in five years at the point of concern near the creek (Table 5 of A-2 and Figure 5.11). This vinyl chloride level is below the ES of 0.2 μg/L set forth in WAC NR 140. The concentration of vinyl chloride is expected to reach below the PAL of 0.02 μg/L within twenty-five years. However, due to the fact that the groundwater flow direction very close to the creek is from the creek to the landfill, the potential for contaminant migration to the creek is minimal. If the hydraulic gradient during the construction does not significantly change, there may not be any need for taking measures to protect the creek from contaminants in the landfill.

5.11 Regulatory Considerations

The results of the contaminant transport modeling and site hydrogeology suggest that migration of vinyl chloride from the landfill to the point of concern near the creek is minimal. No action to isolate the creek from the landfill has been suggested, unless the excessive generation of leachate by recharge of the aquifer becomes a concern or the construction activities significantly alter the site hydrogeology near the creek.

Landfill delineation has also indicated that the landfill limits appear to extend into certain sections of the existing flood conveyance channel of Lincoln Creek. The potential for migration of groundwater contamination into the creek, therefore, exists. Development and implementation of an environmental repair program consisting of placement of a cap on the exposed waste as per WAC NR 500 requirements seems to be necessary in those sections of the creek. Details of conceptual design for isolating the creek from the landfill are discussed in a later Section VIII.

Based on the groundwater quality for of the samples collected from the monitoring wells and peizometers, it appears that a corrective action for the groundwater at the landfill may be warranted. The corrective action may consist of active remediation, remediation by natural attenuation processes, or a combination of the two. As a part of the corrective action a plan for long term monitoring of groundwater may be required.

5.12 Summary of Groundwater Impact

The quality of water in the Lincoln Creek has been evaluated during the wet and dry season as it passes through the former Whitefish Bay Demolition Landfill. Water samples were collected from Lincoln Creek at upstream and downstream locations as it passes through the landfill during the April 1998 and July 1998 sampling rounds. Several water samples had exceedance of ES or PAL with respect to iron, manganese, and chloride.

Based on the water quality of the upstream and downstream samples collected from the Whitefish Bay landfill area of the Lincoln Creek, it appears that the landfill does not have any adverse effect on the water quality of the creek. Level of dissolved iron in excess of ES and that of manganese and chloride in excess of PAL in the water samples collected during the wet season, suggest that there may be source of these constituents upstream of the study area. Our landfill delineation study suggests that the landfill boundary may extend north of the study area. Improvement in the water quality was noted during the dry season. This may also suggest that the landfill indicator parameters may have entered the stream by surface water run-off. However, the concentration of these landfill indicator parameters in the stream water is not very high and the elevated concentration may be attributed to statistical fluctuations.

Figure 5.14 is a stream cross section (F-F') of Lincoln Creek at the Former Whitefish Bay Demolition Landfill area. Shown are the groundwater table elevations for the wet and dry seasons in selected monitoring wells near the creek, along with an indication of probable seasonal recharge from the creek. Also shown are the average elevations of the stream during the dry season, the estimated 100 year flood elevation, and the average stream elevation for the year. The elevated water level in the creek during the 100 year flood may result in very high hydraulic gradient near the creek. This will result in excessive groundwater flow towards the landfill, resulting in an increased leachate generation rate. However, such condition will be transient and of short duration and may not pose a major concern. If the leachate generation is considered a significant problem, it can be resolved by properly lining the sideslopes. A proper landfill cap, consistent with the requirements of the WAC NR 500, would also help to address the leachate generation issue.

The elevation of surface water in the creek was found to be higher than those in the monitoring wells located close to the creek during both the wet and dry season. This would essentially prevent migration of landfill contaminants from entering into the creek. This may be a major factor in mitigating the contaminant transport from the landfill to the creek. During the proposed construction, if the surface water elevations do not substantially change, the effect of the landfill on the water quality of the creek appears to be minimal, if any. However, if the stream elevation is lowered to the point that it intersects the groundwater table, the stream may have to be isolated to prevent any infiltration of contaminants through the groundwater to the creek.

VIII. CONCEPTUAL DESIGN

8.1 Water Quality Along Lincoln Creek

The quality of water in the Lincoln Creek has been evaluated during the wet and dry season as it passes through three landfills. Water samples were collected from the Lincoln Creek at upstream and downstream locations at three landfills during April 1998 and July 1998 sampling rounds. Several water samples had excedances of ES or PAL with respect to vinyl chloride, iron, manganese, chloride, arsenic, and, to a lesser degree, other parameters. The water quality in the creek with respect to these parameters is summarized in Figure 8.1.

Based on the water quality of the upstream and downstream samples collected from the Whitefish Bay landfill area of the Lincoln Creek, it appears that the landfill does not have any adverse effect on the water quality of the creek. Levels of dissolved iron in excess of ES and that of manganese and chloride in excess of PAL in the water samples collected during the wet season suggest that there may be source of these constituents upstream of the study area. Our landfill delineation study suggests that the landfill boundary may extend north of the study area. Improvement in the water quality was noted during the dry season. This may also suggest that the landfill indicator parameters may have entered the stream by surface water run-off. However, the concentration of these landfill indicator parameters in the stream water is not very high and the elevated concentration may be attributed to statistical fluctuations.

The elevation of surface water in the creek was found to be higher than those in the monitoring wells located close to the creek during both wet and dry season. This would prevent migration of landfill contaminants from entering into the creek. This may be a major factor in mitigating the contaminant transport from the landfill to the creek. As a result of the a proposed construction, if the surface water elevations do not substantially change, the effect of the landfill on the water quality of the creek appears to be minimal, if any. However, if the landfill material is exposed during the realignment of the creek, the exposed area needs to be capped as per requirements of WAC NR 500. If the creek channel is lowered, its relationship to the groundwater may have to be reexamined.

As the creek reaches the Havenwoods landfill, its water quality remains substantially unchanged, except that arsenic was noted above PAL. However, the water quality deteriorates at the downstream at the point where it leaves the Havenwoods landfill. The deterioration in water quality is more evident in the wet season when the concentration of vinyl chloride and manganese increased to above their respective ES levels as compared to below detection limit and above PAL levels, respectively. During the dry season the change in water quality is very small and may be attributed to statistical fluctuations.

The groundwater elevation near the creek was found to be below the surface water in the creek during the dry season, but the groundwater elevation was generally higher during the wet season. The positive gradient between groundwater and surface water during the wet season may facilitate movement of contaminants towards or out of the landfill. However, it should be noted that the predominant flow direction of the groundwater is to the south. Concentrations of vinyl chloride, arsenic, iron, and manganese in excess of ES were noted in some of the monitoring wells located close to the creek. This may contribute to deterioration of water quality in the downgradient direction with respect to vinyl chloride, iron, and manganese during the wet season and may suggest need for some kind of corrective action in at least the southern part of the landfill. Lowering of the creek channel this area could increase the groundwater impact on creek quality.

The groundwater quality remains substantially the same as the water enters the USARC Landfill area. Only deterioration in arsenic was noted at that point. The increase in arsenic concentration was more pronounced in the sample collected during the wet weather. The deterioration in water quality was more pronounced with respect to indicator parameters iron and manganese during the wet season. During the wet season in one particular area of the landfill, seep was found to be flowing from the landfill to the Lincoln Creek. The seep had concentrations of iron and manganese an order of magnitude higher than that noted in the upstream sample. There was not a significant change in concentrations of vinyl chloride, chloride, and arsenic in the downgradient sample as compared to those in the upgradient sample. It should be noted that the seep from the landfill is intermittent and was found to be dry during the dry weather sampling.

It appears that the water quality is deteriorated by the migration of contaminants from the landfill. One source of seep was visually noted, there may be others which are not noticeable. The seepage of contaminants from the landfill substantially changes the water quality of the creek. However, based on the upstream and downstream samples collected, it does not appear that the water quality is deteriorated with respect vinyl chloride, chloride, and arsenic.

Interaction of landfill with the creek, as the seep enters the creek from the landfill to the creek, needs to be addressed to protect the creek from landfill contaminants. Corrective action needs to address this issue. As in the case of the Havenwoods landfill, the groundwater elevations in the monitoring wells closer to the creek are higher than the surface water in the creek during the wet season. During the dry season, the groundwater elevations are lower in the monitoring wells as compared to surface water elevation in the creek. During wet weather the migration of contaminant from the landfill to the creek may be facilitated. However, it should be noted that the predominant flow direction of the groundwater is to the south. Lowering of the creek channel in this area could increase the groundwater impact on creek quality.

8.2 Design Considerations For Protecting Lincoln Creek From Contamination

Lincoln Creek appears to have been affected to some extent by contaminants from the Havenwoods and USARC landfills. The section of Lincoln Creek along the USARC landfills seems to have vinyl chloride, dissolved iron, and dissolved manganese at levels exceeding enforcement standards for the respective constituents as per WAC NR 140. The portions of the creek that run adjacent to the Havenwoods and USARC landfills seem to be affected by indicator parameters, such as iron and manganese, from the landfills. At the Havenwoods and USARC landfills, the stream is also affected by vinyl chloride. The impact of the landfills on stream water quality and the groundwater quality in adjacent monitoring wells warrant the need for some engineering measures along the bed and sides of the creek in order to prevent contaminant migration from the leachate/groundwater from the landfills.

Conceptually, encroachment of groundwater/leachate from the landfills into the creek can be prevented by lining the bed and the sides of the creek appropriately. This approach will essentially isolate the surface water in the creek. The liner must have low permeability to mitigate the flow of contaminated groundwater into the creek. Four types of liners for the creek may be considered in the conceptual design.

1. Lining of the creek bed and side slopes with concrete structure.

2. Lining of the creek bed and side slopes with compacted clay and geomembrane.

3. Lining of the creek bed and sides with geosynthetic clay liner (GCL).

4. Compacted clay liner (CCL) and geomembrane on the sides and geomembrane over a layer of sand sprayed with bentonite powder on the bed of the creek.

Lining of the creek may have to be done progressively, section by section, as it may involve dewatering of portions of the creek for installation of the lining. The conceptual design of the various lining methods is described below. Detailed engineering design and cost analysis for each of the design are not provided, as they are beyond the scope of this study.

Concrete Lining: The stream bed and the sideslopes of the creek may be lined with concrete, either pre-fabricated or poured in-place, to provide a low permeability barrier between the landfill and the creek (Figure 8.2). From the construction point of view, the pouring of concrete in-place may not be feasible due to presence of water in the creek. Furthermore, the freeze and thaw cycle is likely to develop crack in the concrete structure over time. If the cracks are developed in the concrete structure over time, there may be possibility of contaminant migration into the surface water of the creek. It is anticipated that the cost of installing a concrete liner will be high. Based on the technical merit and cost considerations, this approach was deleted from further consideration.

Compacted Clay and Geomembrane Liner: In this approach it is proposed that the stream bed and sideslopes be lined with compacted clay followed by geomembrane liner (Figure 8.3). The top portion of the sideslope will have a layer of top soil acting as a rooting layer for vegetation. The bottom portion of the sideslope and the bottom of the creek will have a layer of rounded stones to keep the geomembrane liner in place. The thickness and size of the rounded stone will be such that the membrane can not be displaced by hydraulic uplift. The thickness of various layers should be consistent with the requirements of landfill closure as per NR 500 and to maintain structural stability of the liner.

From the construction point of view, the placement and compaction of clay in the stream-bed may not be feasible. It may be possible to temporarily divert the water to place and compact the clay, but this is likely to result in high cost. Furthermore, it does not appear that clay of acceptable quality is available close to the site. In that case the clay will have to be hauled from long distance resulting in high construction cost. Based on these considerations, this approach was deleted from further consideration.

Geosynthetic Clay Liner (GCL): GCL is a prefabricated lining material consisting of bentonite sandwitched between two layers of geomembrane (Figure 8.4). This prefabricated lining material is available in rolls and are spread in the same manner as the conventional geomembranes. These are being adopted in states like Texas, where clay is not available in the proximity of places to be lined. The top portion of the sideslope will have a layer of top soil acting as a rooting layer for vegetation. The bottom portion of the sideslope and the bottom of the creek will have a layer of cobbles to keep the geosynthetic clay liner in place. The cost of such liners may be high. Based on the cost consideration, this approach may not be feasible.

Compacted Clay, Sand, and Geomembrane Liner: In this approach it is proposed to line the upper portion of the side-slope of the creek with clay. The lower portion of the sideslope and the bottom of the creek are proposed to be lined with sand and sprayed with bentonite. The sand and bentonite layer has the advantage that it does not have to be compacted and it can be installed in the wet condition. The compacted clay and clay-bentonite layers are proposed to underlie a geomembrane layer. The sand layer is not expected to mitigate the vertical migration of the contaminants. In this particular instance a thicker 60 mil geomembrane can be used as compared to 40 mil geomembrane typically used in landfills. As in the previous case the top of the side-slope of the creek will have a layer of top-soil acting as a rooting zone for the vegetation. The lower side-slope and bottom of the creek are proposed to be lined with rounded stones to keep the geomembrane in place. The thickness of the stone layer will be determined by the hydraulic uplift on the geosynthetic liner and to maintain structural integrity of the liner.

This approach is likely to overcome some of the difficulties associated with actual installation of second approach. Use of sand is also likely to result in some cost savings. It is also likely to be most cost effective of the four approaches discussed. Based on the construction logistics and cost, this approach appears to be preferred one for the lining of the creek.

Design and detailed specifications and construction drawings have to be prepared prior to actual construction. Typical cross section of creek liner, as per alternative 4 is included in Figure 8.4. Anchoring of the geomembrane liner on the sides should be done in a manner consistent with the requirements of landfill closure as per NR 500. Also a vegetative surface will need to be maintained to prevent against possible scouring of soil on top of geomembrane. It is suggested that some test pits are performed before implementation of the plan.

8.3 Former Whitefish Bay Demolition Landfill

A summary of groundwater quality test results of the groundwater sampling performed in 1998, indicated the presence of vinyl chloride at elevated levels in some of the wells, at some distance from the creek. The closest monitoring well W-MW-6, at a distance of approximately 140 feet from the creek, has 0.99 ppb of vinyl chloride, which is above the Enforcement Standard (ES) of 0.2 ppb as set forth in NR 140. The level of vinyl chloride in W-PZ-C, at a distance of 260 feet from the creek, is 230 ppb (Figures 5.11). Iron and manganese, which are indicator parameters, were detected above the ES in several wells at the site. Wells W-MW-6, W-MW-A, W-PZ-A, W-MW-B, and W-PZ-B along the creek had the some of highest concentrations on-site (Figures 5.12 and 5.13).

The presence of vinyl chloride, at the levels above the ES in the monitoring wells W-MW-6 and W-PZ-C has the potential for impacting the water quality of the creek. The results of the contaminant transport modeling indicated that a maximum concentration of 0.06 ppb for vinyl chloride could be expected at the point of concern near the creek in 5 years. However, as the groundwater flow near the creek is towards the landfill, the potential for migration of groundwater contamination into the creek is minimal.

Based on these considerations no action is proposed to protect the creek from contaminant migration via groundwater from the landfill.

Based on the positive hydraulic gradient between the creek and the landfill on both sides of the creek during wet and dry seasons, Lincoln Creek in the area of the former Whitefish Bay Demolition Landfill is a losing stream. The recharge of the groundwater from this area may result in increase in leachate generation. Furthermore, the elevated water level in the creek during the 100 year flood may result in very high hydraulic gradient near the creek, resulting in enhanced leachate generation rate. However, such condition will be transient and of short duration and may not pose a major concern. The problem of leachate generation may be adequately addressed by properly lining the sideslopes. A proper landfill cap, consistent with the requirements of the WAC NR 500, would also address the leachate generation issue. The recharge of the landfill is an environmental concern that may need to be addressed during design.

Based on landfill delineation, the landfill boundary comes close to the creek on the western side of the creek and is likely to have effect on the surface water quality of the creek. Concentrations of dissolved iron and dissolved manganese in the monitoring wells located in the vicinity of the creek and concentrations of these constituents in surface water of the creek, it appears that there is interaction between the landfill and the creek. The landfill seems to be affecting the water quality in the creek. In order to provide isolation from the landfill, it may be appropriate to line the creek between Station 497+20 and Station 506+40.

8.4 Havenwoods State Forest Landfill

Groundwater quality test results of the sampling performed in 1998 indicated the presence of Vinyl chloride in excess of the ES (0.2 ppb) in H-MW-6. The surface water quality in the creek has also been affected as downstream water sample H-SW-2 had vinyl chloride in excess of its ES. Historically, vinyl chloride has been detected above the ES in H-MW-6. Groundwater flow is towards the south and southwest, suggesting the possibility of contamination migration onto the U. S. Army property (Figure 6.5). The upstream surface water sample (H-SW-1) from the creek did not show the presence of vinyl chloride. The downstream sample (H-SW-2) had a concentration of 1.5 ppb during wet season sampling. Since 1994, concentrations of vinyl chloride have exceeded the ES in H-MW-6, which is located on the southern side of the property along Lincoln Creek. Lincoln Creek turns to the southwest near H-MW-6, making it very likely that vinyl chloride is migrating into Lincoln Creek, as indicated by the concentration in the sample from H-SW-2. Dissolved iron and dissolved manganese were also found to be at elevated levels in the wells throughout the site along the creek. Arsenic was found above the ES in H-MW-1S and H-MW-2S, and above the PAL in H-MW-4, H-MW-6 and H-MW-7. It was also found in the upstream sample H-SW-1 (Figures 6.6 and Figures 6.7).

Based on the results of contaminant transport modeling, the potential for the migration of vinyl chloride is minimal. However, the presence of vinyl chloride at 1.5 ppb in the creek at H-SW-2 and relatively elevated levels of contaminants in the monitoring wells adjacent to the stream on the south side is considered critical for its impact on the water quality of the creek.

Based on the consideration of the presence of vinyl chloride in the well near the creek and the surface water of the creek, it is recommended that the section of the creek from Station 426+80 to Station 430+90 be lined. This is likely to provide adequate protection to the surface water of the creek from the toxic substances documented to be present in the landfill.

