HUMAN HEALTH AND ENVIRONMENTAL SIGNIFICANCE OF GROUNDWATER QUALITY DATA

GENERAL MOTORS CORPORATION
DANVILLE FOUNDRY LANDFILL
DANVILLE, ILLINOIS

IEPA ID: 1838040024
Permit No: 1985-7-OP
Supplemental Permit No: 2003-011-SP

Prepared for

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Pontiac, Michigan

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April 14, 2005

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[1] This figure is from the Closure/Post-Closure Care Plan (RMT 1994).

1.0 INTRODUCTION

General Motors Corporation (GM) received Notices of Violation (NOVs) from the Illinois Environmental Protection Agency (IEPA) on March 16, 2004 and July 28, 2004 for its Danville Foundry Landfill ("Site") in Danville, Illinois. These NOVs addressed certain aspects of the groundwater monitoring program at the Site, including the potential for certain constituents in groundwater at the Site to pose a potential threat to human health and the environment. The purpose of this report is to present the results of an evaluation that was conducted using existing groundwater quality data to determine whether the concentrations of these constituents have had any significant effect on human health and the environment.

According to the NOVs, the following constituents have concentrations in on-site groundwater that are higher than the Illinois Class IV groundwater quality standards:

- total dissolved solids (TDS)
- pH
- chloride
- fluoride
- iron
- manganese
- sulfate

The evaluation discussed in this report considers the potential for exposure of human and ecological receptors to these constituents via any current or reasonably expected future groundwater use downgradient of the Site, and via groundwater discharge to surface water in the Vermillion River. Discussion of the evaluation and results is organized as follows:

- Section 2 discusses current and reasonably expected future groundwater and surface water uses, and calculations for assessing the potential effects of groundwater discharge on surface water quality in the Vermillion River. Details of the groundwater discharge calculations are provided in Appendix B.

- Section 3 summarizes the conclusions of the evaluation discussed in this report.

- Section 4 lists the references cited in this report.

Tables, figures, and appendices that include supporting information for this evaluation are provided after the text.

2.0 POTENTIAL EXPOSURE TO GROUNDWATER

This section first provides background information on the Site's location, geology, and hydrogeology, and then discusses the current and expected future uses of groundwater and surface water at and near the Site. Potential exposure to groundwater constituents via discharge of groundwater to surface water in the Vermillion River is then discussed for three different scenarios.

2.1 Location, Geology, Hydrogeology

As shown on Figure 1, the Site is located in Vermillion County in the southwestern portion of the City of Danville, Illinois. The landfill is located north of the northern portion of the former GM Danville Foundry and is approximately 200 feet southwest of the Vermillion River (Figure 2). Figure 2 also shows the locations of the groundwater monitoring wells that GM uses for monitoring groundwater quality around the Site, per the requirements specified in the IEPA's post-closure permit for the Site (Permit No. 1985-7-OP).

The geology at the Site consists of a layer of foundry sand with variable thickness, other fill materials, and glacial deposits of dense silty clay. In addition to the glacial deposits, alluvial deposits of light brown, silty sand common in the Vermillion River Valley are present on the north edge of the landfill area. Native clays and silts are underlain by shale bedrock of the Pennsylvanian System.

Within the shale is the Danville Coal Seam. Regional information indicates that this coal seam dips slightly to the south. The seam has been extensively mined, by both strip mining and room and pillar mining, in the southeast and northwest portions of the landfill (see Figure 3). These mining practices have disrupted the materials overlying the coal and resulted in formation of potential conduits for groundwater flow which may have caused iron and other metals to be naturally elevated in the local groundwater.

Extensive groundwater monitoring over many years at the Site shows that groundwater flow in the water-table aquifer is generally north to northeast towards the Vermillion River. Several groundwater contour maps that show the consistency in groundwater flow direction are provided in Appendix A. Based on the groundwater flow patterns shown in these groundwater contours maps, shallow groundwater that flows beneath the Site is expected to discharge to the Vermillion River.

2.2 Groundwater Use

Groundwater in the area between the landfill and the River is not currently used for any purpose and is unlikely to be used in the future due to the physical features of the land in this area. The terrain in this area consists of steeply sloped and heavily vegetated land. Similarly, the area north of the landfill is comprised of steep slopes, wetlands, and heavily vegetated and undeveloped land. Drinking water at and near the Site is supplied by the City of Danville from the Vermillion River reservoir, which is located upstream of the Site. Due to the terrain and the availability of an existing drinking water supply, groundwater at and downgradient of the Site is unlikely to be used in the future as a potable or non-potable water source. Therefore, there is no current or reasonably expected future pathway for human exposure to groundwater downgradient of the Site via groundwater use.

2.3 Surface Water Use

The nearest surface water body downgradient of the Site is the Vermillion River, which is located approximately 200 feet to the northeast as shown on Figure 2. Because groundwater at and downgradient of the Site has no current or reasonably expected future use, the only potential for human or ecological exposure to constituents in groundwater at the Site is via discharge to the Vermillion River and receptor contact with surface water in the River, along and downstream of the Site.

As noted above, a reservoir is located on the Vermillion River upstream of the Site that provides drinking water for the Site and the surrounding area. According to the IEPA, the River segment along the Site is classified for “general use”, and surface water in this segment is subject to the General Use Water Quality Standards (35 IAC 302.204 and 208). However, concentrations of iron in the River upstream of the Site do not meet the General Use Water Quality Standards, according to United States Geological Survey (USGS) surface water quality data (USGS 2004).

2.4 Groundwater Discharge to Surface Water

The potential effects of groundwater discharge from the Site to the Vermillion River were evaluated using different combinations of constituent concentrations in groundwater and volumetric flow rates in the River. The concentrations of groundwater constituents in the Vermillion River estimated under the different conditions were then compared with the General Use Water Quality Standards to evaluate the significance of groundwater discharge.

The constituents included in the calculations are all the constituents identified in the IEPA’s March and July 2004 NOVs. For chloride, fluoride, iron, manganese, and sulfate, both filtered and unfiltered data, if available, were included in the evaluation.

Estimates of concentrations in surface water were calculated under three scenarios that used different assumptions regarding the concentrations of the constituents in groundwater and the surface water volumetric flow rate in the Vermillion River. These scenarios are as follows:

1. Reasonable Maximum Scenario – This scenario used the 95% upper confidence limit (UCL) on the mean concentrations in groundwater at the Site from 1992 to 2003, in combination with the 7-day 10-year low flow (7Q10) for this segment of the River. Using the 95% UCL to represent the concentrations of constituents in groundwater is a conservative estimate of the average concentrations in groundwater over time. Using the 7Q10 low flow to represent the river flow results in an extremely conservative estimation of the mixing between the groundwater and the surface water. The estimated concentrations in the River represent the reasonable maximum concentrations that would be expected due to groundwater discharge from the Site.

2. Central Tendency Scenario – This scenario used the 95% UCLs in combination with the harmonic mean flow in the River. Using the harmonic mean flow to represent the river flow results in an average estimate of the mixing between the groundwater and the surface water. The estimated concentrations in the River represent the typical concentrations that would be expected due to groundwater discharge from the Site.

3. Upper-Bound Scenario – This scenario used the assumption that the highest observed concentrations in groundwater at the Site from 1992 to 2003 discharges to the River during the 7Q10 low flow. This combination of conditions (the highest analyte concentrations observed in any downgradient monitoring well and very low surface water flow) would not be reasonably expected to occur at the Site. Therefore, the estimated concentrations of analytes in surface water for this scenario are considered theoretical upper-bound estimates.

Details of the calculations for estimating the surface water concentrations in the River under these three scenarios are provided in Appendix B. Results of the calculations are discussed below.

2.4.1 Reasonable Maximum Scenario

The reasonable maximum (RM) scenario assumed that constituents in groundwater discharge to the River at the 95% UCL, based on groundwater monitoring data collected from 1992 to 2003, and that surface water in the River is flowing at the 7Q10 rate. The estimated reasonable maximum surface water concentrations in the River are shown in Table 1.