Based on the positive hydraulic gradient between the creek and landfill during the dry season, the recharge of the groundwater from this area may result in increase in leachate generation. Furthermore, the elevated water level in the creek during the 100 year flood may result in very high hydraulic gradient near the creek, resulting in enhanced leachate generation rate. However, such condition will be transient and of short duration and may not pose a major concern. The problem of leachate generation may be adequately addressed by properly lining the sideslopes. A proper landfill cap, consistent with the requirements of the WAC NR 500, would also address the leachate generation issue. The recharge of the landfill is an environmental concern that may need to be addressed during design.

Based on the concentrations of dissolved iron and dissolved manganese in the monitoring wells located in the vicinity of the creek and concentrations of these constituents in surface water of the creek, it appears that there is interaction between the landfill and the creek. The landfill seems to be affecting the water quality in the creek. In order to provide isolation from the landfill, it may be appropriate to line the creek between Station 426+80 and Station 443+90.

SECTION IX. CONCLUSIONS AND RECOMMENDATIONS

9.1 Former Whitefish Bay Demolition Landfill

Based on review of previous site investigations, information obtained during the visual inspections, geo-physical survey and geoprobe borings, hydrogeological investigation, assessment of groundwater quality, and contaminant transport modeling in groundwater the following conclusions and recommendations are made.

- Investigation of the near surface soil and groundwater conditions reveal that the near surface groundwater is divided into a shallow and a deep aquifer. General geology of the site shows that silty clays overlay sandy gravel majority of the site. Hydraulic conductivities for the upper aquifer are on the order of 10^{-4} cm/sec and for the lower aquifer 10^{-3} cm/sec. Groundwater flow for the upper aquifer is towards Lincoln Creek and for the lower aquifer to the south central area of the site just west of the creek.

- High level of halogenated hydrocarbons were found in groundwater samples collected from monitoring wells located in the southwest portion of the landfill property. Based on the site hydrogeology and groundwater transport modeling for vinyl chloride, the migration potential for the contaminant to the flood conveyance channel is minimal. Hence, no action is warranted to mitigate the migration of contaminants from the landfill to the creek via groundwater.

- Groundwater samples collected from the monitoring wells located close to the creek had concentrations of indicator parameters, dissolved iron and dissolved manganese, in excess of their respective ES levels. Water samples collected from the creek also had elevated levels of dissolved iron and dissolved manganese, suggesting that the groundwater from the landfill area is affecting portion of the creek. However, upstream and downstream water samples collected from the creek, suggests that the landfill is not contributing to the deterioration of water quality in the creek.

- The groundwater and surface water quality assessment is based on two rounds of data. It is recommended that additional quarterly monitoring of surface water and wells located within 200 feet of the creek be conducted in order to support the conclusions and to establish a baseline data. It is recommended that such monitoring be conducted till the start of the construction.

- The landfill limits appear to extend into the existing flood conveyance channel between station 502+00 and station 507+00 on the west side of Lincoln Creek. The removal and/or management of soil/solid waste may require an WAC NR 500.08 exemption. There may be a need for development and implementation of environmental repair program consisting of placement of cap on the exposed waste as per NR 500 requirements.

- The landfill limits appear to approach within 50 feet of the Lincoln Creek centerline between station 502+00 and station 504+00 on the east side of Lincoln Creek. The management of soil/solid waste may require NR 500.08 exemption. There may be a need for development and implementation of environmental repair program consisting of placement of cap on the exposed waste as per WAC NR 500 requirements.

- No evidence was found that the landfill limits approach within 100 feet of the center of the creek between stations 498+00 and 502+00, on either side of the creek. It does not appear that the management of soil/solid waste within this reach would require an WAC NR 500.08 exemption.

- There are metal drums, tire rims, steel cylinders, etc. within the creek bed which require removal. This may be performed as a part of WAC NR 500.08 exemption.

- Based on visual inspection, geophysical survey data, soil borings and discussions with a representative of the former Superior Irrigation property, the potential for landfill encroachment exists north of the study area on both sides of the creek.

- It appears that a plan for the management of soil/solid waste will have to be prepared for the management of soil removed from the landfill during widening of the creek. It is recommended that before the actual construction, test pit be dug at selected location to verify the presence of solid waste. The portion of the landfill exposed during widening of the creek will have to be restored as per requirements of WAC NR 500 for landfill closure. Specifically, the side slopes requirements for the final cover of the landfill should be consistent with WAC NR 500.

9.2 Havenwoods State Forest Landfill

Based on review of previous site investigations, hydrogeological investigation, assessment of groundwater quality, and contaminant transport modeling in groundwater the following conclusions and recommendations are made.

- Investigation of the subsurface soil and groundwater conditions reveal that the near surface groundwater is divided into a shallow and a deeper, bedrock aquifer. General geology of the site shows that silty clays overlay interbedded silty, gravelly, sands and clays throughout the site. Bedrock is encountered below these soils. Hydraulic conductivities for the upper aquifer are on the order of 10^{-4} cm/sec and for the lower aquifer 10^{-5} cm/sec. Groundwater flow for the upper aquifer is towards the southwest and for the lower aquifer to the east.

- High level of halogenated hydrocarbons were found in groundwater samples collected from several monitoring wells located on the landfill property. Groundwater samples collected from a monitoring well located southwest of the creek had concentration of vinyl chloride in excess of Enforcement Standard. Surface water collected from the downgradient side of the creek also had concentration of vinyl chloride in excess of ES. Hence, the surface water in the creek seems to have already been contaminated from the contaminants migrating from the landfill. It is recommended that a small section of the creek between Station 426+90 and Station 430+90 be lined in order to protect the surface water from groundwater contaminated with vinyl chloride.

- Groundwater samples collected from the monitoring wells located close to the creek had concentrations of indicator parameters, dissolved iron and dissolved manganese, in excess of their respective Enforcement Standard levels. Water samples collected from the creek also had elevated levels of dissolved iron and dissolved manganese, suggesting that the groundwater from the landfill area is affecting the surface water in the creek. In order to provide complete isolation from the landfill, it is recommended that the creek be lined between Station 426+80 and 443+90.

- The groundwater and surface water quality assessment is based on two rounds of data. It is recommended that additional quarterly monitoring of surface water and wells located within 200 feet of the creek be conducted in order to support the conclusions and to establish a baseline data. It is recommended that such monitoring be conducted till the start of the construction.

- It appears that a plan for the management of soil/solid waste will have to be prepared for the management of soil removed from the landfill during widening of the creek. It is recommended that before the actual construction, test pit be dug at selected location to verify the presence of solid waste. The portion of the landfill exposed during widening of the creek will have to be restored as per requirements of WAC NR 500 for landfill closure. Specifically, the side slopes requirements for the final cover of the landfill should be consistent with WAC NR 500.

Table 3.1
Former Whitefish Bay Demolition Landfill Well Data

Well Number	Elevation PVC	Elevation Surface	Well Bottom	Length of Screen (ft)	Depth of Screen (ftbg)
Monitoring wells previously installed					
MW-A	694.54	695.01	16.36	10.00	4-14
PZ-A	694.92	695.20	22.62	4.00	18-22
MW-B	690.51	691.42	16.58	10.00	4-14
PZ-B	692.11	690.81	24.82	6.00	18-24
MW-C	699.70	698.25	16.73	10.00	5-15
PZ-C	699.91	698.10	26.39	5.00	21-26
MW-D	708.73	707.08	19.42	10.00	7-17
PZ-D	708.68	707.36	31.72	5.00	25-30
MW-E	708.15	707.09	19.22	10.00	7-17
MW-4	698.05	696.82	20.64	5.00	15-20
MW-6	702.97	701.10	20.84	5.00	15-20
MW-9	well abandoned				
MW-10R*	708.14	706.52	30.47	8.00	20-28
MW-11	704.78	703.19	27.81	8.00	17-25
MW-16	well abandoned				
MW-18	703.11	701.55	27.25	10.00	15-25
MW-22	709.02	707.68	27.16	10.00	21-31
MW-24S	711.01	708.70	DNA	5.00	7-12
MW-24D	711.00	708.83	DNA	5.00	18-23
MW-25	709.42	703.54	21.80	10.00	10-20
MW-26	702.03	700.61	24.04	10.00	12-22
MW-27	706.07	706.83	27.65	10.00	18-28
Monitoring wells installed by K. Singh & Associates					
W-MW-1S	699.48	DNA	18.40	10.00	5-15
W-MW-2S	701.35	DNA	15.22	10.00	5-15
W-MW-3S	693.14	DNA	17.80	10.00	3-13
W-MW-4S	696.64	DNA	18.10	10.00	5-15
W-MW-4D	695.63	DNA	22.80	5.00	15-20
W-MW-5S	696.48	DNA	16.40	10.00	5-15

DNA denotes data not available

Table 5.1
Former Whitefish Bay Demolition Landfill Groundwater Elevation Data

Well Number	Elevation		Date	DTW
	PVC	Groundwater		
W-MW-A	694.54	684.44	3/27/98	10.10
		683.35	4/29/98	11.19
		681.55	7/15/98	12.99
W-PZ-A	694.92	682.67	3/27/98	12.25
		683.71	4/29/98	11.21
		680.86	7/15/98	14.06
W-MW-B	690.51	684.72	3/27/98	5.79
		685.13	4/29/98	5.38
		682.29	7/15/98	8.22
W-PZ-B	692.11	684.34	3/27/98	7.77
		685.14	4/29/98	6.97
		682.48	7/15/98	9.63
W-MW-C	699.70	689.48	3/27/98	10.22
		690.41	4/30/98	9.29
		683.20	7/15/98	16.50
W-PZ-C	699.91	684.38	3/27/98	15.53
		685.17	4/30/98	14.74
		682.51	7/15/98	17.40
W-MW-D	708.73	695.95	3/27/98	12.78
		693.72	7/15/98	15.01
W-PZ-D	708.68	684.35	3/27/98	24.33
		682.46	7/15/98	26.22
W-MW-E	708.15	696.82	3/27/98	11.33
		692.78	7/15/98	15.37
W-MW-4	698.05	684.54	3/27/98	13.51
		682.67	7/15/98	15.38
W-MW-6	702.97	685.86	3/27/98	17.11
		687.11	4/29/98	15.86
		683.40	7/15/98	19.57
W-MW-10R*	708.14	684.33	3/27/98	23.81
		682.46	7/15/98	25.68

Table 5.1 (Cont.)
Former Whitefish Bay Demolition Landfill Groundwater Elevation Data

Well Number	Elevation		Date	DTW
	PVC	Groundwater		
W-MW-11	704.78	684.34	3/27/98	20.44
		682.48	7/15/98	22.30
W-MW-18	703.11	685.51	3/27/98	17.60
		682.59	7/15/98	20.52
W-MW-22	709.02	684.34	3/27/98	24.68
		682.48	7/15/98	26.54
W-MW-25	709.42	698.56	3/27/98	10.86
		697.12	7/15/98	12.30
W-MW-26	702.03	684.34	3/27/98	17.69
		682.48	7/15/98	19.55
W-MW-27	706.07	696.46	3/27/98	9.61
		694.99	7/15/98	11.08
W-MW-1S	699.48	686.96	5/12/98	12.52
		682.76	7/15/98	16.72
W-MW-2S	701.35	691.86	5/12/98	9.49
		685.38	7/15/98	15.97
W-MW-3S	693.14	689.42	5/13/98	3.72
		684.01	7/15/98	9.13
W-MW-4S	696.64	687.92	5/12/98	8.72
		686.36	7/15/98	10.28
W-MW-4D	695.63	683.73	5/12/98	11.90
		681.53	7/15/98	14.10
W-MW-5S	696.48	685.10	5/12/98	11.38
		682.54	7/15/98	13.94

Data from W-MW-9, W-MW16, W-MW-24S, and W-MW-24D were not available
*MW-10 was replaced with W-MW-10R after being damaged, 10/14/88 (W6)

Table 5.2

Estimates of Hydraulic Conductivities				
Former Whitefish Bay Demolition Landfill				
	Monitoring	Hvorslev Method		Well
	Well	(cm/sec)	(ft/sec)	depth
Observation wells				
	W-MW-6	5.9 x 10-4	1.9 x 10-5	Shallow
	W-MW-5S	1.2 x 10-4	4.0 x 10-6	Shallow
	W-MW-4S	5.7 x 10-5	1.9 x 10-6	Shallow
	W-MW-3S	3.5 x 10-5	1.1 x 10-6	Shallow
Piezometric wells				
	W-MW-4D	2.0 x 10-3	6.8 x 10-5	Deep
	W-PZ-B	4.4 x 10-3	1.5 x 10-4	Deep
	W-PZ-C	2.2 x 10-3	7.3 x 10-5	Deep
Estimated Shallow Aquifer		2.1 x 10-4	6.5 x 10-6	
Estimated Deep Aquifer		3.2 x 10-3	9.7 x 10-5	
Estimated Confining Layer		3.3 x 10-6	1.0 x 10-7	

Table 5.3 Former Whitefish Bay Demolition Landfill Groundwater Quality Test Results for Selected Parameters

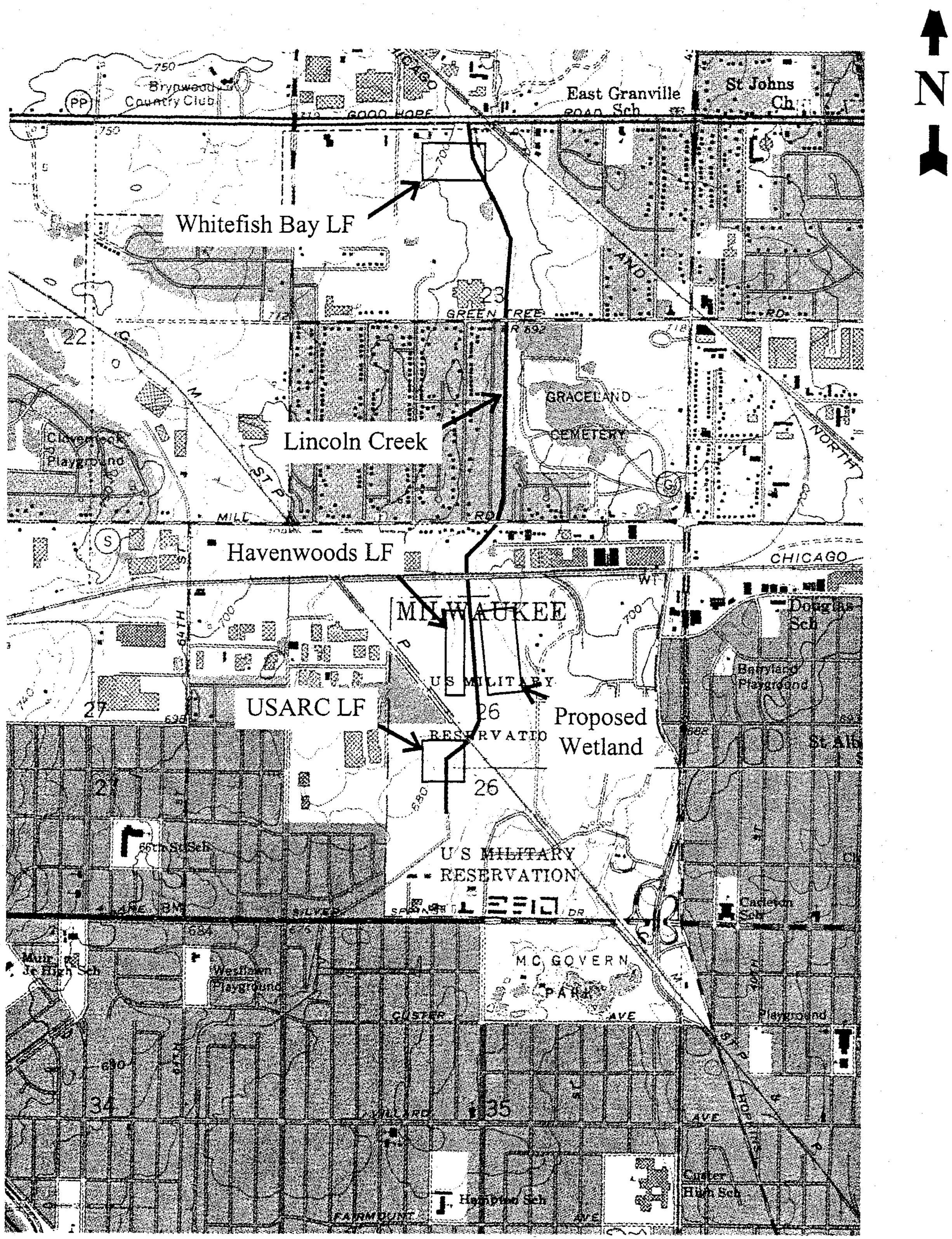
Parameter		Units	PAL	ES	W-MW-1S	W-MW-2S	W-MW-3S	W-MW-4S	W-MW-4D	W-MW-5S	W-MW-6	W-MW-A	W-PZ-A	W-MW-B	W-PZ-B	W-MW-C	W-PZ-C	W-SW-1	W-SW-2
Barium	7/15/98	ug/Liter	400	2,000	NR	< 200	NR	NR	NR	NR	NR	NA	NR	NR	NR	NR	NR	NR	NR
	4/21/98	ug/Liter	400	2,000	< 200	< 200	< 200	350.	300.	< 200	**590.**	**450.**	260.	< 200	< 200	**430.**	< 200	< 200	< 200
	6/19/97	ug/Liter	400	2,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	6/7/96	ug/Liter	400	2,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Selenium	7/15/98	ug/Liter	10	50	NR	NA	NR	NR	NR	NR	NR	NA	NR	NR	NR	NR	NR	NR	NR
	4/21/98	ug/Liter	10	50	**51**	< 2.6	2.7	0.8	< 2.6	< 2.6	0.6	< 2.6	< 2.6	< 2.6	< 2.6	< 2.6	< 2.6	< 2.6	**20**
	6/19/97	ug/Liter	10	50	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	6/7/96	ug/Liter	10	50	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Iron	7/15/98	ug/Liter	150	300	NR	NR	NR	NR	< 50	NR	**290**	NA	620	< 50	< 50	NR	NR	< 50	< 50
	4/21/98	ug/Liter	150	300	< 50.	**220.**	< 50.	< 50.	480.	< 50.	23000	5200.	670.	4500	480.	2200.	< 50.	370.	100.
	6/19/97	ug/Liter	150	300	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	6/7/96	ug/Liter	150	300	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	7/15/98	ug/Liter	25	50	NR	110	**31**	89	98	120	130	NA	780	88	130	NR	NR	**45**	**27**
	4/21/98	ug/Liter	25	50	260.	360.	120.	270.	130.	99.	320.	620.	430.	250.	290.	2600.	18.	**36.**	**38.**
	6/19/97	ug/Liter	25	50	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	6/7/96	ug/Liter	25	50	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Arsenic	7/15/98	ug/Liter	1.2	6.0	NR	**1.4**	NR	NR	NR	NR	NR	NA	NR	NR	NR	NR	NR	NR	NR
	4/21/98	ug/Liter	1.2	6.0	< 1.0	< 1.0	< 1.0	< 1.0	**2.4**	**4**	15	**4.4**	< 1.0	< 1.0	< 1.0	13	< 1.0	**1.1**	< 1.0
	6/19/97	ug/Liter	1.2	6.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	6/7/96	ug/Liter	1.2	6.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloride	7/15/98	mg/Liter	125.0	250.0	NR	NR	NR	NR	340	80	NR	NA	NR	NR	NR	NR	NR	NR	NR
	4/21/98	mg/Liter	125.0	250.0	41.	15.	43.	120.	320.	**140.**	**230.**	20.	**220.**	**180.**	**190.**	23.	**180.**	**220.**	270.
	6/19/97	mg/Liter	125.0	250.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	6/7/96	mg/Liter	125.0	250.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate	7/15/98	mg/Liter	2.0	10.0	NR	NR	NR	NR	NR	NR	NR	NA	NR	NR	NR	NR	NR	NR	NR
	4/21/98	mg/Liter	2.0	10.0	15.	0.97	0.11	0.51	**3.6**	0.37	0.030	0.10	0.46	0.21	0.47	0.45	0.050	0.29	0.26
	6/19/97	mg/Liter	2.0	10.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	6/7/96	mg/Liter	2.0	10.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 5.3 (Cont.) Former Whitefish Bay Demolition Landfill Groundwater Quality Test Results for Selected Parameters

Parameter		Units	PAL	ES	W-MW-1S	W-MW-2S	W-MW-3S	W-MW-4S	W-MW-4D	W-MW-5S	W-MW-6	W-MW-A	W-PZ-A	W-MW-B	W-PZ-B	W-MW-C	W-PZ-C	W-SW-1	W-SW-2
Sulfate	7/15/98	mg/Liter	125.0	250.0	NR	NR	NR	NR	NR	NR	NR	NA	NR	NR	NR	NR	NR	NR	NR
	4/21/98	mg/Liter	125.0	250.0	**920.**	82.	110.	**200.**	110.	120.	110.	**160.**	99.	**200.**	94.	82.	**170.**	63.	58.
	6/19/97	mg/Liter	125.0	250.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	6/7/96	mg/Liter	125.0	250.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1-Dichloroethylene	7/15/98	ug/Liter	0.7	7.0	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	NA	NR	NR	NR	NR	< 0.47	< 0.47	< 0.47
	4/21/98	ug/Liter	0.7	7.0	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	**0.80**	< 0.47	< 0.47
	6/19/97	ug/Liter	0.7	7.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	6/7/96	ug/Liter	0.7	7.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichloroethylene	7/15/98	ug/Liter	20.0	100.0	< 0.9	< 0.9	< 0.9	< 0.9	1.3	12	< 1.1	NA	NR	NR	NR	NR	**82**	< 0.9	9.7
	4/21/98	ug/Liter	20.0	100.0	NR	< 0.90	NR	NR	< 0.90	NR	< 0.90	< 0.90	2.7	< 0.90	< 0.90	**51.**	**200.**	< 0.90	2.5
	6/19/97	ug/Liter	20.0	100.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	6/7/96	ug/Liter	20.0	100.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzene	7/15/98	ug/Liter	0.5	5.0	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	NA	NR	NR	NR	NR	< 0.44	< 0.44	< 0.44
	4/21/98	ug/Liter	0.5	5.0	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	< 0.44	**0.58**	< 0.44	< 0.44	< 0.44
	6/19/97	ug/Liter	0.5	5.0	NA	NA	NA	NA	NA	NA	**< 0.41**	**0.45**	**2.1**	< 0.41	< 0.41	**< 2.0**	< 0.41	NA	NA
	6/7/96	ug/Liter	0.5	5.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethylene	7/15/98	ug/Liter	0.5	5.0	< 0.41	< 0.41	< 0.41	< 0.41	< 0.41	< 0.41	< 0.41	NA	NR	NR	NR	NR	< 0.41	< 0.41	< 0.41
	4/21/98	ug/Liter	0.5	5.0	< 0.41	< 0.41	< 0.41	< 0.41	< 0.41	< 0.41	< 0.41	< 0.41	< 0.41	< 0.41	< 0.41	**8.1**	< 0.41	< 0.41	< 0.41
	6/19/97	ug/Liter	0.5	5.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	6/7/96	ug/Liter	0.5	5.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trichloroethylene	7/15/98	ug/Liter	0.5	5.0	< 0.49	< 0.49	**< 0.63**	< 0.49	< 0.49	**1.2**	< 0.49	NA	NR	NR	NR	NR	**0.89**	< 0.49	< 0.49
	4/21/98	ug/Liter	0.5	5.0	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	< 0.49	**13.**	**16.**	< 0.49	< 0.49
	6/19/97	ug/Liter	0.5	5.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	6/7/96	ug/Liter	0.5	5.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vinyl chloride	7/15/98	ug/Liter	0.02	0.2	< 0.52	< 0.52	< 0.52	< 0.52	< 0.52	**43**	**1.3**	NA	NR	NR	NR	NR	**150**	< 0.52	< 0.52
	4/21/98	ug/Liter	0.02	0.2	< 0.52	< 0.52	< 0.52	< 0.52	< 0.52	**22.**	**0.99**	< 0.52	< 0.52	< 0.52	< 0.52	**3.1**	**230.**	< 0.52	< 0.52
	6/19/97	ug/Liter	0.02	0.2	NA	NA	NA	NA	NA	NA	**0.37**	<0.23	**0.79**	< 0.23	< 0.23	**14.0**	**150**	NA	NA
	6/7/96	ug/Liter	0.02	0.2	NA	NA	NA	NA	NA	NA	ND	NA	NA	NA	NA	NA	NA	NA	NA

NA denotes not analyzed, ND denotes no detection limit given, NR denotes not requested

Boldface type indicates concentrations above the Preventive Action Limit. Shaded boldface type indicates concentrations above the Enforcement Standar



Scale: 1 inch = 2,000 feet

Figure 2.1: Project Location Map

NOTES:

"W" IDENTIFIER ELIMINATED FROM EXISTING WELLS FOR CLARITY.

BASE MAP AND PRELIMINARY LOW FLOW/ FLOOD CONVEYANCE CHANNELS HAVE BEEN ADAPTED FROM DRAWINGS PROVIDED BY CAMP DRESSER & McKEE

LEGEND

- LOW FLOW CHANNEL
- FLOOD CONVEYANCE CHANNEL
- MONITORING WELL OR PIEZOMETER

OWNER	MILWAUKEE METROPOLITAN SEWERAGE DISTRICT
PROJECT LOCATION	WHITEFISH BAY LANDFILL REACH 9 - LINCOLN CREEK MILWAUKEE, WISCONSIN

ENGINEER

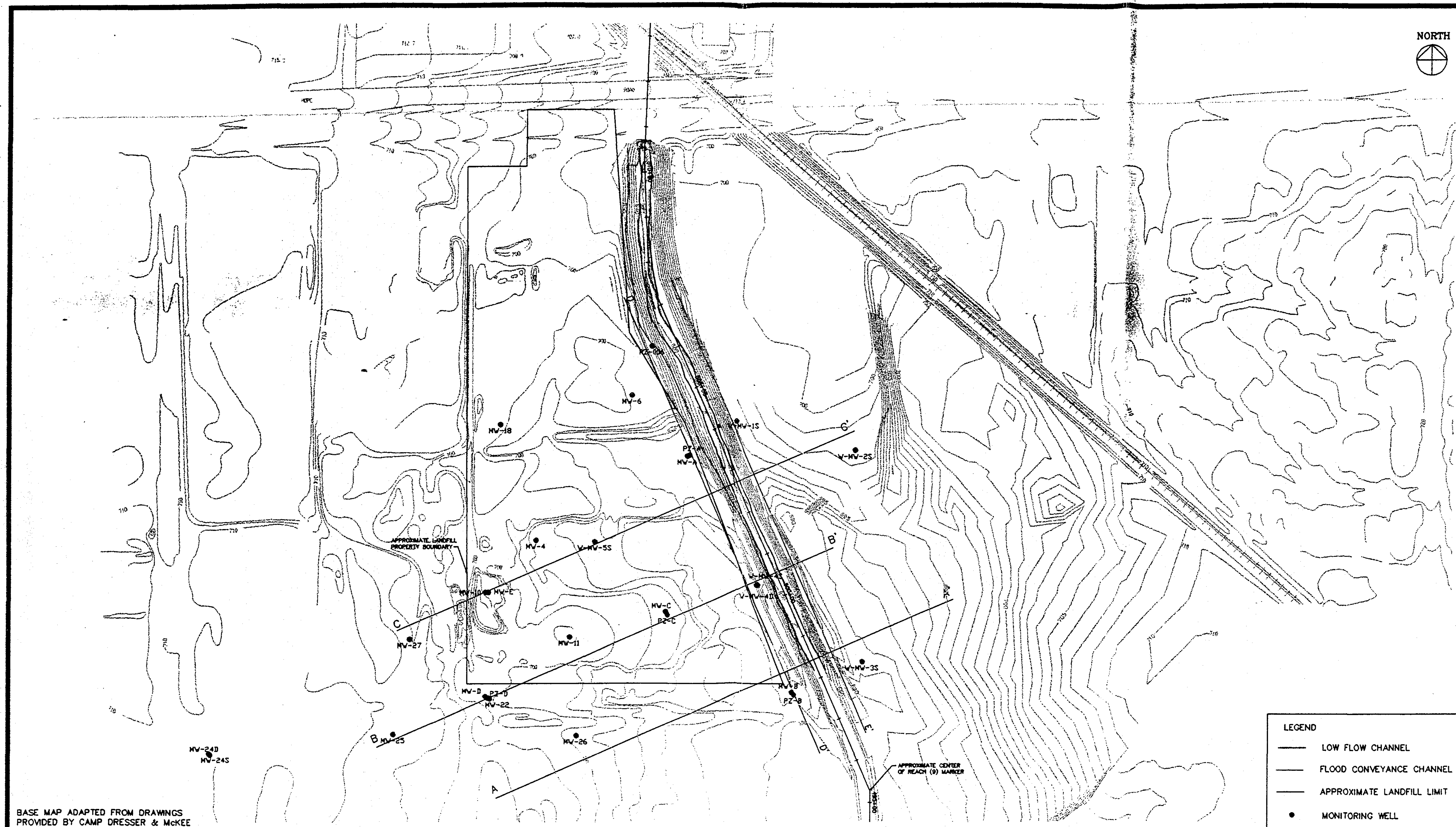
K. SINGH & ASSOCIATES, INC.

ENGINEERS, SCIENTISTS & ENVIRONMENTAL MANAGEMENT CONSULTANTS

1135 LEGION DRIVE, ELM GROVE, WISCONSIN 53122, (414)821-1171

FIGURE 3.1 LOCATION OF MONITORING WELLS AT FORMER WHITEFISH BAY DEMOLITION LANDFILL

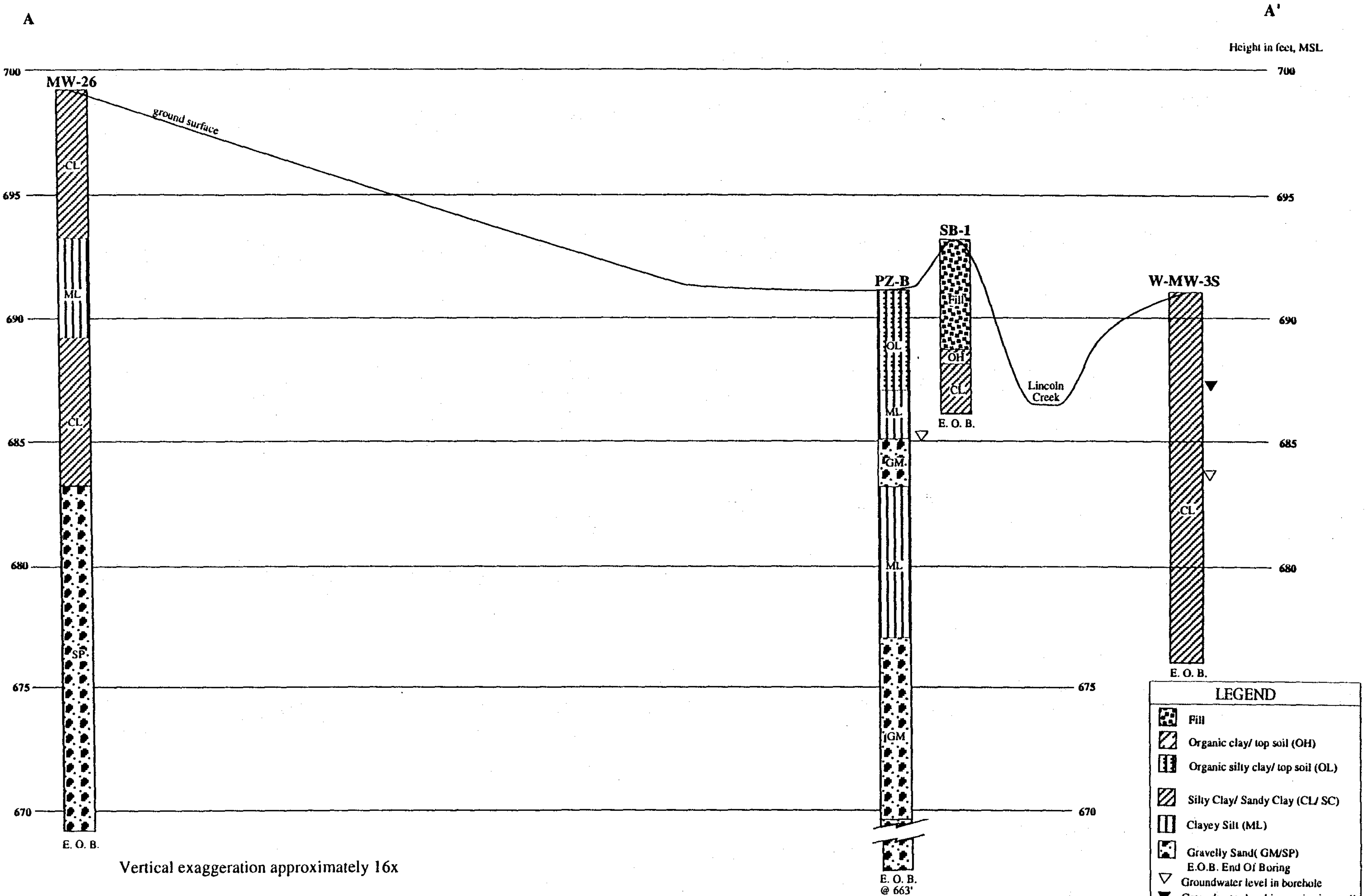
DATE	DRAWN BY	REVISED BY	DATE	PROJECT NO.
SEPTEMBER 17, 1998	P.A.R.			4283
SCALE	CHECKED BY			SHEET NO.
0 50' 100'	D.K.S.			1



OWNER	ENGINEER
MILWAUKEE METROPOLITAN SEWERAGE DISTRICT	K. SINGH & ASSOCIATES, INC.
PROJECT LOCATION WHITEFISH BAY LANDFILL REACH 9 – LINCOLN CREEK MILWAUKEE, WISCONSIN	ENGINEERS & ENVIRONMENTAL MANAGEMENT CONSULTANTS 1135 LEGION DRIVE, ELM GROVE, WISCONSIN 53122, (414)821-1171