The estimated concentrations of constituents in surface water (assuming negligible upstream concentrations) were compared to the laboratory reporting limits on Table 1 to determine if the groundwater discharge would cause a measurable change in surface water quality in the River. As shown in Table 1, iron (total and dissolved) and TDS have estimated surface water concentrations due to the discharge of groundwater to the Vermillion River that would be measurable under the RM scenario. In other words, with the possible exception of iron and TDS, there would be no measurable effect on surface water quality in the River as a result of groundwater discharge from the Site under the RM assumptions about constituent concentrations in groundwater and River flow. Moreover, all of the estimated constituent concentrations in surface water, including iron and TDS, are orders of magnitude below the General Use Water Quality Standards, when negligible upstream concentrations are assumed. This shows that groundwater discharge to the River in this scenario does not pose a significant threat.

When the estimated groundwater discharge is combined with actual upstream concentrations in the River, only iron (total) has an estimated surface water concentration that is higher than the General Use Water Quality Standards. However, the estimated iron (total) concentration in the River is entirely attributable to an upstream concentration that is already higher than its General Use Water Quality Standard. As shown on Table 1, the estimated contribution of iron from on-site groundwater to surface water is two orders of magnitude lower than the existing upstream concentration of iron.

2.4.2 Central Tendency Scenario

The central tendency (CT) scenario assumed that concentrations of constituents in groundwater discharging to the River are the 95% UCLs of concentrations in groundwater, and that surface water is flowing at an average flow rate represented by the harmonic mean. The estimated typical concentrations in the River are shown in Table 2.

The estimated concentrations of constituents in surface water (assuming negligible upstream concentrations) were compared to the laboratory reporting limits on Table 2 to determine if groundwater discharge would cause a measurable change in surface water quality in the River. As shown on Table 2, iron (total) is the only parameter with an estimated surface water concentration that would be measurable under the CT scenario. In other words, with the possible exception of iron, there would be no measurable effect on surface water quality in the River as a result of groundwater discharge from the Site under the CT assumptions about constituent concentrations in groundwater and River flow. Moreover, the estimated constituent concentrations in surface water, including iron, are orders of magnitude below the General Use Water Quality Standards, when negligible upstream concentrations are assumed. This shows that groundwater discharge to the River in this scenario does not pose a significant threat. As noted in Section 2.4, the concentrations estimated in this scenario represent the typical concentrations that would be expected due to groundwater discharge from the Site.

Similar to the RM scenario, when the estimated groundwater discharge is combined with actual upstream concentrations in the River, only iron (total) has an estimated surface water concentration that is higher than the General Use Water Quality Standards. However, as discussed in Section 2.4.1, the estimated iron (total) concentration in the River is entirely attributable to an upstream concentration that is already higher than its General Use Water Quality Standard. As shown on Table 2, the estimated contribution of iron from on-site groundwater to surface water is two orders of magnitude lower than the existing upstream concentration of iron.

2.4.3 Upper-Bound Scenario

The upper-bound scenario assumed that constituents in groundwater discharge to the River at the maximum observed concentrations, based on the same groundwater data used in the RM scenario, and that surface water in the River is flowing at the unusually low flow rate characterized by the 7Q10 flow. As noted above, this combination of conditions (the highest analyte concentrations observed in any downgradient monitoring well from 1992 to 2003 and very low surface water flow) would not be reasonably expected to occur at the Site. The estimated theoretical upper-bound surface water concentrations are shown in Table 3.

The estimated concentrations of constituents in surface water (assuming negligible upstream concentrations) were compared to the reporting limits on Table 3 to determine if the estimated change in surface water quality due to groundwater discharge would be measurable in the River. As shown on Table 3, iron (total and dissolved) and TDS have estimated surface water concentrations that would be measurable under these theoretical upper-bound conditions. In other words, with the possible exception of iron and TDS, there would be no measurable effect on surface water quality in the River as a result of groundwater discharge from the Site, even under the theoretical worst-case assumptions about constituent concentrations in groundwater and River flow. Moreover, all of the estimated concentrations of constituents in the River, including iron and TDS, are well below the applicable General Use Water Quality Standards. This shows that groundwater discharge to the River in this scenario does not pose a significant threat, even under these theoretical upper-bound conditions.

Similar to the other scenarios, when the estimated groundwater discharge is combined with actual upstream concentrations in the River, only iron (total) has an estimated surface water concentration that is higher than the General Use Water Quality Standards. However, as discussed previously, the estimated iron (total) concentration in the River is attributable to an upstream concentration that is already higher than its General Use Water Quality Standard. As shown on Table 3, the estimated contribution of iron from on-site groundwater to surface water is an order of magnitude lower than existing upstream concentration of iron.

3.0 CONCLUSIONS

The results for the three scenarios discussed in Section 2.4 show that concentrations of constituents in groundwater discharging to surface water in the Vermillion River may result in measurable changes in surface water quality for only iron and TDS. However, these estimated changes in surface water quality are at least an order of magnitude lower than existing upstream surface water concentrations for both iron and TDS. Furthermore, none of the estimated changes would cause surface water concentrations in the River to exceed applicable surface water quality standards (where the upstream concentrations do not already exceed the standards). The findings of this evaluation show that groundwater discharge from the Site to the River does not pose a significant threat, even under theoretical upper-bound conditions.

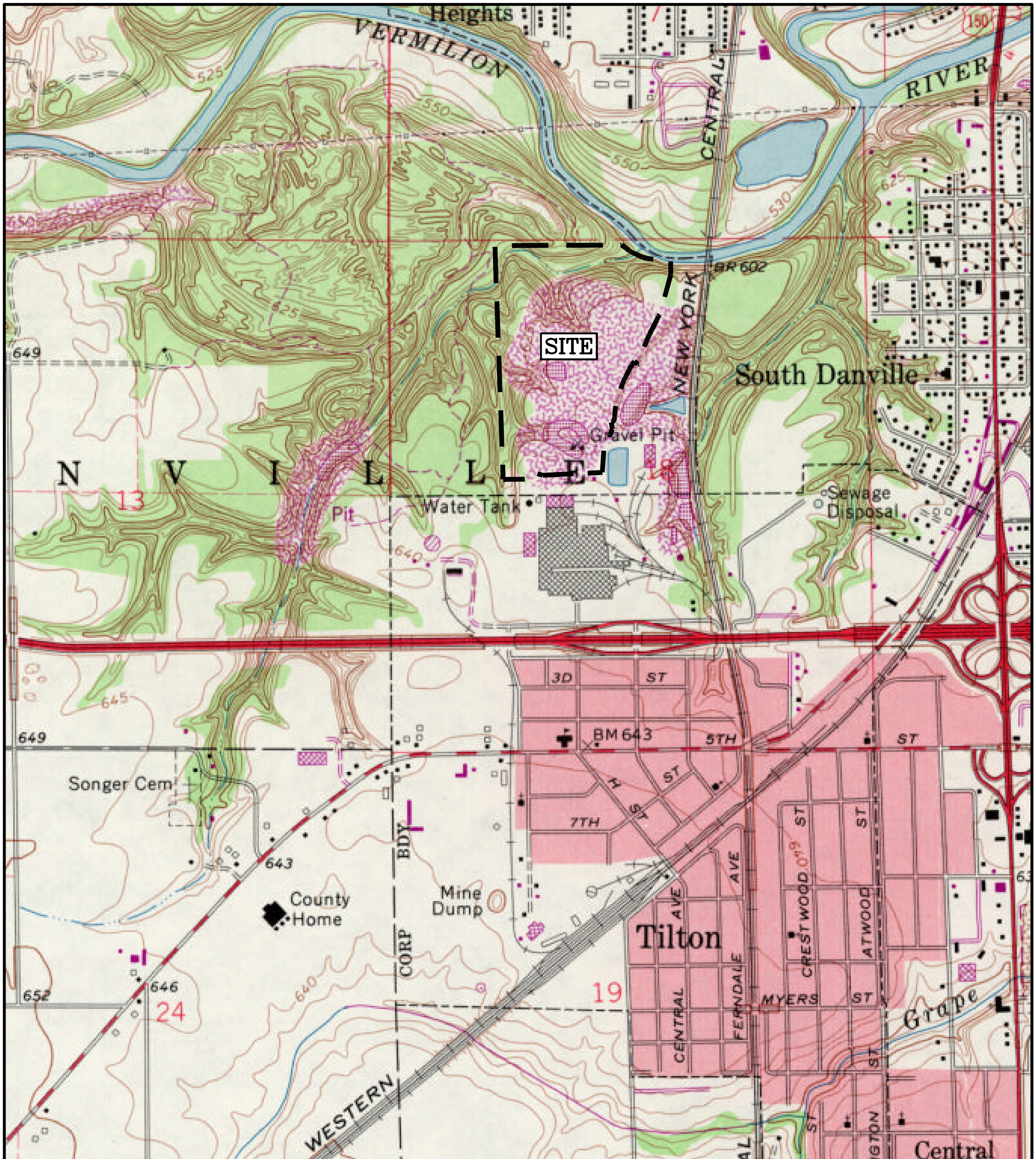
4.0 REFERENCES

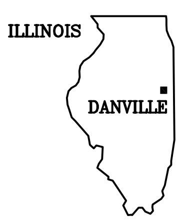
RMT, Inc. (RMT). 1994. Closure/Post-Closure Care Plan Groundwater Monitoring Network Evaluation, General Motors-Powertrain Division Landfill, Danville, Illinois. January.