FIGURE 5.1 MAP OF GEOLOGIC CROSS SECTIONS

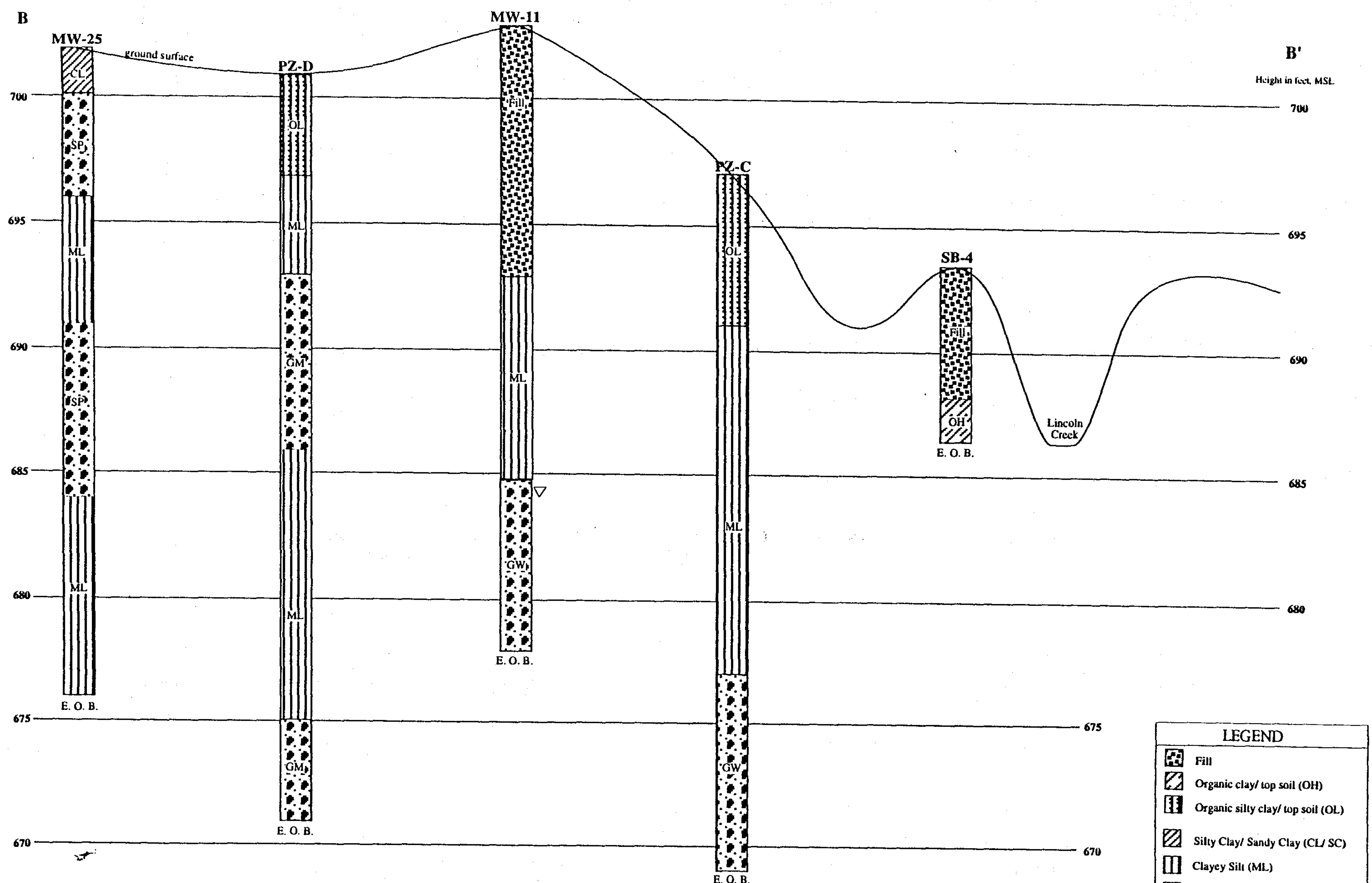
DATE	DRAWN BY	REVISED BY	DATE	PROJECT NO.
JULY 23, 1998	P.A.R.			4283
SCALE 0 50' 100'	CHECKED BY			SHEET NO.
	D.K.S.			1



Owner	Engineer
Milwaukee Metropolitan Sewerage District Project Location Whitefish Bay Landfill Reach 7 - Lincoln Creek Milwaukee, Wisconsin	**K. SINGH & ASSOCIATES, INC.,** Engineers, Scientists & Environmental Management Consultants 1135 Legion Drive, Elm Grove, Wisconsin 53122, (414) 821-1171

Figure 5.2: Geologic Section A-A'

DATE	DRAWN BY	REVISIONS BY	DATE	PROJECT NO.
May 21, 1998	A.S.M.			4283
HORIZONTAL SCALE 0' 80'	CHECKED BY			



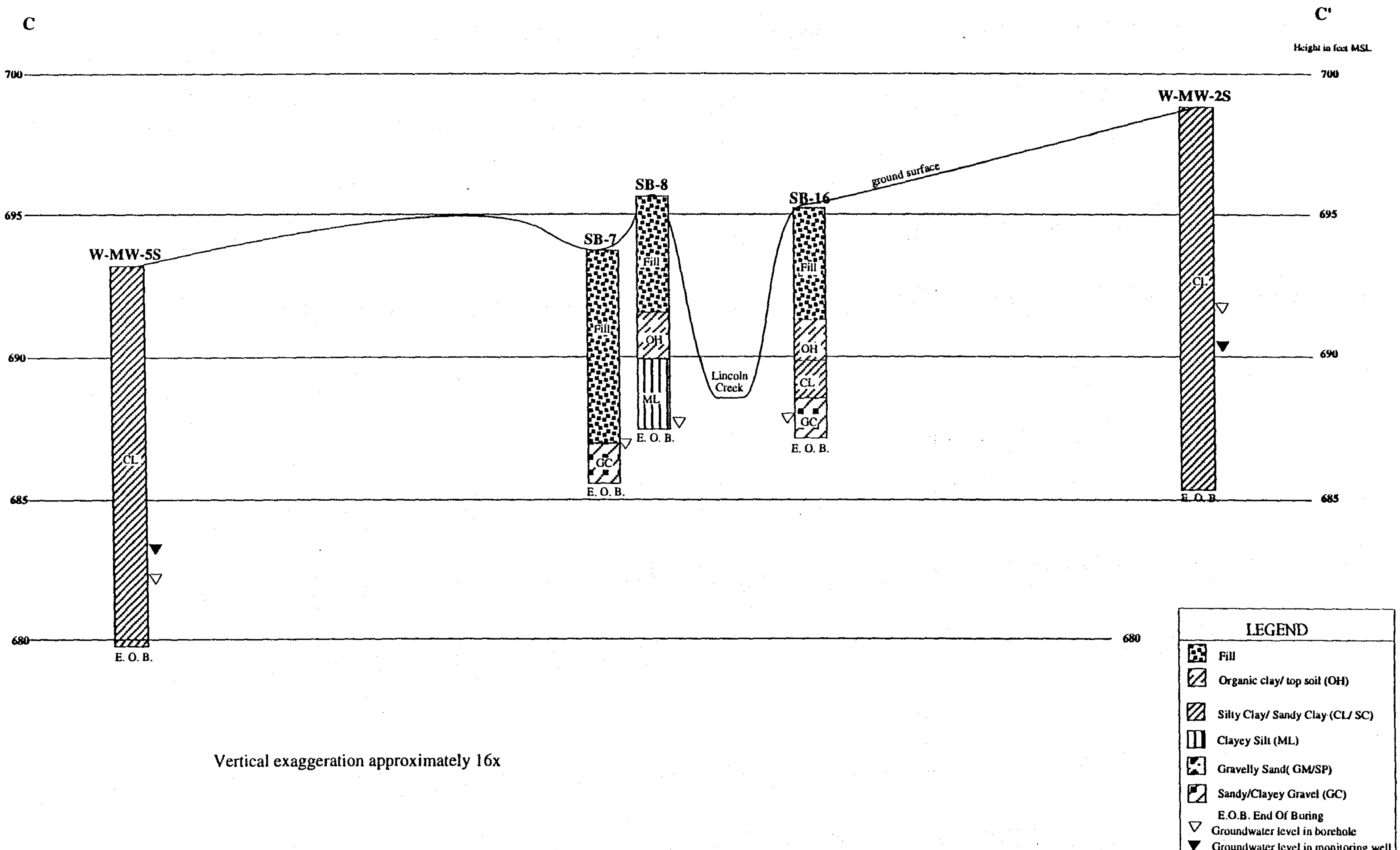
Vertical exaggeration approximately 28x

Owner
Milwaukee Metropolitan Sewerage District
Project Location
Whitefish Bay Landfill
Reach 7 - Lincoln Creek
Milwaukee, Wisconsin

Engineer
K. SINGH & ASSOCIATES, INC.,
Engineers, Scientists & Environmental Management Consultants
1135 Legion Drive, Elm Grove, Wisconsin 53122, (414) 821-1171

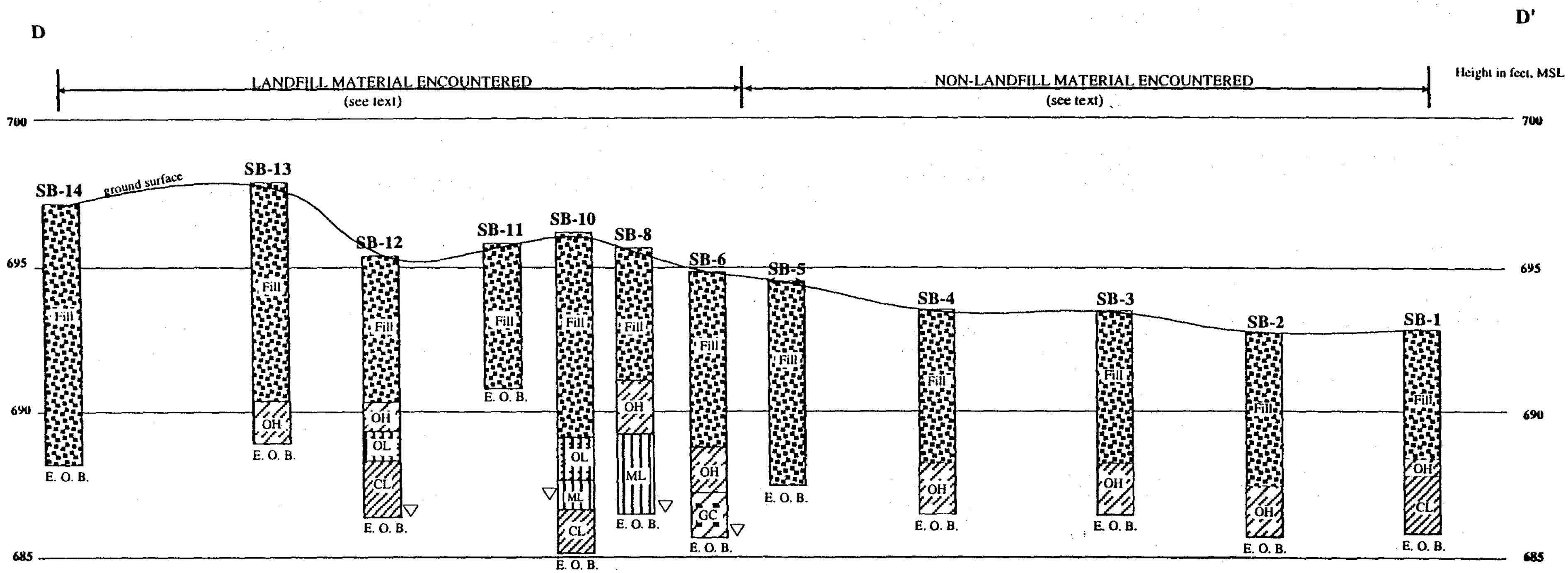
Figure 5.3: Geologic Section B-B'

DATE	DRAWN BY	REVISIONS BY	DATE	PROJECT NO.
May 21, 1998	A.S.M.			4283
HORIZONTAL SCALE 0' – 140'	CHECKED BY			



Vertical exaggeration approximately 16x

Owner Milwaukee Metropolitan Sewerage District Project Location Whitefish Bay Landfill Reach 7 - Lincoln Creek Milwaukee, Wisconsin	Engineer K. SINGH & ASSOCIATES, INC., Engineers, Scientists & Environmental Management Consultants 1135 Legion Drive, Elm Grove, Wisconsin 53122, (414) 821-1171	**Figure 5.4: Geologic Section C-C'**				
		DATE May 21, 1998	DRAWN BY A.S.M.	REVISIONS BY	DATE	PROJECT NO. 4283
		HORIZONTAL SCALE 0' 80'	CHECKED BY			



Vertical exaggeration approximately 20x

LEGEND

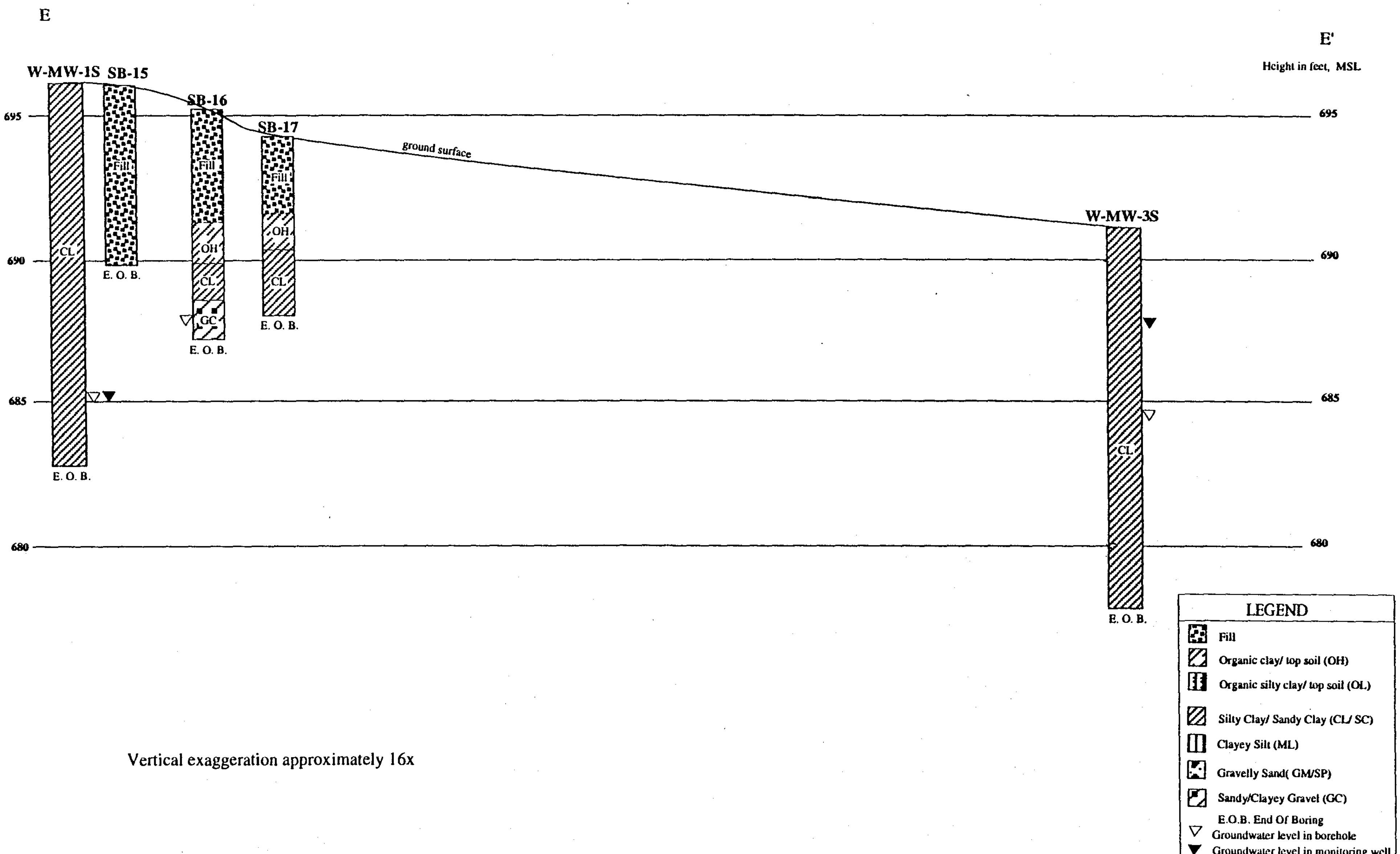
- Fill
- Organic clay/ top soil (OH)
- Organic silty clay/ top soil (OL)
- Silty Clay/ Sandy Clay (CL/ SC)
- Clayey Silt (ML)
- Gravelly Sand(GM/SP)
- Sandy/Clayey Gravel (GC)
- E.O.B. End Of Boring
- ▽ Groundwater level in borehole
- ▼ Groundwater level in monitoring well

Owner
Milwaukee Metropolitan Sewerage District
Project Location
Whitefish Bay Landfill
Reach 7 - Lincoln Creek
Milwaukee, Wisconsin

Engineer
K. SINGH & ASSOCIATES, INC.,
Engineers, Scientists & Environmental Management Consultants
1135 Legion Drive, Elm Grove, Wisconsin 53122, (414) 821-1171

Figure 5.5: Geologic Section D-D'