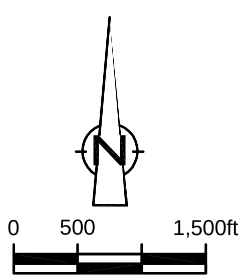
United States Environmental Protection Agency (USEPA). 1987. Alternate Concentration Limit Guidance, Part I, ACL Policy and Information Requirements, Interim Final. OSWER Directive 9481.00-6C. EPA/530-SW-87-017. July.

United States Geological Survey (USGS). 2004. Online Streamflow Statistics. http://www.usgs.gov/.

F I G U R E S







BASE SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC QUADRANGLE; DANVILLE, ILLINOIS 1978

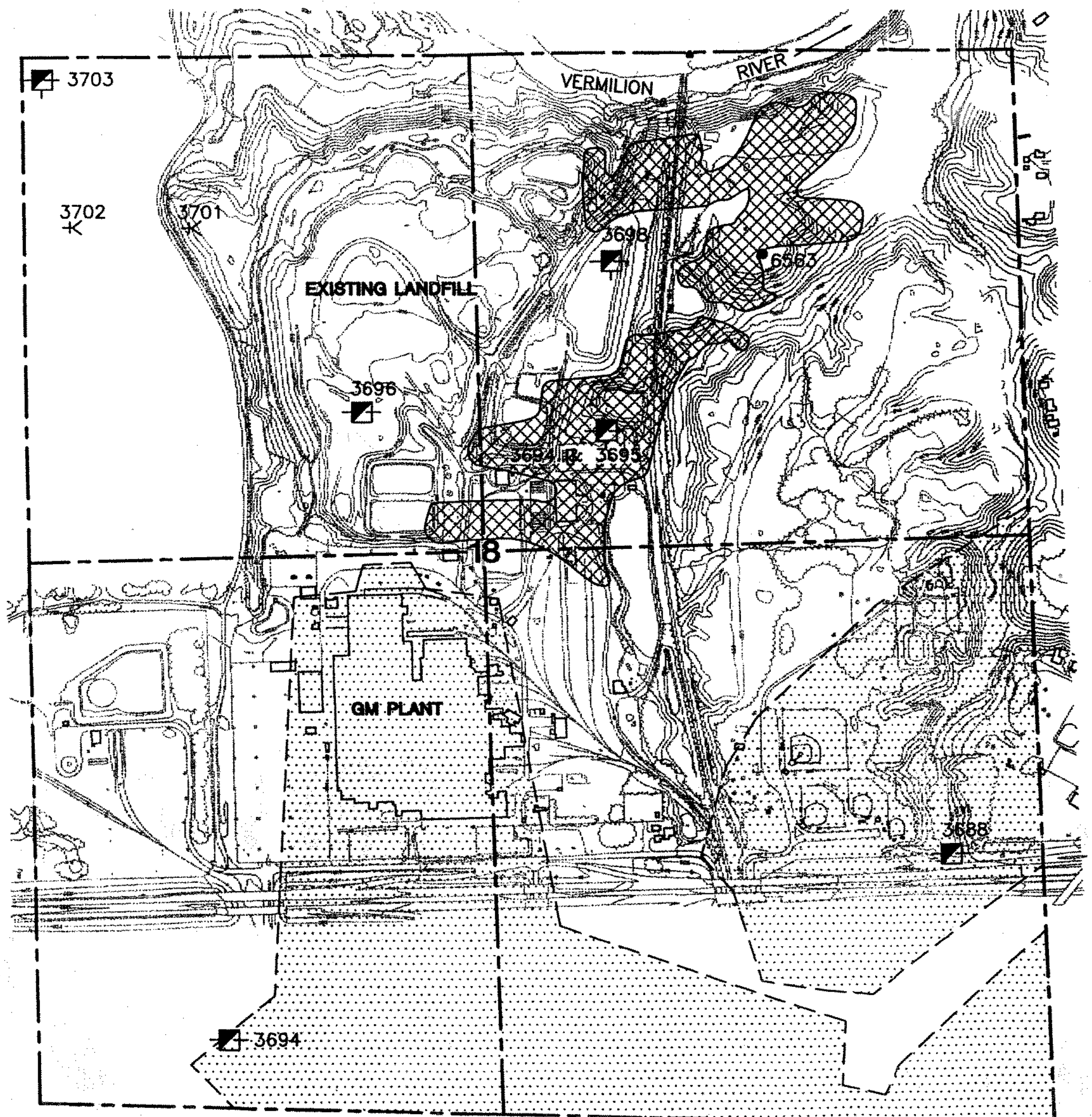
figure 1

SITE LOCATION
GM DANVILLE FOUNDRY LANDFILL
Danville, Illinois

figure 2

SITE PLAN
GM DANVILLE FOUNDRY LANDFILL
Danville, Illinois

12615-00(SOURCE)GN-CO005 SEP 28/2004



LEGEND

(shaft symbol)	ABANDONED SHAFT
(slope symbol)	ABANDONED SLOPE
●	UNCERTAIN TYPE OR LOCATION
(drift symbol)	ABANDONED DRIFT
(dotted pattern)	INFERRED LIMIT OF UNDERGROUND MINES
(crosshatch pattern)	"DANVILLE DRIFT" MINE AREA
— - —	SECTION LINE
6563	ILLINOIS STATE GEOLOGICAL SURVEY INDEX NUMBER

NOTES

1. BASE MAP WAS PRODUCED BY AIR LAND SURVEYS INC. OF CLARKSTON, MICHIGAN. (DATED 3-92)
2. MINE LOCATIONS AND TYPE SHOWN WERE REFERENCED FROM "DIRECTORY OF COAL MINES IN ILLINOIS", ILLINOIS DEPARTMENT OF ENERGY AND NATURAL RESOURCES; DATED JANUARY 1991. (VERMILION CO.)
3. BASE MAP IS SHOWING FORMER COAL MINE LOCATIONS IN SECTION 18, T. 19 N., R. 11 W., OF VERMILION, CO.
4. MINES REFERENCED IN THE DIRECTORY (NOTE 2) NOT SHOWN ON THIS MAP BUT ARE WITHIN SECTION 18 ARE; 3699 AND 3693. (ISGS INDEX NUMBER)

0 600 1200

SCALE: 1" = 600'

COAL MINE LOCATIONS MAP
GM POWERTRAIN PLANT
DANVILLE, ILLINOIS

RMT INC.

DWN. BY:	EAS/DKJ
DATE:	SEPTEMBER 1994
PROJ.#	2219.14
FILE #	22191404

Figure 3

T A B L E S

Table 1: Reasonable Maximum Scenario
Potential Groundwater Effects on Vermillion River using 95% UCL Groundwater Concentration and 7Q10 Low Flow Rate
General Motors Foundry Landfill, Danville, Illinois

Chem Group	Constituents	CASRN	95% Upper Confidence Limit on the Mean Concentration Detected from Groundwater Monitoring [1] (mg/L)	Class IV Groundwater Standard (35 IAC 620.440) [2] (mg/L)	Estimated Constituent Concentration in Surface Water Assuming Negligible Upstream Concentrations [3] (mg/L)	Upstream Constituent Concentration in the Vermillion River [4] (mg/L)	Estimated Constituent Concentration in Surface Water Assuming Upstream Concentrations [3] (mg/L)	General Use Water Quality Standards (35 IAC 302.204-pH and 208-others) (mg/L)	Reporting Limit for Aqueous Analysis [5] (mg/L)
WQ	Chloride	16887-00-6	4.1E+01	2.2E+01	4.0E-02	N/A	N/A	5.0E+02	5.0E+00
INORG	Fluoride	16984-48-8	5.4E+00	4.0E+00	5.2E-03	N/A	N/A	1.4E+00	5.0E-01
INORG	Iron	7439-89-6	6.4E+01	2.1E-01	6.1E-02	***2.3E+00***	***2.3E+00***	1.0E+00	1.0E-02
INORG	Manganese	7439-96-5	2.6E+00	1.2E+00	2.5E-03	1.1E-01	1.1E-01	1.0E+00	1.0E-02
WQ	Sulfate	14808-79-8	7.9E+02	1.9E+02	7.6E-01	N/A	N/A	5.0E+02	1.5E+01
PHYS	Total Dissolved Solids (TDS)	C-010	1.3E+03	7.3E+02	1.3E+00	N/A	N/A	1.0E+03	1.0E+00
WQ	pH Field	C-006	5.63 - 8.12 (s.u.; range)	6.5 - 9 (s.u.)	6.99 - 7.02 (s.u.)	6.7 - 8.8 (s.u.)	6.7 - 8.8 (s.u.)	6.5 - 9 (s.u.)	field measurement
WQ	Chloride (Dissolved)	16887-00-6	3.6E+01	2.2E+01	3.4E-02	3.6E+01	3.6E+01	5.0E+02	5.0E+00
INORG	Fluoride (Dissolved)	16984-48-8	N/A	4.0E+00	N/A	3.1E-01	N/A	1.4E+00	5.0E-01
INORG	Iron (Dissolved)	7439-89-6	3.1E+01	2.1E-01	3.0E-02	4.7E-02	7.7E-02	1.0E+00	1.0E-02
INORG	Manganese (Dissolved)	7439-96-5	2.1E+00	1.2E+00	2.0E-03	1.9E-02	2.1E-02	1.0E+00	1.0E-02
WQ	Sulfate (Dissolved)	14808-79-8	6.1E+02	1.9E+02	5.8E-01	9.0E+01	9.1E+01	5.0E+02	1.5E+01

Notes:

N/A - Not Analyzed

(1) Wells include: G19S, G32S, G41S, G41D, G42S, G42D (from 1992-2003)

The 95% UCL is calculated using a non-parametric bootstrap method known as the bias-corrected and accelerated method (Efron and Tibshirani 1998) with 4,000 bootstrap replications to ensure adequate accuracy.

If the 95% UCL is greater than the maximum detected concentration, then the maximum detected concentration is shown.

(2) According to IEPA, the Class IV Objective for fluoride is set to its Class II Objective, and the Class IV Objectives for the other parameters are based on background levels.

(3) The following assumptions and equations are used to calculate the concentration of constituents in the Vermillion River

Values in bold, italics exceed General Use Water Quality Standards.

The cross-sectional area where groundwater seeps into the River is assumed to be the average depth of the River multiplied by the width of the site next to the River.

Length of Groundwater Seepage to River =	75	ft	Estimated based on site knowledge; Depth of River + 1/2 Width of River
Width of Site =	850	ft	Estimated from site figures
Cross-Sectional Area of Groundwater Seepage =	63750	ft^2	Calculated; A = Length of Groundwater Seepage to River x Width of Site
Flow Rate of River =	4.2E+01	ft^3/sec	Value shown is the 7 Day Low Flow For a 10 Year Recurrence (7Q10); based on USGS site #03339000 Verr
Distance from Closest Well to River =	200	ft	Estimated based on the closest well to the river, G32S
Hydraulic Conductivity of Soil =	1.0E-05	ft/sec	Average of measured hydraulic conductivities at wells G19S, G32S, G41S, G41D, G42S, and G42D (RMT, 1
Hydraulic Head Difference Between Site and River =	12.6	ft	Based on average difference between water level elevation in well G32S (CRA) and elevation of river surface
Hydraulic Gradient Between Site and River =	0.0632	unitless	Calculated; dh/dl
Groundwater Velocity =	6.3E-07	ft/sec	Calculated based on values above and Darcy's equation; V = -k(dh/dl)
Flow of Groundwater to River =	4.0E-02	ft^3/sec	Calculated; Q = V x A
Dilution Factor =	1.0E+03	unitless	Flow Rate of River / Flow of Groundwater to River

(4) USGS Water Quality Data for site #03339000 Vermilion River Near Danville, IL. Data from 1978 to 1997. Values shown are arithmetic mean of data set.

Values in bold, italics exceed General Use Water Quality Standards.

(5) First Environmental Laboratories. Analytical Laboratory Report, May 2004.

(6) Calculated values are based on assuming negligible upstream concentrations.

Table 2: Central Tendency Scenario
Potential Groundwater Effects on Vermillion River using 95% UCL Groundwater Concentration and Harmonic Mean Flow Rate
General Motors Foundry Landfill, Danville, Illinois

Chem Group	Constituents	CASRN	95% Upper Confidence Limit on the Mean Concentration Detected from Groundwater Monitoring (1) (mg/L)	Class IV Groundwater Standard (35 IAC 620.440) (2) (mg/L)	Estimated Constituent Concentration in Surface Water Assuming Negligible Upstream Concentrations (3) (mg/L)	Upstream Constituent Concentration in the Vermillion River (4) (mg/L)	Estimated Constituent Concentration in Surface Water Assuming Upstream Concentrations (3) (mg/L)	General Use Water Quality Standards (35 IAC 302.204-pH and 208-others) (mg/L)	Reporting Limit for Aqueous Analysis (5) (mg/L)
WQ	Chloride	16887-00-6	4.1E+01	2.2E+01	1.2E-02	N/A	N/A	5.0E+02	5.0E+00
INORG	Fluoride	16984-48-8	5.4E+00	4.0E+00	1.5E-03	N/A	N/A	1.4E+00	5.0E-01
INORG	Iron	7439-89-6	6.4E+01	2.1E-01	1.8E-02	***2.3E+00***	***2.3E+00***	1.0E+00	1.0E-02
INORG	Manganese	7439-96-5	2.6E+00	1.2E+00	7.4E-04	1.1E-01	1.1E-01	1.0E+00	1.0E-02
WQ	Sulfate	14808-79-8	7.9E+02	1.9E+02	2.3E-01	N/A	N/A	5.0E+02	1.5E+01
PHYS	Total Dissolved Solids (TDS)	C-010	1.3E+03	7.3E+02	3.8E-01	N/A	N/A	1.0E+03	1.0E+00
WQ	pH Field	C-006	5.63 - 8.12 (s.u.; range)	6.5 - 9 (s.u.)	7 - 7.01 (s.u.)	6.7 - 8.8 (s.u.)	6.7 - 8.8 (s.u.)	6.5 - 9 (s.u.)	field measurement
WQ	Chloride (Dissolved)	16887-00-6	3.6E+01	2.2E+01	1.0E-02	3.6E+01	3.6E+01	5.0E+02	5.0E+00
INORG	Fluoride (Dissolved)	16984-48-8	N/A	4.0E+00	N/A	3.1E-01	N/A	1.4E+00	5.0E-01
INORG	Iron (Dissolved)	7439-89-6	3.1E+01	2.1E-01	8.9E-03	4.7E-02	5.6E-02	1.0E+00	1.0E-02
INORG	Manganese (Dissolved)	7439-96-5	2.1E+00	1.2E+00	6.1E-04	1.9E-02	2.0E-02	1.0E+00	1.0E-02
WQ	Sulfate (Dissolved)	14808-79-8	6.1E+02	1.9E+02	1.7E-01	9.0E+01	9.0E+01	5.0E+02	1.5E+01

Notes:

N/A - Not Analyzed

(1) Wells include: G19S, G32S, G41S, G41D, G42S, G42D (from 1992-2003)

The 95% UCL is calculated using a non-parametric bootstrap method known as the bias-corrected and accelerated method (Efron and Tibshirani 1998) with 4,000 bootstrap replications to ensure adequate accuracy.

If the 95% UCL is greater than the maximum detected concentration, then the maximum detected concentration is shown.

(2) According to IEPA, the Class IV Objective for fluoride is set to its Class II Objective, and the Class IV Objectives for the other parameters are based on background levels.

(3) The following assumptions and equations are used to calculate the concentration of constituents in the Vermillion River

Values in bold, italics exceed General Use Water Quality Standards.