DATE	DRAWN BY	REVISIONS BY	DATE	PROJECT NO.
May 21, 1998	A.S.M.			4283
HORIZONTAL SCALE 0' 100'	CHECKED BY			

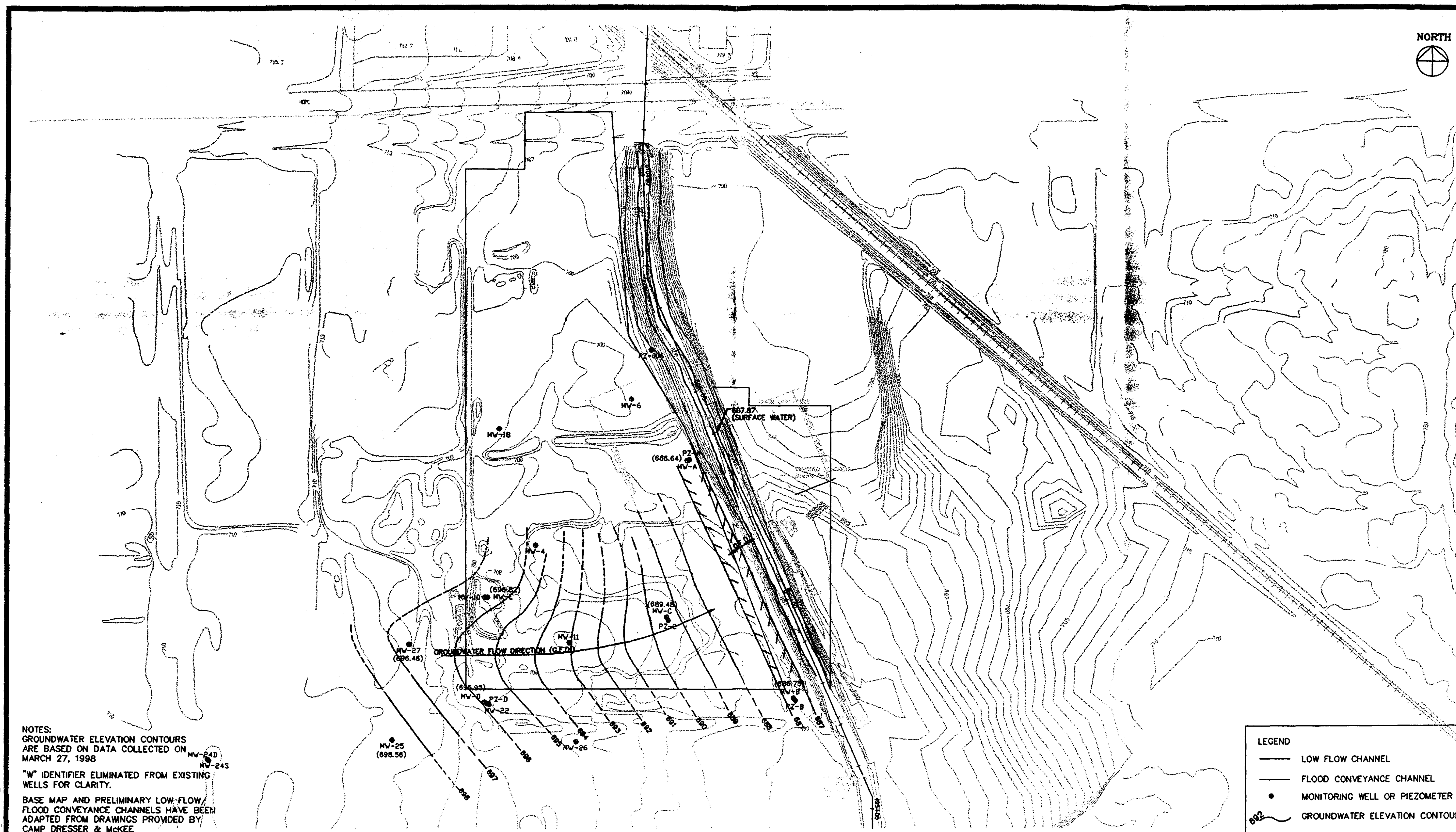


Owner
Milwaukee Metropolitan Sewerage District
Project Location
Whitefish Bay Landfill
Reach 7 - Lincoln Creek
Milwaukee, Wisconsin

Engineer
K. SINGH & ASSOCIATES, INC.,
Engineers, Scientists & Environmental Management Consultants
1135 Legion Drive, Elm Grove, Wisconsin 53122, (414) 821-1171

Figure 5.6: Geologic Section E-E'

DATE	DRAWN BY	REVISIONS BY	DATE	PROJECT NO.
May 21, 1998	A.S.M.			4283
HORIZONTAL SCALE 0' — 80'	CHECKED BY			



NOTES:
GROUNDWATER ELEVATION CONTOURS ARE BASED ON DATA COLLECTED ON MARCH 27, 1998

"W" IDENTIFIER ELIMINATED FROM EXISTING WELLS FOR CLARITY.

BASE MAP AND PRELIMINARY LOW FLOW/ FLOOD CONVEYANCE CHANNELS HAVE BEEN ADAPTED FROM DRAWINGS PROVIDED BY CAMP DRESSER & McKEE

LEGEND
- LOW FLOW CHANNEL
- FLOOD CONVEYANCE CHANNEL
- MONITORING WELL OR PIEZOMETER
- 692 GROUNDWATER ELEVATION CONTOUR

CLIENT	ENGINEER	FIGURE 5.7 SHALLOW AQUIFER GROUNDWATER ELEVATION CONTOUR MAP, WET SEASON
MILWAUKEE METROPOLITAN SEWERAGE DISTRICT	K. SINGH & ASSOCIATES, INC.	
PROJECT LOCATION: WHITEFISH BAY LANDFILL, REACH 7 – LINCOLN CREEK, MILWAUKEE, WISCONSIN	ENGINEERS, SCIENTISTS & ENVIRONMENTAL MANAGEMENT CONSULTANTS, 1135 LEGION DRIVE, ELM GROVE, WISCONSIN 53122, (414)821-1171	

DATE	DRAWN BY	REVISED BY	DATE	PROJECT NO.
MAY 22, 1998	P.A.R.	B.M.S.	AUGUST 15, 1998	4283
SCALE	CHECKED BY			SHEET NO.
0 50' 100'	D.K.S.			1

NOTES:
CONTOURS ARE BASED ON DATA COLLECTED MARCH 26, 1998

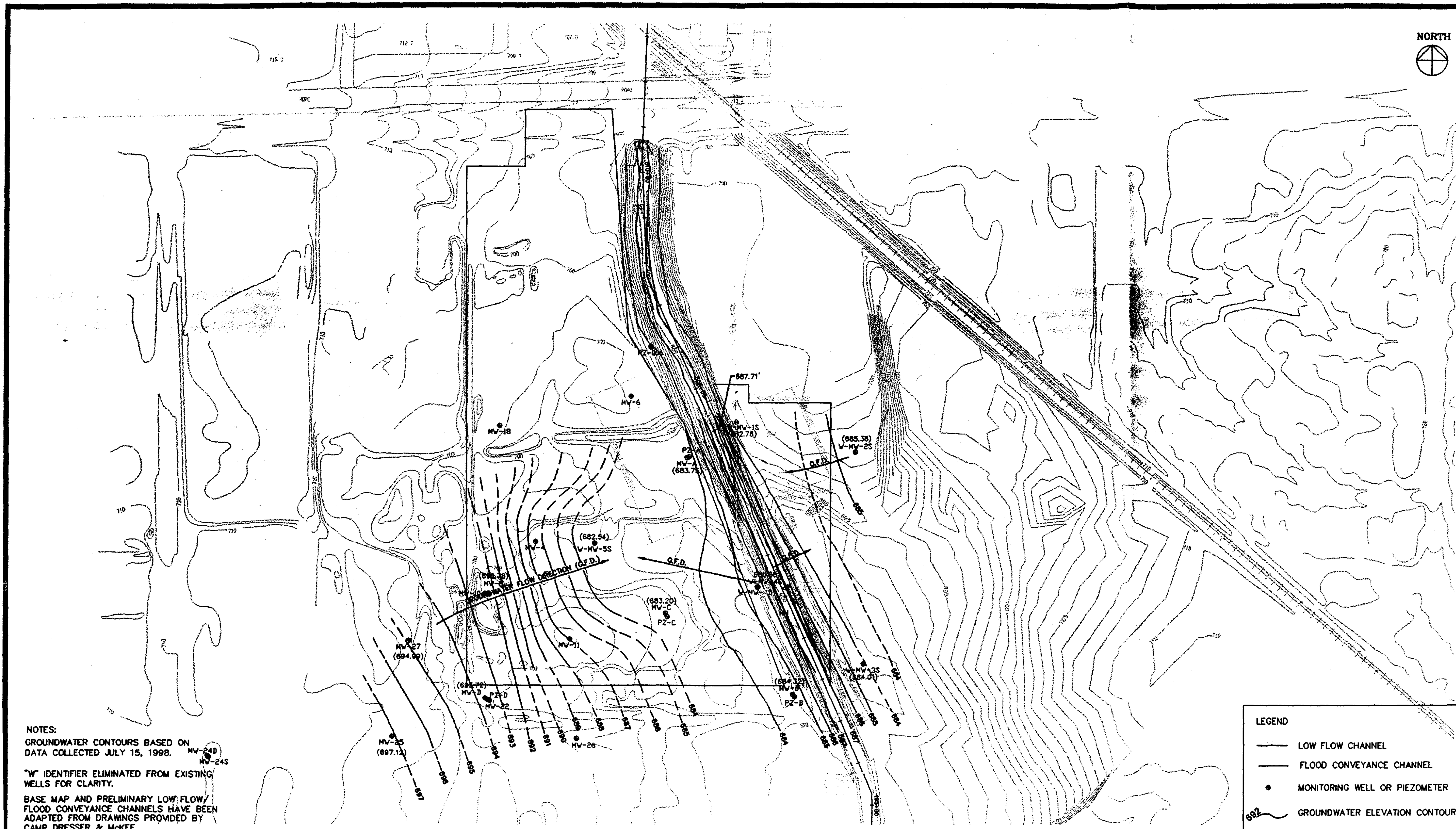
"W" IDENTIFIER ELIMINATED FROM EXISTING WELLS FOR CLARITY.

BASE MAP AND PRELIMINARY LOW FLOW/ FLOOD CONVEYANCE CHANNELS HAVE BEEN ADAPTED FROM DRAWINGS PROVIDED BY CAMP DRESSER & McKEE

LEGEND
- LOW FLOW CHANNEL
- FLOOD CONVEYANCE CHANNEL
- MONITORING WELL OR PIEZOMETER
- 692 GROUNDWATER ELEVATION CONTOUR

CLIENT	ENGINEER	FIGURE 5.8 DEEP AQUIFER GROUNDWATER ELEVATION CONTOUR MAP, WET SEASON				
MILWAUKEE METROPOLITAN SEWERAGE DISTRICT	K. SINGH & ASSOCIATES, INC.	DATE	DRAWN BY	REVISED BY	DATE	PROJECT NO.
PROJECT LOCATION	ENGINEERS, SCIENTISTS & ENVIRONMENTAL MANAGEMENT CONSULTANTS	MAY 22, 1998	P.A.R.	B.M.S.	AUGUST 20, 1998	4283
WHITEFISH BAY LANDFILL REACH 9 - LINCOLN CREEK MILWAUKEE, WISCONSIN	1135 LEGION DRIVE, ELM GROVE, WISCONSIN 53122, (414)821-1171	SCALE	CHECKED BY			SHEET NO.
			D.K.S.			1

C:\MMSD\WFD1_R.DWG



NOTES:

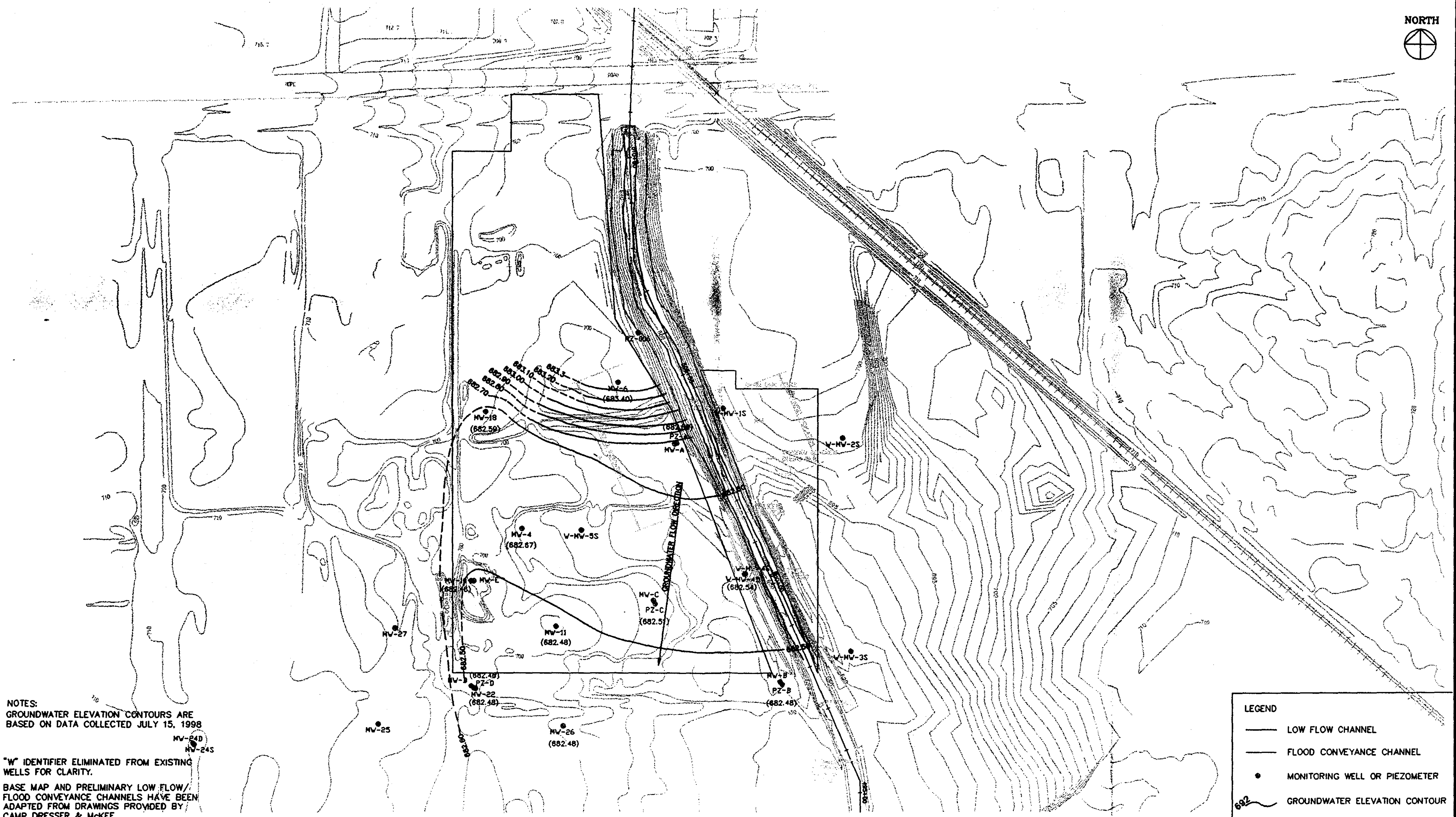
GROUNDWATER CONTOURS BASED ON DATA COLLECTED JULY 15, 1998.

"W" IDENTIFIER ELIMINATED FROM EXISTING WELLS FOR CLARITY.

BASE MAP AND PRELIMINARY LOW FLOW/ FLOOD CONVEYANCE CHANNELS HAVE BEEN ADAPTED FROM DRAWINGS PROVIDED BY CAMP DRESSER & McKEE

OWNER	ENGINEER	FIGURE 5.9 SHALLOW AQUIFER GROUNDWATER ELEVATION CONTOUR MAP, DRY SEASON
MILWAUKEE METROPOLITAN SEWERAGE DISTRICT	K. SINGH & ASSOCIATES, INC.	
PROJECT LOCATION WHITEFISH BAY LANDFILL REACH 9 – LINCOLN CREEK MILWAUKEE, WISCONSIN	ENGINEERS, SCIENTISTS & ENVIRONMENTAL MANAGEMENT CONSULTANTS 1135 LEGION DRIVE, ELM GROVE, WISCONSIN 53122, (414)821-1171	

DATE	DRAWN BY	REVISED BY	DATE	PROJECT NO.
MAY 22, 1998	P.A.R.			4283
SCALE	CHECKED BY			SHEET NO.
0 50' 100'	D.K.S.			1



NOTES:
GROUNDWATER ELEVATION CONTOURS ARE BASED ON DATA COLLECTED JULY 15, 1998

"W" IDENTIFIER ELIMINATED FROM EXISTING WELLS FOR CLARITY.

BASE MAP AND PRELIMINARY LOW FLOW/FLOOD CONVEYANCE CHANNELS HAVE BEEN ADAPTED FROM DRAWINGS PROVIDED BY CAMP DRESSER & McKEE

LEGEND
- LOW FLOW CHANNEL
- FLOOD CONVEYANCE CHANNEL
- MONITORING WELL OR PIEZOMETER
- 682 GROUNDWATER ELEVATION CONTOUR

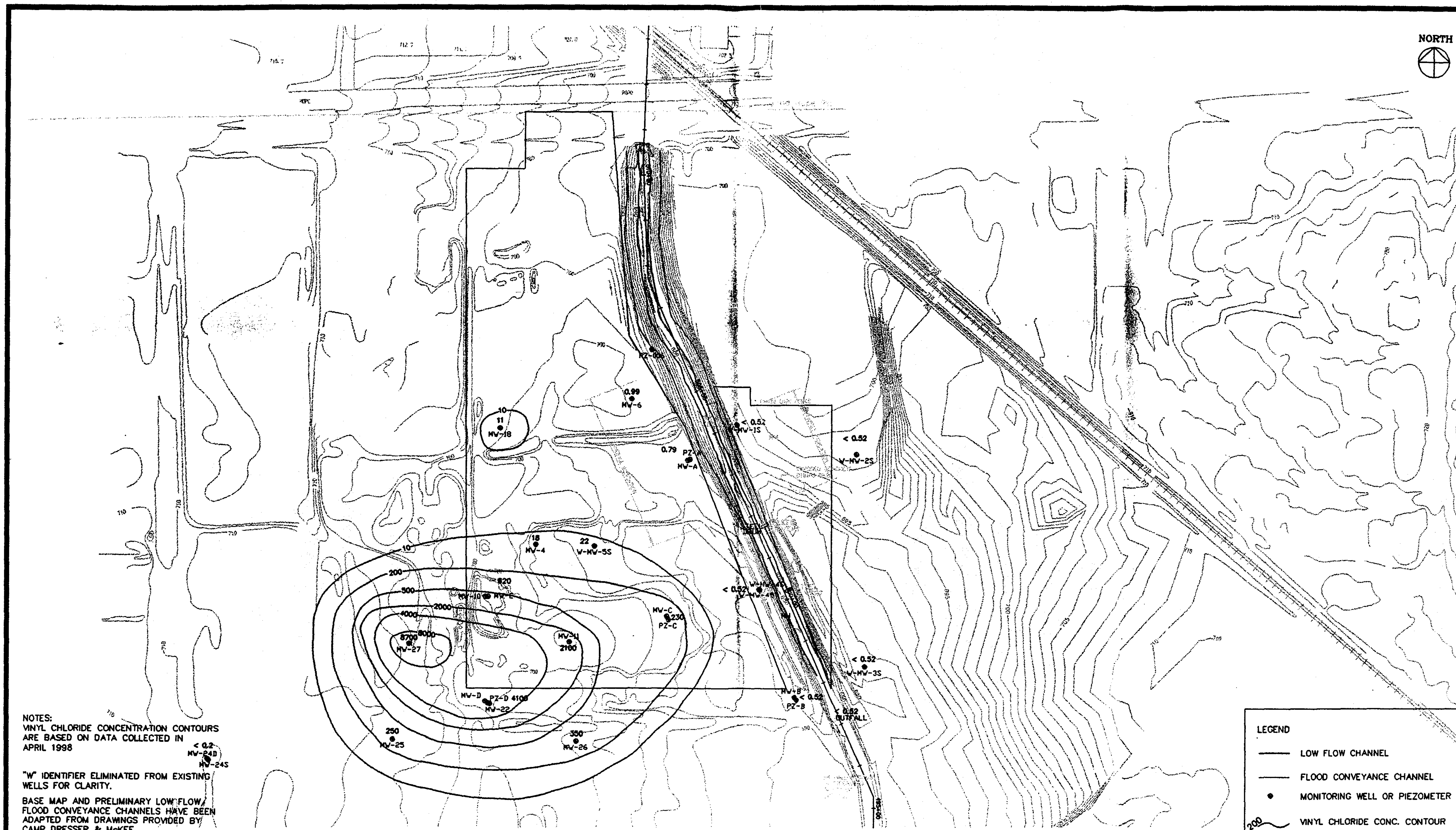
OWNER
MILWAUKEE METROPOLITAN SEWERAGE DISTRICT

PROJECT LOCATION
WHITEFISH BAY LANDFILL
REACH 9 – LINCOLN CREEK
MILWAUKEE, WISCONSIN

ENGINEER
K. SINGH & ASSOCIATES, INC.
ENGINEERS, SCIENTISTS & ENVIRONMENTAL MANAGEMENT CONSULTANTS
1135 LEGION DRIVE, ELM GROVE, WISCONSIN 53122, (414)821-1171

FIGURE 5.10 DEEP AQUIFER GROUNDWATER ELEVATION CONTOUR MAP, DRY SEASON

DATE	DRAWN BY	REVISED BY	DATE	PROJECT NO.
SEPTEMBER 17, 1998	P.A.R.			4283
SCALE	CHECKED BY			SHEET NO.
0 50' 100'	D.K.S.			1



NOTES:
VINYL CHLORIDE CONCENTRATION CONTOURS ARE BASED ON DATA COLLECTED IN APRIL 1998

"W" IDENTIFIER ELIMINATED FROM EXISTING WELLS FOR CLARITY.