The cross-sectional area where groundwater seeps into the River is assumed to be the average depth of the River multiplied by the width of the site next to the River.

Length of Groundwater Seepage to River =	75	ft	Estimated based on site knowledge; Depth of River + 1/2 Width of River
Width of Site =	850	ft	Estimated from site figures
Cross-Sectional Area of Groundwater Seepage =	63750	ft^2	Calculated; A = Length of Groundwater Seepage to River x Width of Site
Flow Rate of River =	1.4E+02	ft^3/sec	Value shown is the harmonic mean of river flow rates from 1915 - 2002; based on USGS site #03339000 Ver
Distance from Closest Well to River =	200	ft	Estimated based on the closest well to the river, G32S
Hydraulic Conductivity of Soil =	1.0E-05	ft/sec	Average of measured hydraulic conductivities at wells G19S, G32S, G41S, G41D, G42S, and G42D (RMT, 1
Hydraulic Head Difference Between Site and River =	12.6	ft	Based on average difference between water level elevation in well G32S (CRA) and elevation of river surface
Hydraulic Gradient Between Site and River =	0.0632	unitless	Calculated; dh/dl
Groundwater Velocity =	6.3E-07	ft/sec	Calculated based on values above and Darcy's equation; V = -k(dh/dl)
Flow of Groundwater to River =	4.0E-02	ft^3/sec	Calculated; Q = V x A
Dilution Factor =	3.5E+03	unitless	Flow Rate of River / Flow of Groundwater to River

(4) USGS Water Quality Data for site #03339000 Vermilion River Near Danville, IL. Data from 1978 to 1997. Values shown are arithmetic mean of data set.

Values in bold, italics exceed General Use Water Quality Standards.

(5) First Environmental Laboratories. Analytical Laboratory Report, May 2004.

(6) Calculated values are based on assuming negligible upstream concentrations.

Table 3: Upper-Bound Scenario
Potential Groundwater Effects on Vermillion River using Maximum Groundwater Concentration and 7Q10 Low Flow Rate
General Motors Foundry Landfill, Danville, Illinois

Chem Group	Constituent	CASRN	Maximum Concentration Detected from Groundwater Monitoring (1) (mg/L)	Class IV Groundwater Standard (35 IAC 620.440) (2) (mg/L)	Estimated Constituent Concentration in Surface Water Assuming Negligible Upstream Concentrations (3) (mg/L)	Upstream Constituent Concentration in the Vermillion River (4) (mg/L)	Estimated Constituent Concentration in Surface Water Assuming Upstream Concentrations (3) (mg/L)	General Use Water Quality Standards (35 IAC 302.204-pH and 208-others) (mg/L)	Reporting Limit for Aqueous Analysis (5) (mg/L)
WQ	Chloride	16887-00-6	6.5E+01	2.2E+01	6.2E-02	N/A	N/A	5.0E+02	5.0E+00
INORG	Fluoride	16984-48-8	1.6E+01	4.0E+00	1.5E-02	N/A	N/A	1.4E+00	5.0E-01
INORG	Iron	7439-89-6	1.9E+02	2.1E-01	1.8E-01	***2.3E+00***	***2.4E+00***	1.0E+00	1.0E-02
INORG	Manganese	7439-96-5	5.3E+00	1.2E+00	5.1E-03	1.1E-01	1.1E-01	1.0E+00	1.0E-02
WQ	Sulfate	14808-79-8	1.5E+03	1.9E+02	1.5E+00	N/A	N/A	5.0E+02	1.5E+01
PHYS	Total Dissolved Solids (TDS)	C-010	3.2E+03	7.3E+02	3.1E+00	N/A	N/A	1.0E+03	1.0E+00
WQ	pH Field	C-006	5.63 - 8.76 (s.u.; range)	6.5 - 9 (s.u.)	6.99 - 7.02 (s.u.)	6.7 - 8.8 (s.u.)	6.7 - 8.8 (s.u.)	6.5 - 9 (s.u.)	field measurement
WQ	Chloride (Dissolved)	16887-00-6	8.1E+01	2.2E+01	7.7E-02	3.6E+01	3.6E+01	5.0E+02	5.0E+00
INORG	Fluoride (Dissolved)	16984-48-8	N/A	4.0E+00	N/A	3.1E-01	N/A	1.4E+00	5.0E-01
INORG	Iron (Dissolved)	7439-89-6	1.3E+02	2.1E-01	1.2E-01	4.7E-02	1.7E-01	1.0E+00	1.0E-02
INORG	Manganese (Dissolved)	7439-96-5	5.3E+00	1.2E+00	5.1E-03	1.9E-02	2.4E-02	1.0E+00	1.0E-02
WQ	Sulfate (Dissolved)	14808-79-8	2.0E+03	1.9E+02	1.9E+00	9.0E+01	9.2E+01	5.0E+02	1.5E+01

Notes:

N/A - Not Analyzed

(1) Wells include: G19S, G32S, G41S, G41D, G42S, G42D (from 1992-2003)

(2) According to IEPA, the Class IV Objective for fluoride is set to its Class II Objective, and the Class IV Objectives for the other parameters are based on background levels.

(3) The following assumptions and equations are used to calculate the concentration of constituents in the Vermillion River

Values in bold, italics exceed General Use Water Quality Standards.

The cross-sectional area where groundwater seeps into the River is assumed to be the average depth of the River multiplied by the width of the site next to the River.

Length of Groundwater Seepage to River =	75	ft	Estimated based on site knowledge; Depth of River + 1/2 Width of River
Width of Site =	850	ft	Estimated from site figures
Cross-Sectional Area of Groundwater Seepage =	63750	ft^2	Calculated; A = Length of Groundwater Seepage to River x Width of Site
River Flow Rate=	4.2E+01	ft^3/sec	Value shown is the 7 Day Low Flow For a 10 Year Recurrence (7Q10); based on USGS site #03339000 Vermil
Distance from Closest Well to River =	200	ft	Estimated based on the closest well to the river, G32S
Hydraulic Conductivity of Soil =	1.0E-05	ft/sec	Average of measured hydraulic conductivities at wells G19S, G32S, G41S, G41D, G42S, and G42D (RMT, 199
Hydraulic Head Difference Between Site and River =	12.6	ft	Based on average difference between water level elevation in well G32S (CRA) and elevation of river surface (
Hydraulic Gradient Between Site and River =	0.0632	unitless	Calculated; dh/dl
Groundwater Velocity =	6.3E-07	ft/sec	Calculated based on values above and Darcy's equation; V = -k(dh/dl)
Groundwater Flow Rate =	4.0E-02	ft^3/sec	Calculated; Q = V x A
Dilution Factor =	1.0E+03	unitless	River Flow Rate / Groundwater Flow Rate

(4) USGS Water Quality Data for site #03339000 Vermilion River Near Danville, IL. Data from 1978 to 1997. Values shown are arithmetic mean of data set.

Values in bold, italics exceed General Use Water Quality Standards.

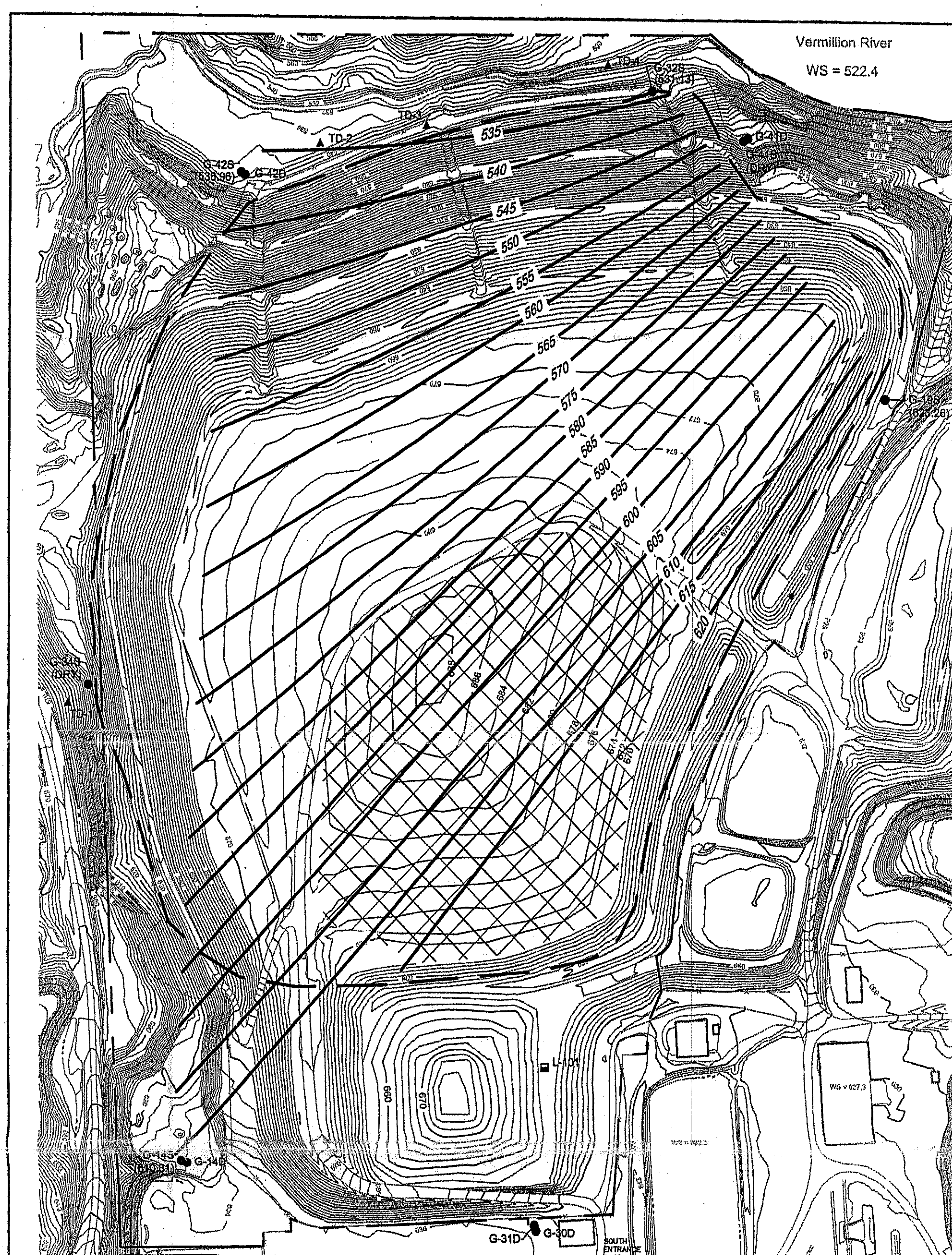
(5) First Environmental Laboratories. Analytical Laboratory Report, May 2004.

(6) Calculated values are based on assuming negligible upstream concentrations.

A P P E N D I C E S

APPENDIX A

GROUNDWATER CONTOUR MAPS



RECEIVED
JUL 17 2001
IEPA-BOL
PERMIT SECTION

0 100 200ft

LEGEND:

G-14S ● SHALLOW MONITORING WELL LOCATION AND IDENTIFIER

G-14D ● DEEP MONITORING WELL LOCATION AND IDENTIFIER

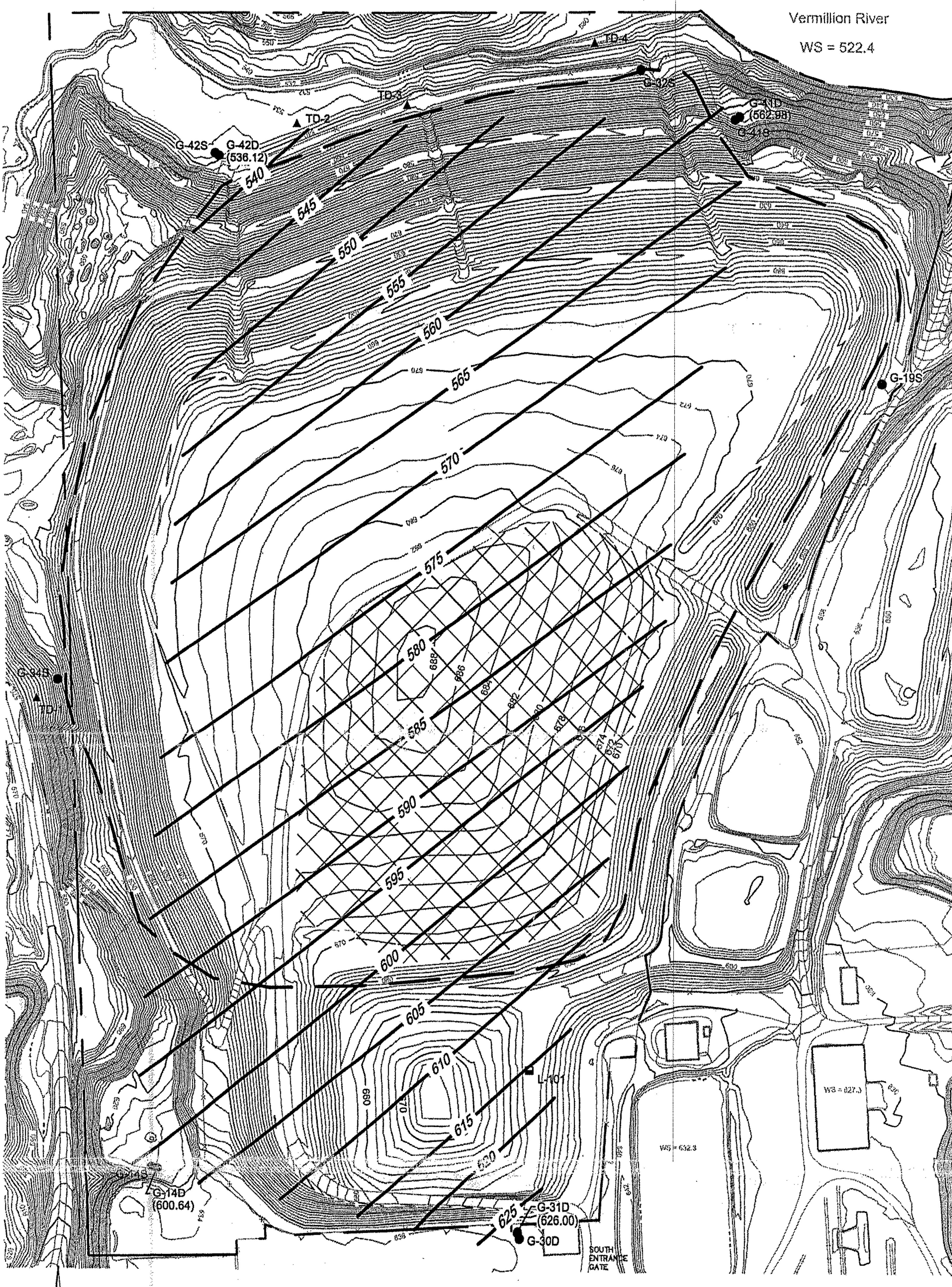
(610.31) GROUNDWATER ELEVATION

530 ——— GROUNWATER CONTOUR (ft. AMSL) CONTOUR INTERVALS =5'

figure 1

SHALLOW GROUNDWATER CONTOURS
ON-SITE LANDFILL
GENERAL MOTORS CORPORATION
Danville, Illinois

12615-00(006)GN-CO001 JUL 13/2001



LEGEND:

G-14S ● SHALLOW MONITORING WELL LOCATION AND IDENTIFIER

G-14D ● DEEP MONITORING WELL LOCATION AND IDENTIFIER

(610.31) GROUNDWATER ELEVATION

540 —— GROUNWATER CONTOUR (ft. AMSL) CONTOUR INTERVALS =5'