BASE MAP AND PRELIMINARY LOW FLOW/FLOOD CONVEYANCE CHANNELS HAVE BEEN ADAPTED FROM DRAWINGS PROVIDED BY CAMP DRESSER & McKEE

LEGEND
- LOW FLOW CHANNEL
- FLOOD CONVEYANCE CHANNEL
- MONITORING WELL OR PIEZOMETER
- 200 VINYL CHLORIDE CONC. CONTOUR

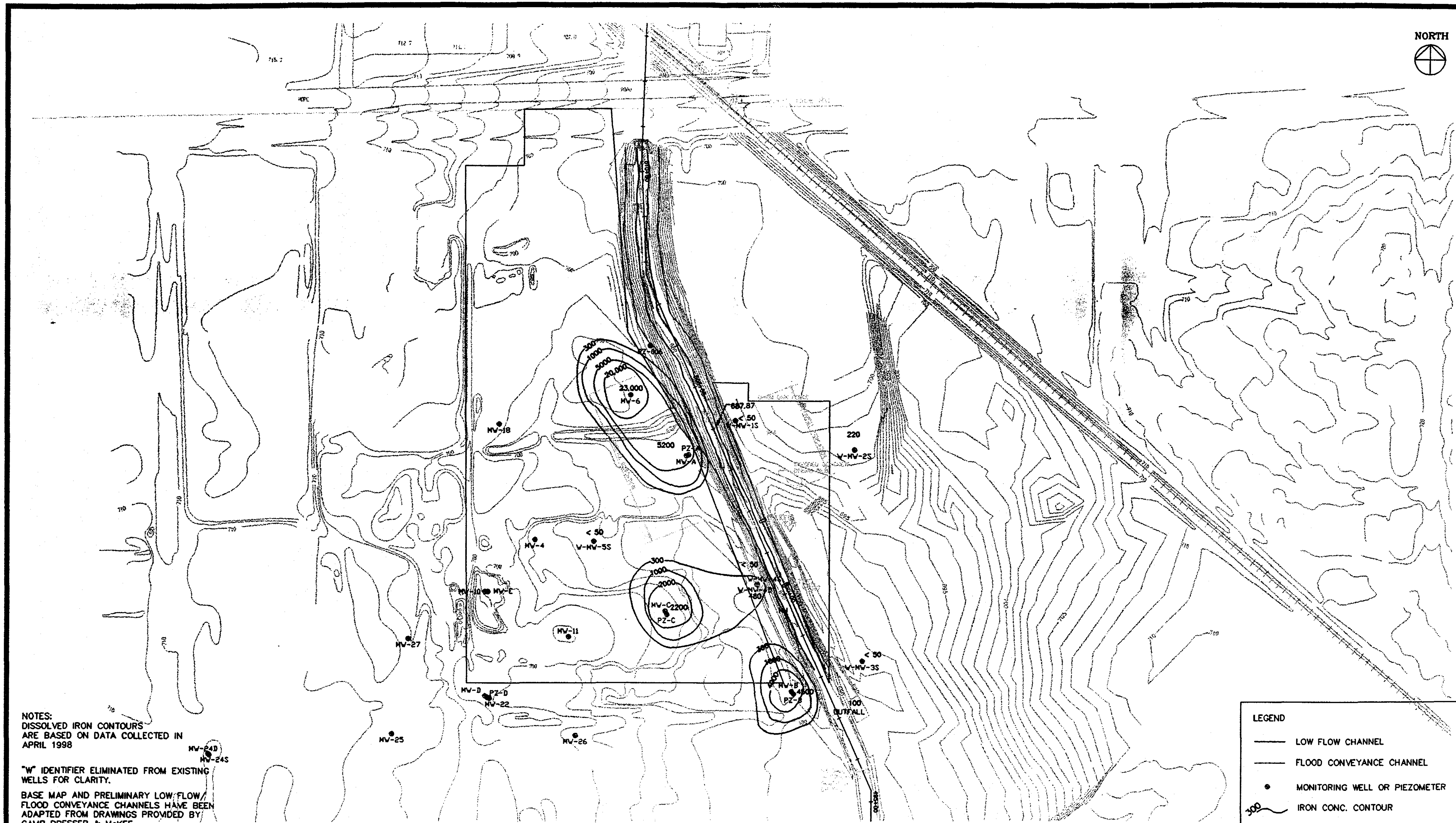
CLIENT
MILWAUKEE METROPOLITAN SEWERAGE DISTRICT

PROJECT LOCATION
WHITEFISH BAY LANDFILL
REACH 9 – LINCOLN CREEK
MILWAUKEE, WISCONSIN

ENGINEER
K. SINGH & ASSOCIATES, INC.
ENGINEERS, SCIENTISTS & ENVIRONMENTAL MANAGEMENT CONSULTANTS
1135 LEGION DRIVE, ELM GROVE, WISCONSIN 53122, (414)821-1171

FIGURE 5.11 CONTOUR MAP OF VINYL CHLORIDE CONCENTRATIONS IN GROUNDWATER

DATE	DRAWN BY	REVISED BY	DATE	PROJECT NO.
SEPTEMBER 17, 1998	P.A.R.	B.M.S.	AUGUST 15, 1998	4283
SCALE	CHECKED BY			SHEET NO.
0 50' 100'	D.K.S.			1



NOTES:
DISSOLVED IRON CONTOURS ARE BASED ON DATA COLLECTED IN APRIL 1998

"W" IDENTIFIER ELIMINATED FROM EXISTING WELLS FOR CLARITY.

BASE MAP AND PRELIMINARY LOW FLOW/ FLOOD CONVEYANCE CHANNELS HAVE BEEN ADAPTED FROM DRAWINGS PROVIDED BY CAMP DRESSER & McKEE

CLIENT	ENGINEER	FIGURE 5.12 CONTOUR MAP OF DISSOLVED IRON CONCENTRATIONS IN GROUNDWATER
MILWAUKEE METROPOLITAN SEWERAGE DISTRICT	K. SINGH & ASSOCIATES, INC.	
PROJECT LOCATION WHITEFISH BAY LANDFILL REACH 9 – LINCOLN CREEK MILWAUKEE, WISCONSIN	ENGINEERS, SCIENTISTS & ENVIRONMENTAL MANAGEMENT CONSULTANTS 1135 LEGION DRIVE, ELM GROVE, WISCONSIN 53122, (414)821-1171	

DATE	DRAWN BY	REVISED BY	DATE	PROJECT NO.
SEPTEMBER 17, 1998	P.A.R.	B.M.S.	AUGUST 15, 1998	4283
SCALE	CHECKED BY			SHEET NO.
0 50' 100'	D.K.S.			1

NOTES:
DISSOLVED MANGANESE CONTOURS ARE BASED ON DATA COLLECTED IN APRIL 1998

"W" IDENTIFIER ELIMINATED FROM EXISTING WELLS FOR CLARITY.

BASE MAP AND PRELIMINARY LOW FLOW/ FLOOD CONVEYANCE CHANNELS HAVE BEEN ADAPTED FROM DRAWINGS PROVIDED BY CAMP DRESSER & McKEE

LEGEND

- LOW FLOW CHANNEL
- FLOOD CONVEYANCE CHANNEL
- ● MONITORING WELL OR PIEZOMETER
- 500 MANGANESE CONC. CONTOUR

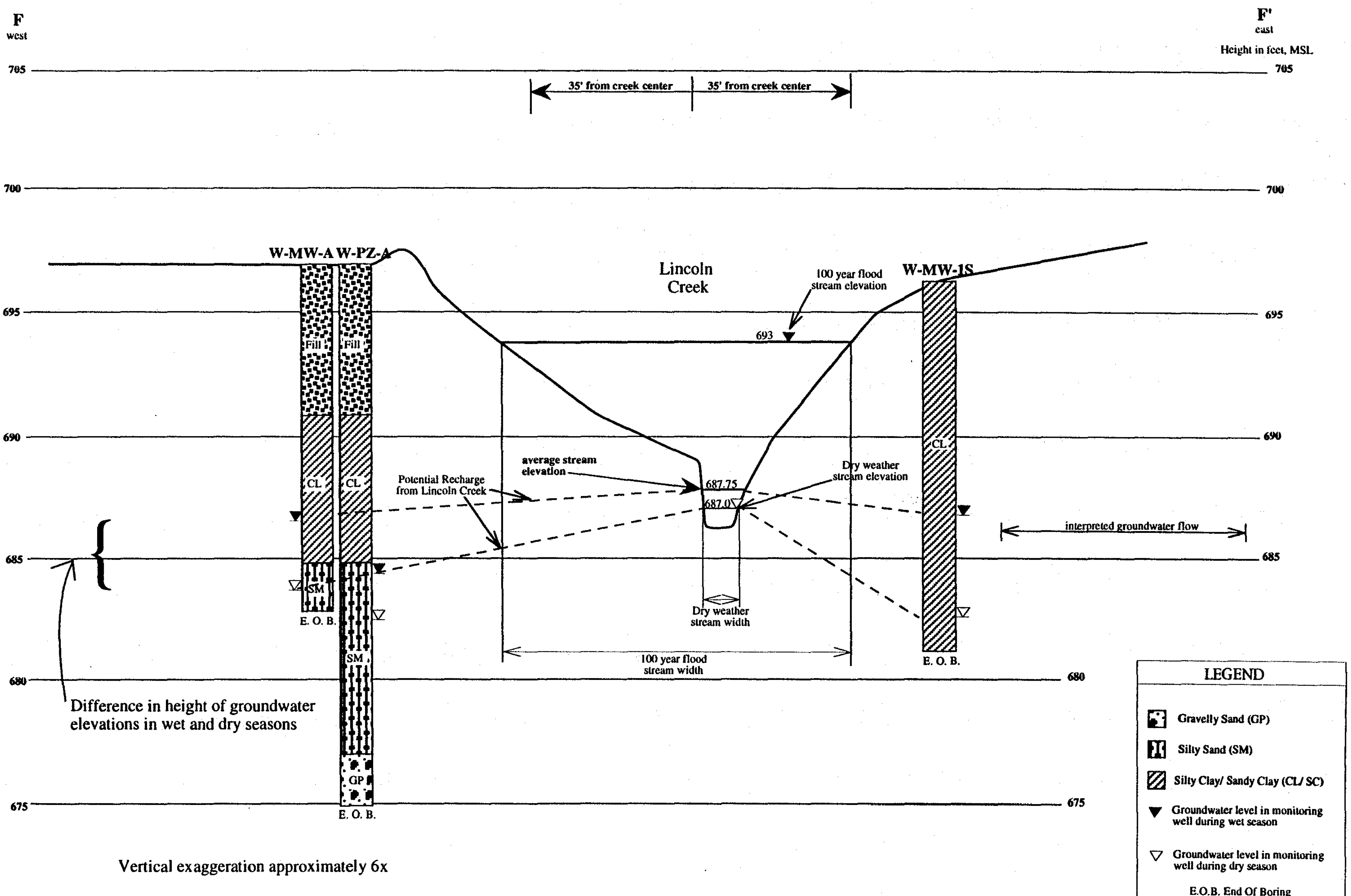
CLIENT
MILWAUKEE METROPOLITAN SEWERAGE DISTRICT

PROJECT LOCATION
WHITEFISH BAY LANDFILL
REACH 9 – LINCOLN CREEK
MILWAUKEE, WISCONSIN

ENGINEER
K. SINGH & ASSOCIATES, INC.
ENGINEERS, SCIENTISTS & ENVIRONMENTAL MANAGEMENT CONSULTANTS
1135 LEGION DRIVE, ELM GROVE, WISCONSIN 53122, (414)821-1171

FIGURE 5.13 CONTOUR MAP OF DISSOLVED MANGANESE CONCENTRTIONS IN GROUNDWATER

DATE	DRAWN BY	REVISED BY	DATE	PROJECT NO.
SEPTEMBER 17, 1998	P.A.R.	B.M.S.	AUGUST 15, 1998	4283
SCALE	CHECKED BY			SHEET NO.
0 50' 100'	D.K.S.			1

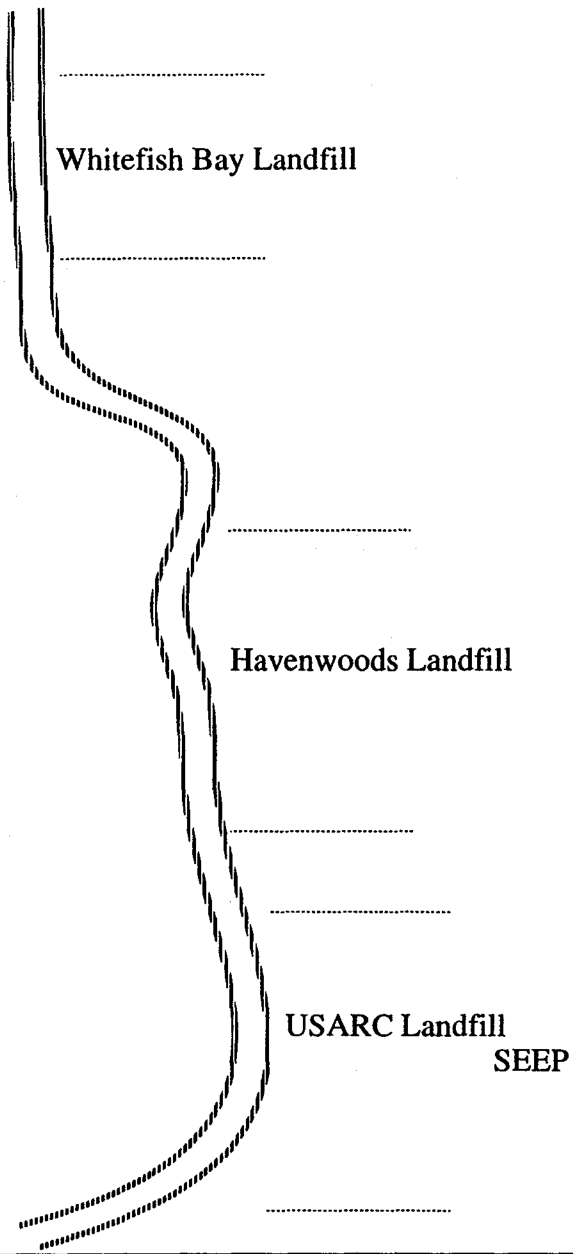


Owner
Milwaukee Metropolitan Sewerage District
Project Location
Former Whitefish Bay Demolition Landfill
Reach 7 - Lincoln Creek
Milwaukee, Wisconsin

Engineer
K. SINGH & ASSOCIATES, INC.,
Engineers, Scientists & Environmental Management Consultants
1135 Legion Drive, Elm Grove, Wisconsin 53122, (414) 821-1171

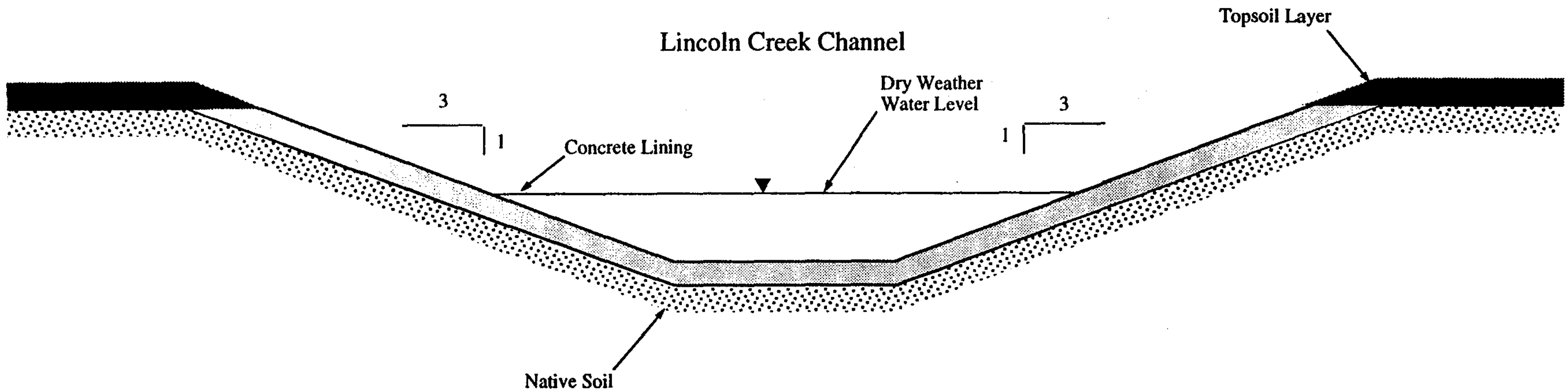
Figure 5.14: Stream Cross-Section F-F'