N

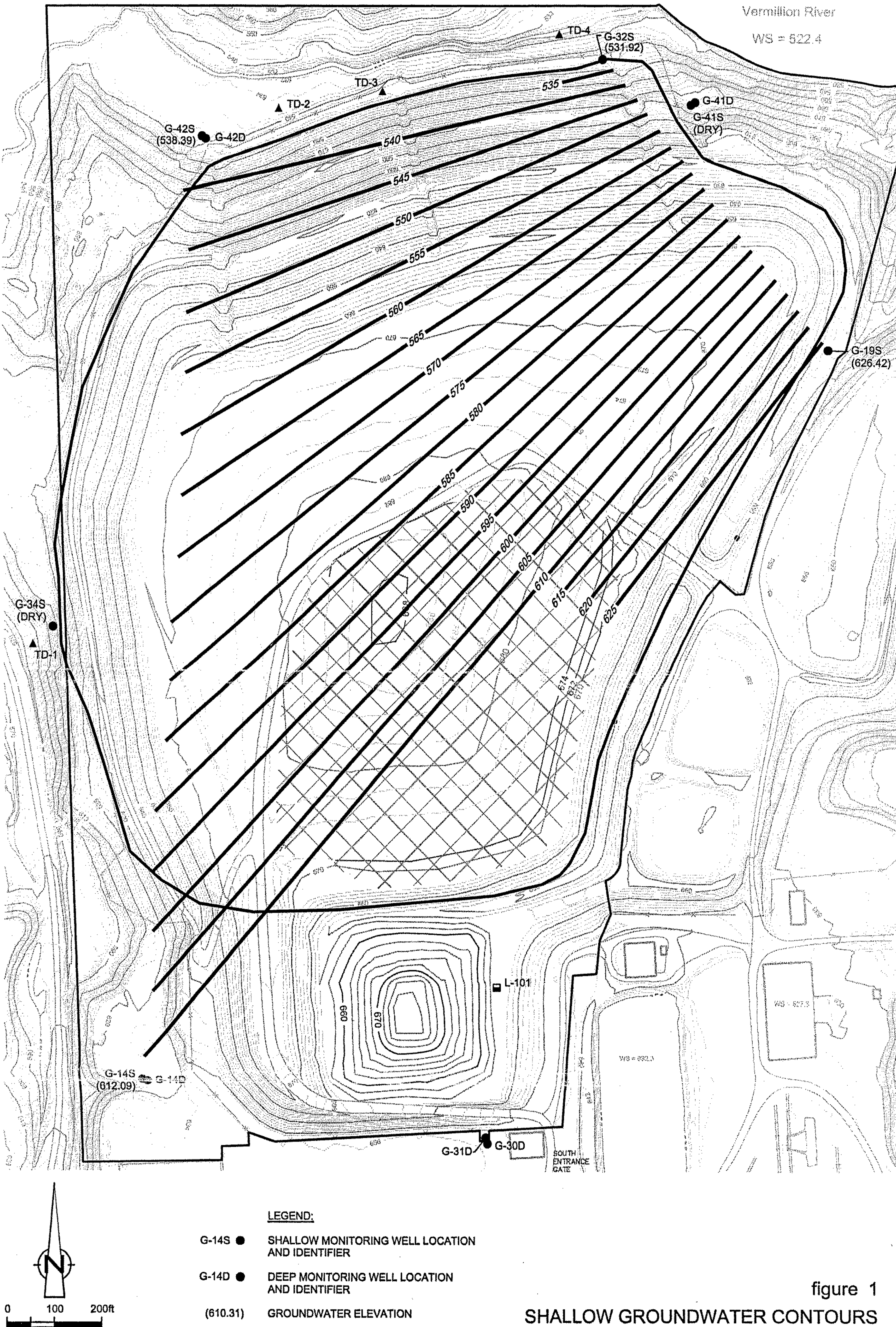
0 100 200ft

CRA

figure 2

DEEP GROUNDWATER CONTOURS
ON-SITE LANDFILL
GENERAL MOTORS CORPORATION
Danville, Illinois

12615-00(006)GN-CO002 JUL 13/2001



LEGEND:

G-14S ● SHALLOW MONITORING WELL LOCATION AND IDENTIFIER

G-14D ● DEEP MONITORING WELL LOCATION AND IDENTIFIER

(610.31) GROUNDWATER ELEVATION

GROUNDWATER CONTOUR (ft. AMSL) CONTOUR INTERVALS =5'

figure 1

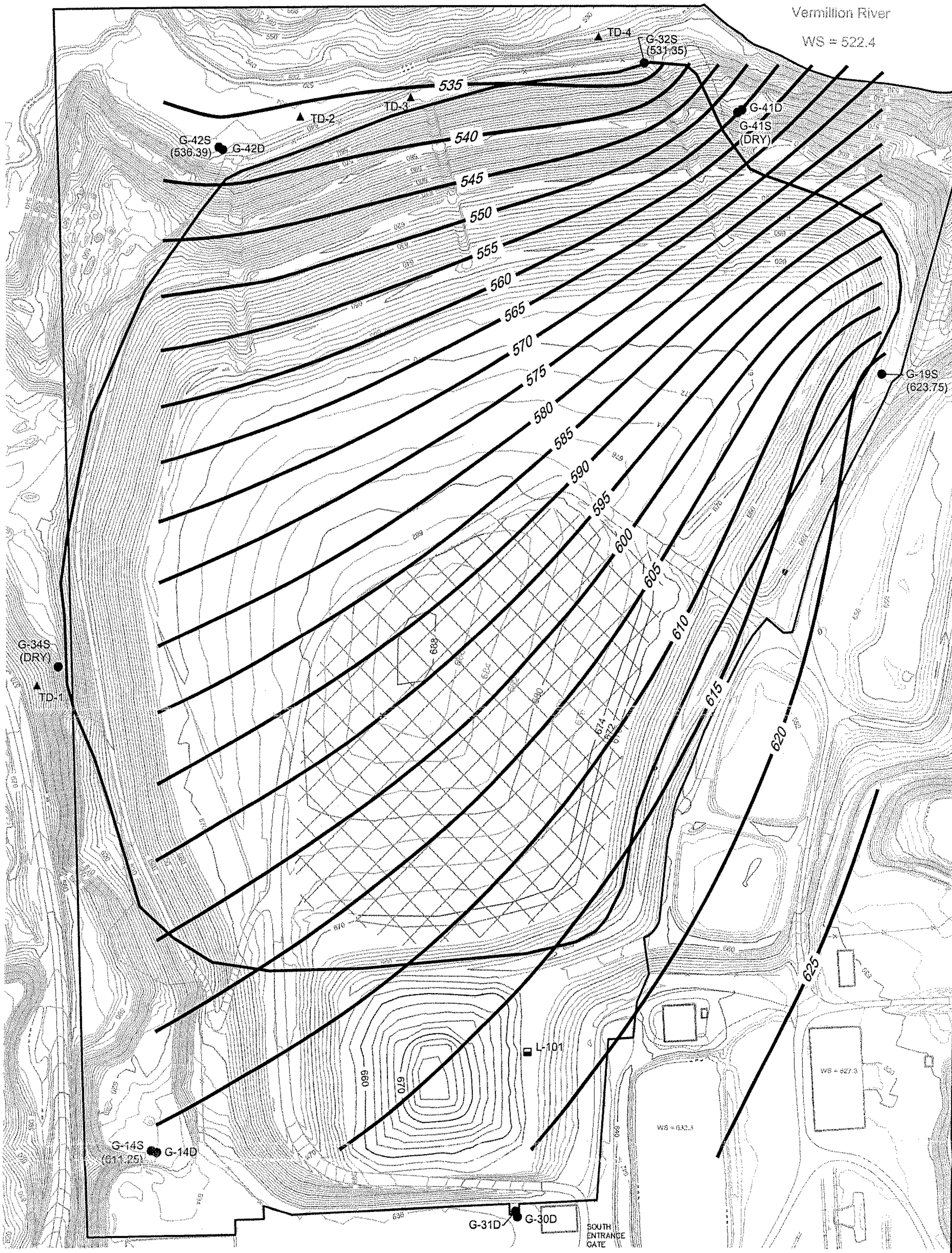
SHALLOW GROUNDWATER CONTOURS
ON-SITE LANDFILL
GENERAL MOTORS CORPORATION
Danville, Illinois

12615-00(IEPA001)GN-CO001 JUL 11/2002

figure 2

DEEP GROUNDWATER CONTOURS
ON-SITE LANDFILL
GENERAL MOTORS CORPORATION
Danville, Illinois

12615-00(IEPA001)GN-CO002 JUL 10/2002



LEGEND:

G-14S ●	SHALLOW MONITORING WELL LOCATION AND IDENTIFIER	
G-14D ●	DEEP MONITORING WELL LOCATION AND IDENTIFIER	
(610.31)	GROUNDWATER ELEVATION	
	GROUNDWATER CONTOUR (ft. AMSL) CONTOUR INTERVALS =5'	