DATE	DRAWN BY	REVISIONS BY	DATE	PROJECT NO.
September 25, 1998	A.S.M.			4283
HORIZONTAL SCALE 0' 20'	CHECKED BY			SHEET NO. ONE

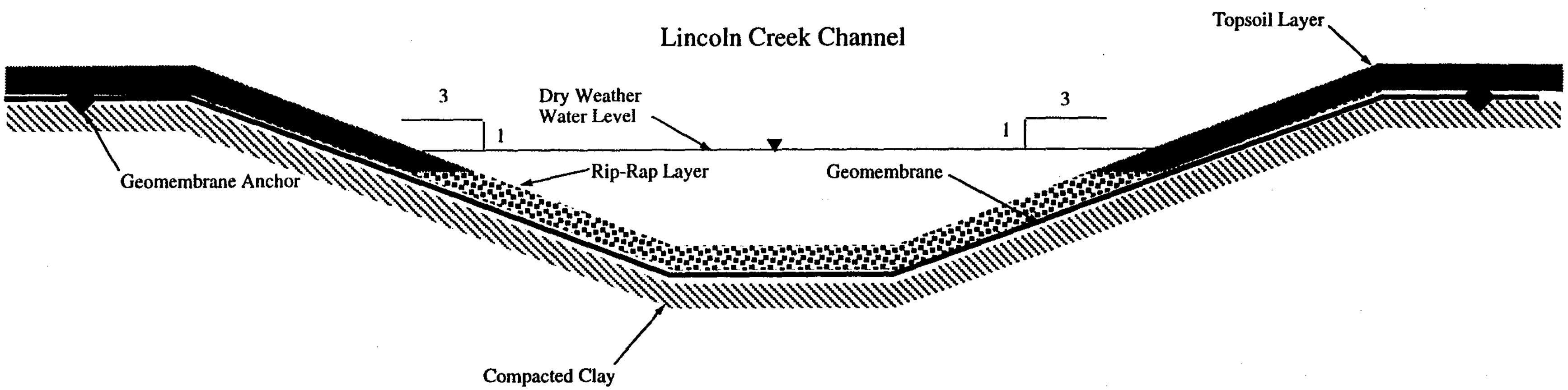


	Vinyl Chloride	Iron	Manganese	Chloride	Arsenic
ES	***0.2***	***300***	***50***	***250***	***6***
PAL	*0.02*	*150*	*25*	*125*	*1.2*
wet	<0.52	***370***	*36*	*220*	
dry	<0.52	<50	<5	NR	
wet	<0.52	100	*38*	***270***	
dry	<0.52	<50	*27*	NR	
wet	<0.52	55	*40*	***270***	2
dry	<0.52	51	24	84	NR
wet	***1.5***	*210*	***69***	***270***	<1
dry	<0.52	74	*33*	71	<1
wet	***1.4***	78	***68***	*170*	1.1
dry	***0.73***	80	***89***	NR	***6.3***
SEEP wet	<0.52	***1,500***	***380***	62	*1.9*
SEEP dry	NA	NA	NA	NA	NA
wet	***0.96***	***830***	***83***	*150*	*1.9*
dry	***1.4***	NR	NR	NR	*4.7*

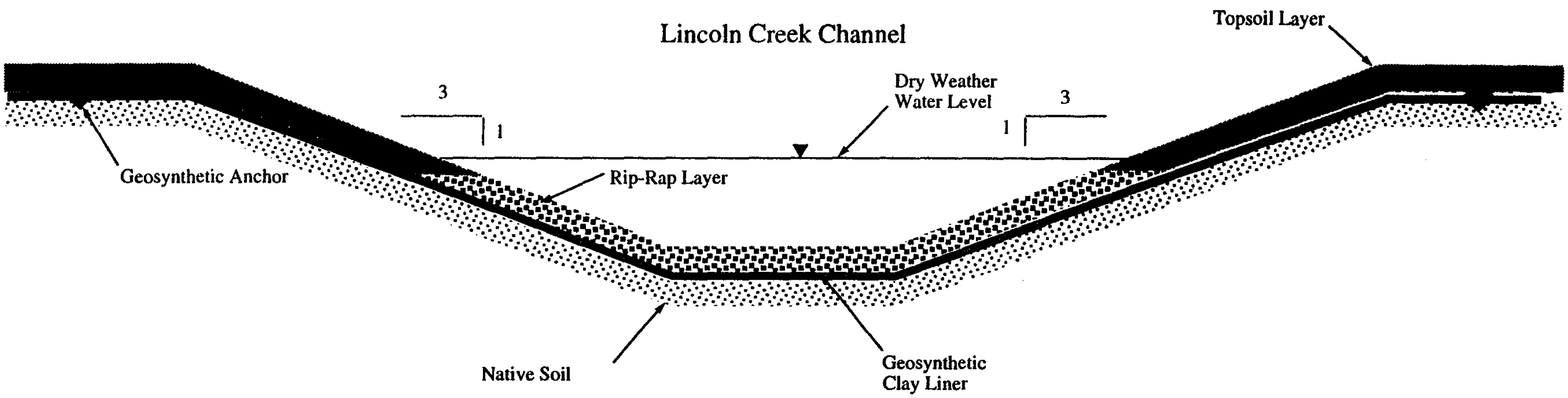
Site	Engineer	Figure 8.1: Water Quality Along Lincoln Creek
Lincoln Creek Reaches 7 and 9 Milwaukee, Wisconsin	**K. SINGH & ASSOCIATES, INC.,** Engineers, Scientists & Environmental Management Consultants 1135 Legion Drive, Elm Grove, Wisconsin 53122, (414) 821-1171	DATE September 25, 1998 · DRAWN BY A.S.M. · REVISIONS BY · DATE · PROJECT NO. 4283 NOT TO SCALE · CHECKED BY · SHEET NO. ONE



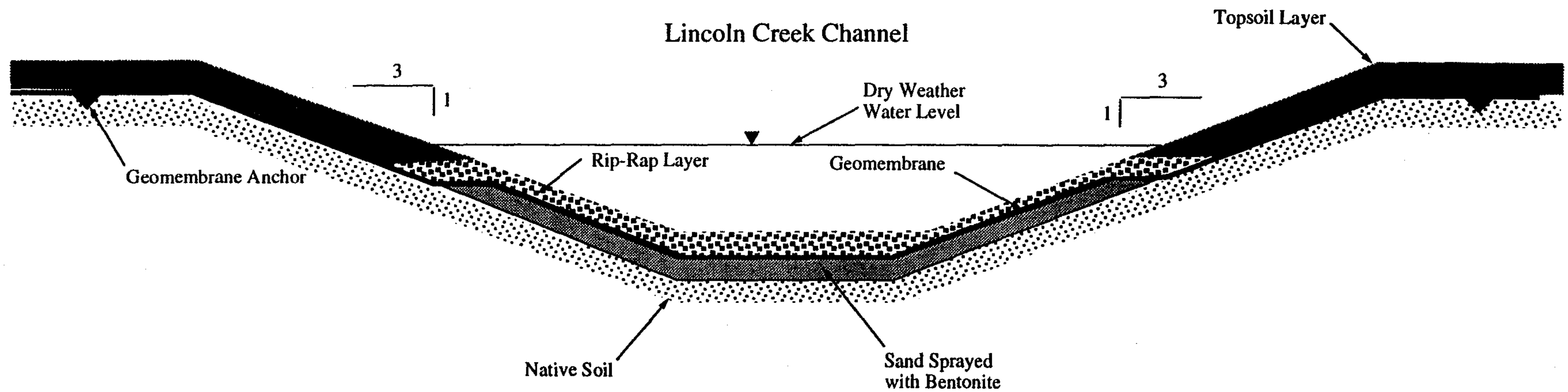
Site **Lincoln Creek** Reaches 7 and 9 Milwaukee, Wisconsin	Engineer **K. SINGH & ASSOCIATES, INC.,** Engineers, Scientists & Environmental Management Consultants 1135 Legion Drive, Elm Grove, Wisconsin 53122, (414) 821-1171	Figure 8.2. Conceptual Design # 1 - Concrete Liner Schematic				
		DATE September 11, 1998	DRAWN BY R.T.R.	REVISIONS BY	DATE	PROJECT NO. 4283
		NOT TO SCALE	CHECKED BY D. K. S.			SHEET NO. ONE



Site	Engineer	Figure 8.3. Conceptual Design # 2 - Compacted Clay & Geomembrane LinerSchematic				
Lincoln Creek Reaches 7 and 9 Milwaukee, Wisconsin	**K. SINGH & ASSOCIATES, INC.,** Engineers, Scientists & Environmental Management Consultants 1135 Legion Drive, Elm Grove, Wisconsin 53122, (414) 821-1171	DATE September 11, 1998	DRAWN BY R.T.R.	REVISIONS BY	DATE	PROJECT NO. 4283
		NOT TO SCALE	CHECKED BY D. K. S.			SHEET NO. ONE



Site	Engineer	Figure 8.4. Conceptual Design # 3 - Geosynthetic Clay Liner Schematic				
Lincoln Creek	**K. SINGH & ASSOCIATES, INC.,**	DATE September 11, 1998	DRAWN BY R.T.R.	REVISIONS BY	DATE	PROJECT NO.
Reaches 7 and 9	Engineers, Scientists & Environmental Management Consultants	NOT TO SCALE	CHECKED BY			4283
Milwaukee, Wisconsin	1135 Legion Drive, Elm Grove, Wisconsin 53122, (414) 821-1171		D. K. S.			SHEET NO.
						ONE



Site
Lincoln Creek
Reaches 7 and 9
Milwaukee, Wisconsin

Engineer
K. SINGH & ASSOCIATES, INC.,
Engineers, Scientists & Environmental Management Consultants
1135 Legion Drive, Elm Grove, Wisconsin 53122, (414) 821-1171

Figure 8.5. Conceptual Design # 4- Compacted Clay, Sand & Geomembrane Liner Schematic

DATE	DRAWN BY	REVISIONS BY	DATE	PROJECT NO.
September 11, 1998	R.T.R.			4283
NOT TO SCALE	CHECKED BY			SHEET NO.
	D. K. S.			ONE

MMSD LABORATORY ANALYSIS - CONTRACT SAMPLES

Field Data

Sample Location: LINCOLN CREEK	Samplers: A. Mc. / R. N.
Sample Type: ☐ Composite ☒ Grab ☐ Time	pH Start / pH End / pH Field
Composite Collection Date(s): to:	Time: to:
Grab Collection Date: 4/28/98	No. Of Bottles: 12
Field Notes: W-SW-1	Samples on Ice: Yes ☒ No ☐

PLEASE CHECK APPLICABLE BOX: **All Parameters requested: ☐** **Only Volatiles requested: ☐**

Analytes Requested

	Analytes *		Bottle #	Bot.Type	Preservative
	Barium ICP Sol. (Ba)	(305)	1	1L	HNO3 < 2 pH
	Calcium ICP Sol. (Ca)	(307)	1	1L	HNO3 < 2 pH
	Chromium ICP Sol. (Cr)	(310)	1	1L	HNO3 < 2 pH
	Iron ICP Sol. (Fe)	(312)	1	1L	HNO3 < 2 pH
	Magnesium ICP Sol. (Mg)	(316)	1	1L	HNO3 < 2 pH
	Manganese ICP Sol. (Mn)	(317)	1	1L	HNO3 < 2 pH
	Zinc ICP Sol. (Zn)	(329)	1	1L	HNO3 < 2 pH
	Arsenic As (GFAA) Sol.	(562)	1	1L	HNO3 < 2 pH
	Cadmium Cd (GFAA) Sol.	(567)	1	1L	HNO3 < 2 pH
	Lead Pb (GFAA) Sol.	(579)	1	1L	HNO3 < 2 pH
	Selenium Se (GFAA) Sol.	(581)	1	1L	HNO3 < 2 pH
	Silver Ag (GFAA) Sol.	(560)	1	1L	HNO3 < 2 pH
	Mercury Hg Sol.	(341)	2	500 mL	HNO3 < 2 pH
	BOD	(003)	3	1L	None
	Alkalinity as CaCO3 Sol.	(402)	4	1L	None
	Chloride Soluble	(403)	4	1L	None
	Nitrate Sol.	(410)	4	1L	None
	Nitrite Sol.	(411)	4	1L	None
	Sulfate Soluble	(407)	4	1L	None
	COD	(007)	5	250 mL	H2SO4 < 2 pH
	Ammonia Nitrogen Sol.	(405)	5	250 mL	H2SO4 < 2 pH
	" " (If no COD requested)		5	125 mL	H2SO4 < 2 pH
X	Hardness as CaCO3	(401)		Calculated	

	Analytes	Bottle Type	Preservative
X	VOC Volatiles List (452)		
	1,2-Dichloropropane	4-40 mL vials	HCl < 2 pH
	1,1-Dichloroethane		
	1,1,2-Trichloroethane		
	1,1-Dichloroethylene		
	1,1,1-Trichloroethane		
	1,2-Dichloroethylene (total)		
	1,2-Dichloroethane		
	2-Butanone		
	4-Methyl-2-Pentanone		
	Benzene		
	Bromodichloromethane		
	Bromoform		
	Bromomethane		
	Carbon Tetrachloride		
	Carbon Disulfide		
	Chlorobenzene		
	Chloroethane		
	Chloroform		
	Chloromethane		
	Cis-1,3-Dichloropropene		
	Dibromochloromethane		
	Ethyl Benzene		
	Methylene Chloride		
	Styrene		
	Tetrachloroethylene		
	Trans-1,3-Dichloropropene		
	Trichloroethylene		
	Vinyl Chloride		
	Xylenes		
x	~~Acetone **~~	~~3-40 mL vials~~	~~HCl < 2 pH~~
x	~~2-Hexanone **~~	~~3-40 mL vials~~	~~HCl < 2 pH~~

* Samples filtered (.45 μm Filter) in the field (with the exception of VOC's). Bottles preserved in the Laboratory. ** Contract Lab Analysis

Lab Notes:

Lab Custody

Relinquished By:	Date:	Time:	Received By:	Date:	Time:
Dalton S. McKeehan	4/29/98	8:15 AM	WCW	4/29	8:20

Samples Received on Ice: ☒ Yes ☐ No — Sample Temperature Upon Receipt in Lab ________ °C

Lab Charge No. W003YC000 **Source Code: 00933** **Lab Number: 3005**

c: custody/lc-grnd2 4/98

MMSD LABORATORY ANALYSIS - CONTRACT SAMPLES

Field Data

Sample Location: LINCOLN CREEK		Samplers: A. Mc. / R. N.	
Sample Type: ☐ Composite ☒ Grab ☐ Time	pH Start	pH End	pH Field
Composite Collection Date(s): to:	Time: to:		
Grab Collection Date: 4/28/98	No. Of Bottles: 12		
Field Notes: W-SW-2	Samples on Ice: Yes ☒ No ☐		

LEASE CHECK APPLICABLE BOX: **All Parameters requested: ☐** **Only Volatiles requested: ☐**

Analytes Requested

Analytes *		Bottle #	Bot.Type	Preservative
Barium ICP Sol. (Ba)	(305)	1	1L	HNO3 < 2 pH
Calcium ICP Sol. (Ca)	(307)	1	1L	HNO3 < 2 pH
Chromium ICP Sol. (Cr)	(310)	1	1L	HNO3 < 2 pH
Iron ICP Sol. (Fe)	(312)	1	1L	HNO3 < 2 pH
Magnesium ICP Sol. (Mg)	(316)	1	1L	HNO3 < 2 pH
Manganese ICP Sol. (Mn)	(317)	1	1L	HNO3 < 2 pH
Zinc ICP Sol. (Zn)	(329)	1	1L	HNO3 < 2 pH
Arsenic As (GFAA) Sol.	(562)	1	1L	HNO3 < 2 pH
Cadmium Cd (GFAA) Sol.	(567)	1	1L	HNO3 < 2 pH
Lead Pb (GFAA) Sol.	(579)	1	1L	HNO3 < 2 pH
Selenium Se (GFAA) Sol.	(581)	1	1L	HNO3 < 2 pH
Silver Ag (GFAA) Sol.	(560)	1	1L	HNO3 < 2 pH
Mercury Hg Sol.	(341)	2	500 mL	HNO3 < 2 pH
BOD	(003)	3	1L	None
Alkalinity as CaCO3 Sol.	(402)	4	1L	None
Chloride Soluble	(403)	4	1L	None
Nitrate Sol.	(410)	4	1L	None
Nitrite Sol.	(411)	4	1L	None
Sulfate Soluble	(407)	4	1L	None
COD	(007)	5	250 mL	H2SO4 < 2 pH
Ammonia Nitrogen Sol.	(405)	5	250 mL	H2SO4 < 2 pH
" " (If no COD requested)		5	125 mL	H2SO4 < 2 pH
Hardness as CaCO3	(401)	Calculated		

	Analytes	Bottle Type	Preservative
X	VOC Volatiles List (452)		
	1,2-Dichloropropane	4-40 mL vials	HCl < 2 pH
	1,1-Dichloroethane		
	1,1,2-Trichloroethane		
	1,1-Dichloroethylene		
	1,1,1-Trichloroethane		
	1,2-Dichloroethylene (total)		
	1,2-Dichloroethane		
	2-Butanone		
	4-Methyl-2-Pentanone		
	Benzene		
	Bromodichloromethane		
	Bromoform		
	Bromomethane		
	Carbon Tetrachloride		
	Carbon Disulfide		
	Chlorobenzene		
	Chloroethane		
	Chloroform		
	Chloromethane		
	Cis-1,3-Dichloropropene		
	Dibromochloromethane		
	Ethyl Benzene		
	Methylene Chloride		
	Styrene		
	Tetrachloroethylene		
	Trans-1,3-Dichloropropene		
	Trichloroethylene		
	Vinyl Chloride		
	Xylenes		
x	~~Acetone **~~	~~3-40 mL vials~~	~~HCl < 2 pH~~
x	~~2-Hexanone **~~	~~3-40 mL vials~~	~~HCl < 2 pH~~

Samples filtered (.45 μm Filter) in the field (with the exception of VOC's). Bottles preserved in the Laboratory. .** Contract Lab Analysis

ıb Notes:

Lab Custody

linquished By	Date:	Time:	Received By:	Date:	Time:
Alan S. McIlheran	4/29/98	8:15AM	XW	4/29	8:20

ımples Received on Ice: ☒ Yes ☐ No

Sample Temperature Upon Receipt in Lab ________ °C

ıb Charge No. W003YC000	**Source Code: 00933**	**Lab Number:** 3006

Sample Site	Sample Date	Lab ID	Test Description	Value Reported	Reporting Units	Level Of Detection	QA Flag	Analytical Method	Analytical Laboratory
TB (Trip Blank)	4/28/1998	3010	Xylene (Total)	ND	ug/Liter	1.2		SW846 8260	EN CHEM
TB (Trip Blank)	4/28/1998	3010	2-Butanone (MEK)	ND	ug/Liter	1.2		SW846 8260	EN CHEM
TB (Trip Blank)	4/28/1998	3010	4-Methyl-2-pentanone (MIBK)	ND	ug/Liter	0.61		SW846 8260	EN CHEM
TB (Trip Blank)	4/28/1998	3010	Carbon disulfide	3.5	ug/Liter	0.40		SW846 8260	EN CHEM
TB (Trip Blank)	4/28/1998	3010	Styrene	ND	ug/Liter	0.37		SW846 8260	EN CHEM
TB (Trip Blank)	4/28/1998	3010	1,2-Dichloroethylene (Total)	ND	ug/Liter	0.90		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	BOD (Soluble)	0.76	mg/Liter	0.2		SM(19) 5210B	MMSD
W-SW-1	4/28/1998	3005	COD (Disolved)	ND	mg/Liter	30.		SM(19) 5220D	MMSD
W-SW-1	4/28/1998	3005	Barium (Soluble) ICP Method	ND	ug/Liter	200.		EPA-846-6010	MMSD
W-SW-1	4/28/1998	3005	Calcium (Soluble) ICP Method	74000.	ug/Liter	88.		EPA-846-6010	MMSD
W-SW-1	4/28/1998	3005	Chromium (Soluble) ICP Method	ND	ug/Liter	5.0		EPA-846-6010	MMSD
W-SW-1	4/28/1998	3005	Iron (Soluble) ICP Method	370.	ug/Liter	50.	Flag	EPA-846-6010	MMSD
W-SW-1	4/28/1998	3005	Magnesium (Soluble) ICP Method	31000.	ug/Liter	780.		EPA-846-6010	MMSD
W-SW-1	4/28/1998	3005	Manganese (Soluble) ICP Method	36.	ug/Liter	1.2		EPA-846-6010	MMSD
W-SW-1	4/28/1998	3005	Zinc (Soluble) ICP Method	22.	ug/Liter	1.1		EPA-846-6010	MMSD
W-SW-1	4/28/1998	3005	Mercury (soluble) Cold-Vapor	ND	ug/Liter	0.045		EPA 7470/7471	MMSD
W-SW-1	4/28/1998	3005	Hardness (Soluble) As CaCO3	314.	mg/Liter	5.0		EPA-846-6010 Calculate	MMSD
W-SW-1	4/28/1998	3005	Alkalinity As CaCO3 (Soluble) Technicon	201.	mg/Liter	3.0	Flag	EPA-600/4-79-020 310.2	MMSD
W-SW-1	4/28/1998	3005	Chloride (Soluble) Technicon	220.	mg/Liter	0.60	Flag	EPA-600/4-79-020 325.2	MMSD
W-SW-1	4/28/1998	3005	Ammonia Nitrogen (Soluble) Technicon	0.080	mg/Liter	0.070		EPA-600/4-79-020 350.1	MMSD
W-SW-1	4/28/1998	3005	Sulfate (Soluble)	63.	mg/Liter	0.27		EPA-600/4-79-020 375.4	MMSD
W-SW-1	4/28/1998	3005	Nitrate (Soluble)	0.29	mg/Liter	0.02		EPA-600/4-79-020 353.2	MMSD
W-SW-1	4/28/1998	3005	Nitrite (Soluble)	0 .0090	mg/Liter	0.006		EPA-600/4-79-020 353.2	MMSD
W-SW-1	4/28/1998	3005	Silver (Soluble) AA-Graphite Furnace	0.50	ug/Liter	0.3	Flag	EPA 7761	MMSD
W-SW-1	4/28/1998	3005	Arsenic (Soluble) AA-Graphite Furnace	1.1	ug/Liter	1.0	Flag	EPA 7060A/7740	MMSD
W-SW-1	4/28/1998	3005	Cadmium (Soluble) AA-Graphite Furnace	ND	ug/Liter	0.10		EPA 7000 Series	MMSD

Sample Site	Sample Date	Lab ID	Test Description	Value Reported	Reporting Units	Level Of Detection	QA Flag	Analytical Method	Analytical Laboratory
W-SW-1	4/28/1998	3005	Lead (Soluble) AA-Graphite Furnace	ND	ug/Liter	2.0		EPA 3070A/7761	MMSD
W-SW-1	4/28/1998	3005	Selenium (Soluble) AA-Graphite Furnace	ND	ug/Liter	2.6	Flag	EPA 7740	MMSD
W-SW-1	4/28/1998	3005	Chloromethane	ND	ug/Liter	0.44		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Bromomethane	ND	ug/Liter	0.94		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Vinyl chloride	ND	ug/Liter	0.52		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Chloroethane	ND	ug/Liter	0.63		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Methylene chloride	ND	ug/Liter	0.38		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	1,1-Dichloroethylene	ND	ug/Liter	0.47		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	1,1-Dichloroethane	ND	ug/Liter	0.61		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Chloroform	ND	ug/Liter	0.41		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Bromoform	ND	ug/Liter	0.58		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	1,2-Dichloroethane	ND	ug/Liter	0.54		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	1,1,1-Trichloroethane	ND	ug/Liter	0.53		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Carbon tetrachloride	ND	ug/Liter	0.90		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Bromodichloromethane	ND	ug/Liter	0.41		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	1,2-Dichloropropane	ND	ug/Liter	0.34		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Cis-1,3-dichloropropene	ND	ug/Liter	0.54		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Trans-1,3-dichloropropene	ND	ug/Liter	0.26		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Trichloroethylene	ND	ug/Liter	0.49		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Benzene	ND	ug/Liter	0.44		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Dibromochloromethane	ND	ug/Liter	0.43		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	1,1,2-Trichloroethane	ND	ug/Liter	0.47		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Tetrachloroethylene	ND	ug/Liter	0.41		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Chlorobenzene	ND	ug/Liter	0.43		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Ethylbenzene	ND	ug/Liter	0.50		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Xylene (Total)	ND	ug/Liter	1.2		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	2-Butanone (MEK)	ND	ug/Liter	1.2		SW846 8260	EN CHEM

Sample Site	Sample Date	Lab ID	Test Description	Value Reported	Reporting Units	Level Of Detection	QA Flag	Analytical Method	Analytical Laboratory
W-SW-1	4/28/1998	3005	4-Methyl-2-pentanone (MIBK)	ND	ug/Liter	0.61		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Carbon disulfide	ND	ug/Liter	0.40		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	Styrene	ND	ug/Liter	0.37		SW846 8260	EN CHEM
W-SW-1	4/28/1998	3005	1,2-Dichloroethylene (Total)	ND	ug/Liter	0.90		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	BOD (Soluble)	1.1	mg/Liter	0.2		SM(19) 5210B	MMSD
W-SW-2	4/28/1998	3006	COD (Disolved)	41.	mg/Liter	30.		SM(19) 5220D	MMSD
W-SW-2	4/28/1998	3006	Barium (Soluble) ICP Method	ND	ug/Liter	200.		EPA-846-6010	MMSD
W-SW-2	4/28/1998	3006	Calcium (Soluble) ICP Method	73000.	ug/Liter	88.		EPA-846-6010	MMSD
W-SW-2	4/28/1998	3006	Chromium (Soluble) ICP Method	ND	ug/Liter	5.0		EPA-846-6010	MMSD
W-SW-2	4/28/1998	3006	Iron (Soluble) ICP Method	100.	ug/Liter	50.	Flag	EPA-846-6010	MMSD
W-SW-2	4/28/1998	3006	Magnesium (Soluble) ICP Method	31000.	ug/Liter	780.		EPA-846-6010	MMSD
W-SW-2	4/28/1998	3006	Manganese (Soluble) ICP Method	38.	ug/Liter	1.2		EPA-846-6010	MMSD
W-SW-2	4/28/1998	3006	Zinc (Soluble) ICP Method	28.	ug/Liter	1.1		EPA-846-6010	MMSD
W-SW-2	4/28/1998	3006	Mercury (soluble) Cold-Vapor	ND	ug/Liter	0.045		EPA 7470/7471	MMSD
W-SW-2	4/28/1998	3006	Hardness (Soluble) As CaCO3	307.	mg/Liter	5.0		EPA-846-6010 Calculate	MMSD
W-SW-2	4/28/1998	3006	Alkalinity As CaCO3 (Soluble) Technicon	195.	mg/Liter	3.0	Flag	EPA-600/4-79-020 310.2	MMSD
W-SW-2	4/28/1998	3006	Chloride (Soluble) Technicon	270.	mg/Liter	0.60	Flag	EPA-600/4-79-020 325.2	MMSD
W-SW-2	4/28/1998	3006	Ammonia Nitrogen (Soluble) Technicon	0.10	mg/Liter	0.070		EPA-600/4-79-020 350.1	MMSD
W-SW-2	4/28/1998	3006	Sulfate (Soluble)	58.	mg/Liter	0.27		EPA-600/4-79-020 375.4	MMSD
W-SW-2	4/28/1998	3006	Nitrate (Soluble)	0.26	mg/Liter	0.02		EPA-600/4-79-020 353.2	MMSD
W-SW-2	4/28/1998	3006	Nitrite (Soluble)	0.010	mg/Liter	0.006		EPA-600/4-79-020 353.2	MMSD
W-SW-2	4/28/1998	3006	Silver (Soluble) AA-Graphite Furnace	0.60	ug/Liter	0.3	Flag	EPA 7761	MMSD
W-SW-2	4/28/1998	3006	Arsenic (Soluble) AA-Graphite Furnace	ND	ug/Liter	1.0	Flag	EPA 7060A/7740	MMSD
W-SW-2	4/28/1998	3006	Cadmium (Soluble) AA-Graphite Furnace	ND	ug/Liter	0.10		EPA 7000 Series	MMSD
W-SW-2	4/28/1998	3006	Lead (Soluble) AA-Graphite Furnace	ND	ug/Liter	2.0		EPA 3070A/7761	MMSD
W-SW-2	4/28/1998	3006	Selenium (Soluble) AA-Graphite Furnace	20.	ug/Liter	2.6	Flag	EPA 7740	MMSD

Sample Site	Sample Date	Lab ID	Test Description	Value Reported	Reporting Units	Level Of Detection	QA Flag	Analytical Method	Analytical Laboratory
W-SW-2	4/28/1998	3006	Chloromethane	ND	ug/Liter	0.44		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	Bromomethane	ND	ug/Liter	0.94		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	Vinyl chloride	ND	ug/Liter	0.52		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	Chloroethane	ND	ug/Liter	0.63		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	Methylene chloride	ND	ug/Liter	0.38		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	1,1-Dichloroethylene	ND	ug/Liter	0.47		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	1,1-Dichloroethane	ND	ug/Liter	0.61		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	Chloroform	ND	ug/Liter	0.41		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	Bromoform	ND	ug/Liter	0.58		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	1,2-Dichloroethane	ND	ug/Liter	0.54		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	1,1,1-Trichloroethane	ND	ug/Liter	0.53		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	Carbon tetrachloride	ND	ug/Liter	0.90		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	Bromodichloromethane	ND	ug/Liter	0.41		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	1,2-Dichloropropane	ND	ug/Liter	0.34		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	Cis-1,3-dichloropropene	ND	ug/Liter	0.54		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	Trans-1,3-dichloropropene	ND	ug/Liter	0.26		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	Trichloroethylene	ND	ug/Liter	0.49		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	Benzene	ND	ug/Liter	0.44		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	Dibromochloromethane	ND	ug/Liter	0.43		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	1,1,2-Trichloroethane	ND	ug/Liter	0.47		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	Tetrachloroethylene	ND	ug/Liter	0.41		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	Chlorobenzene	ND	ug/Liter	0.43		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	Ethylbenzene	ND	ug/Liter	0.50		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	Xylene (Total)	ND	ug/Liter	1.2		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	2-Butanone (MEK)	ND	ug/Liter	1.2		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	4-Methyl-2-pentanone (MIBK)	ND	ug/Liter	0.61		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	Carbon disulfide	ND	ug/Liter	0.40		SW846 8260	EN CHEM

'ND' Not Detected 'NR' Not Requested 'NS' Sample Lost

Sample Site	Sample Date	Lab ID	Test Description	Value Reported	Reporting Units	Level Of Detection	QA Flag	Analytical Method	Analytical Laboratory
W-SW-2	4/28/1998	3006	Styrene	ND	ug/Liter	0.37		SW846 8260	EN CHEM
W-SW-2	4/28/1998	3006	1,2-Dichloroethylene (Total)	2.5	ug/Liter	0.90		SW846 8260	EN CHEM
FB (Field Blank	4/29/1998	3039	BOD (Soluble)	NR	mg/Liter	0.2		SM(19) 5210B	MMSD
FB (Field Blank	4/29/1998	3039	COD (Disolved)	NR	mg/Liter	30.		SM(19) 5220D	MMSD
FB (Field Blank	4/29/1998	3039	Barium (Soluble) ICP Method	NR	ug/Liter	200.		EPA-846-6010	MMSD
FB (Field Blank	4/29/1998	3039	Calcium (Soluble) ICP Method	NR	ug/Liter	88.		EPA-846-6010	MMSD
FB (Field Blank	4/29/1998	3039	Chromium (Soluble) ICP Method	NR	ug/Liter	5.0		EPA-846-6010	MMSD
FB (Field Blank	4/29/1998	3039	Iron (Soluble) ICP Method	NR	ug/Liter	50.		EPA-846-6010	MMSD
FB (Field Blank	4/29/1998	3039	Magnesium (Soluble) ICP Method	NR	ug/Liter	780.		EPA-846-6010	MMSD
FB (Field Blank	4/29/1998	3039	Manganese (Soluble) ICP Method	NR	ug/Liter	1.2		EPA-846-6010	MMSD
FB (Field Blank	4/29/1998	3039	Zinc (Soluble) ICP Method	NR	ug/Liter	1.1		EPA-846-6010	MMSD
FB (Field Blank	4/29/1998	3039	Mercury (soluble) Cold-Vapor	NR	ug/Liter	0.045		EPA 7470/7471	MMSD
FB (Field Blank	4/29/1998	3039	Hardness (Soluble) As CaCO3	NR	mg/Liter	5.0		EPA-846-6010 Calculate	MMSD
FB (Field Blank	4/29/1998	3039	Alkalinity As CaCO3 (Soluble) Technicon	NR	mg/Liter	3.0		EPA-600/4-79-020 310.2	MMSD
FB (Field Blank	4/29/1998	3039	Chloride (Soluble) Technicon	NR	mg/Liter	0.60		EPA-600/4-79-020 325.2	MMSD
FB (Field Blank	4/29/1998	3039	Ammonia Nitrogen (Soluble) Technicon	NR	mg/Liter	0.070		EPA-600/4-79-020 350.1	MMSD
FB (Field Blank	4/29/1998	3039	Sulfate (Soluble)	NR	mg/Liter	0.27		EPA-600/4-79-020 375.4	MMSD
FB (Field Blank	4/29/1998	3039	Nitrate (Soluble)	NR	mg/Liter	0.02		EPA-600/4-79-020 353.2	MMSD
FB (Field Blank	4/29/1998	3039	Nitrite (Soluble)	NR	mg/Liter	0.006		EPA-600/4-79-020 353.2	MMSD
FB (Field Blank	4/29/1998	3039	Silver (Soluble) AA-Graphite Furnace	NR	ug/Liter	0.3		EPA 7761	MMSD
FB (Field Blank	4/29/1998	3039	Arsenic (Soluble) AA-Graphite Furnace	NR	ug/Liter	1.0		EPA 7060A/7740	MMSD
FB (Field Blank	4/29/1998	3039	Cadmium (Soluble) AA-Graphite Furnace	NR	ug/Liter	0.10		EPA 7000 Series	MMSD
FB (Field Blank	4/29/1998	3039	Lead (Soluble) AA-Graphite Furnace	NR	ug/Liter	2.0		EPA 3070A/7761	MMSD
FB (Field Blank	4/29/1998	3039	Selenium (Soluble) AA-Graphite Furnace	NR	ug/Liter	2.6		EPA 7740	MMSD
FB (Field Blank	4/29/1998	3039	Chloromethane	ND	ug/Liter	0.44		SW846 8260	EN CHEM