0 100 200ft

figure 1

SHALLOW GROUNDWATER CONTOURS
ON-SITE LANDFILL
GENERAL MOTORS CORPORATION
Danville, Illinois

12615-00(SOURCE)GN-CO001 APR 27/2004

LEGEND:

G-14S ● SHALLOW MONITORING WELL LOCATION AND IDENTIFIER

G-14D ● DEEP MONITORING WELL LOCATION AND IDENTIFIER

(610.31) GROUNDWATER ELEVATION

GROUNDWATER CONTOUR (ft. AMSL) CONTOUR INTERVALS =5'

0 100 200ft

figure 2

DEEP GROUNDWATER CONTOURS
ON-SITE LANDFILL
GENERAL MOTORS CORPORATION
Danville, Illinois

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APPENDIX B

SURFACE WATER CONCENTRATIONS FROM GROUNDWATER DISCHARGE

APPENDIX B

SURFACE WATER CONCENTRATIONS FROM GROUNDWATER DISCHARGE

B.1 Introduction

This appendix discusses the methods and assumptions used for estimating the surface water concentrations of groundwater constituents in the Vermillion River as a result of groundwater discharge from the GM Danville Landfill in Danville, Illinois (hereafter referred to as the "Site"). The appendix is organized as follows:

- Section B.2 discusses the selection of groundwater data used in the calculations.
- Section B.3 presents the equations and parameters used to estimate groundwater loading to the Vermillion River.
- Section B.4 discusses the application of the groundwater loading estimates.
- Section B.5 lists the references cited in this appendix.

B.2 Groundwater Data

The groundwater data used in the calculations were obtained from the Illinois Environmental Protection Agency's (IEPA's) groundwater monitoring database for the Site. These data were collected from January 29, 1992 to May 28, 2003, and covers the period of monitoring cited in IEPA's March 16, 2004 and July 28, 2004 Notices of Violation (NOVs). The monitoring wells identified in the Closure/Post-Closure Care Plan (RMT 1994) that are downgradient of the Site were used for the calculations. The specific monitoring wells selected are:

- G-19S

- G-32S
- G-41S
- G-41D
- G-42S
- G-42D

The parameters included in the calculations include: total dissolved solids, pH, total and dissolved chloride, total and dissolved sulfate, total and dissolved fluoride, total and dissolved iron, and total and dissolved manganese. Although the dissolved concentration data (from filtered samples) would be more representative of the concentrations likely to migrate to the Vermillion River, both total (i.e., unfiltered) and dissolved data, where available, were included in the calculations.

During a review of the groundwater monitoring data obtained from IEPA, several concentrations in the data were identified as having large discrepancies when compared to GM's copies of the original laboratory reports for the data. Most of these discrepancies involved differing units between the IEPA data and the data in the laboratory reports. These discrepancies were addressed in this evaluation by using concentrations from the original laboratory reports. The affected concentrations include the following:

- iron (total) and manganese (total) results for all wells sampled on 5/22/1996;
- iron (total) result for G-32S sampled on 2/18/2003; and
- manganese (total) result for G-19S sampled on 5/19/02

It should be noted that every record in IEPA's database was not verified for consistency with the original laboratory reports, as all of these reports are no longer available. However, when these reports were available, the electronic data obtained from IEPA's database were compared to the hard-copy reports.

The maximum detected groundwater concentrations among the selected monitoring wells were used in the upper-bound scenario estimates of impacts from groundwater to the Vermillion River. The reasonable maximum (RM) and central tendency (CT) scenario estimates use the 95% upper confidence limit on the mean (95% UCL) among all monitoring wells to estimate potential impacts to surface water.

The 95% UCL for a constituent is calculated using the nonparametric bootstrap method known as the bias-corrected and accelerated (BCa) method with 4,000 bootstrap replications (Efron and

Tibshirani 1998). A nonparametric bootstrap confidence interval does not rely on assumptions about the data's underlying probability distribution which are often difficult to confirm, but are instead based on statistical re-sampling of the empirical distribution of the observed concentrations.

For an empirical distribution that is approximately normal, the bootstrap confidence interval will be essentially the same as the normal confidence interval. For an empirical distribution that is not normal, however, the bootstrap confidence interval will be more accurate than a confidence interval calculated assuming a normal (or even lognormal) distribution (USEPA 1997).

B.3 Groundwater to Surface Water Loading

This loading calculation conservatively assumed that all constituents measured in groundwater are completely mobile and would mix with surface water in the Vermillion River. The following equations were used in the loading calculations.

Groundwater discharge to the Vermillion River is estimated based on Darcy's equation as follows:

$$Q_{gw} = -K \cdot A \cdot \frac{dh}{dl}$$

where:

Q_{gw}	=	groundwater discharge rate
K	=	hydraulic conductivity
A	=	cross-sectional area of groundwater discharge to river
dh/dl	=	hydraulic gradient between monitoring wells and river

The parameters used to calculate the groundwater discharge rate are discussed below. The specific values used for each scenario are shown in the notes of the tables included with the memorandum. The basis for the selecting these parameters is as follows:

- Hydraulic conductivity is estimated as the average of the field-measured hydraulic conductivity values at monitoring wells G-19S, G-32S, G-41S, G-41D, G-42S, and G-42D (RMT 1994, Table 5);
- Cross-sectional area of groundwater discharge is estimated by conservatively assuming that the groundwater plume is the entire width of the Site from monitoring well G-32S to

monitoring well G-42S, and that groundwater discharges into the River through half of the river bed (i.e., half the width of the river bottom + the depth of the river); and

- Hydraulic gradient is calculated by dividing the hydraulic head difference between the monitoring wells and the River (dh) by the distance between the monitoring wells and the River (dl). The elevation of the river surface is based on United States Geological Survey (USGS) data for site #03339000, "Vermilion River Near Danville, IL" from 1914 through 2003 (USGS 2004). dh is estimated using the average difference between the water level elevation at monitoring well G-32S (see Appendix A) and the elevation of the river surface from 1992 through 2003. dl is estimated using the distance between the river and the closest monitoring well, G-32S.

The mixing of constituents in groundwater with those in surface water is described by the following mass balance equation:

$$C_{Rd} = \frac{\left(C_{gw} \cdot Q_{gw} + C_{Ru} \cdot Q_{Ru}\right)}{\left(Q_{gw} + Q_{Ru}\right)}$$

where:

C_{Rd}	=	concentration in river downstream of the Site
C_{gw}	=	concentration in groundwater from the Site
Q_{gw}	=	groundwater discharge rate from the Site
C_{Ru}	=	concentration in River upstream of the Site
Q_{Ru}	=	flow rate in River upstream of the Site

Concentrations of constituents in the River upstream of the Site are based on the arithmetic mean concentration from USGS water quality data collected between 1978 and 1997 (USGS 2004). For calculations assuming negligible upstream calculations, these values were assumed to be zero.

River flow rates for the upper-bound, RM, and CT scenarios were calculated using USGS data from 1914 through 2003 (USGS 2004). The upper-bound and RM scenarios use the 7-day 10-year low flow rate (7Q10) (Singh et al. 1988). The CT scenario uses the harmonic mean flow rate (USGS 2004).

Concentrations of pH in the surface water are calculated in the same manner as other constituents after converting the measured pH to the molarity of H_3O^+ ions for acidic mixtures and the molarity of OH^- ions for basic mixtures.

B.4 Applications

The groundwater loading to surface water for the constituents shown in the tables included with the memorandum were estimated assuming RM, CT, and upper-bound ("worst-case") scenarios. The results of the calculations (i.e., estimates of C_{Rd}) for these scenarios are summarized in Tables 1 to 3 of the memorandum and are discussed in the memorandum.

The results in Tables 1 to 3 also show that the surface water concentration of a constituent is a certain fraction of the concentration in groundwater under each of the three scenarios. These fractions are as follows:

- Reasonable Maximum: $9.6x10^{-4}$
- Central Tendency: $2.8x10^{-4}$
- Upper-Bound: $9.6x10^{-4}$

These fractions can be calculated directly from the equation for C_{Rd} in Section B.3 by setting C_{Ru} to zero and C_{gw} to unit concentration. The inverse of these fractions are the "dilution factors" for the three scenarios. These dilution factors could be used to calculate the maximum allowable groundwater concentrations to ensure protection against adverse effects in the River.

B.5 References

Efron, B. and R. J. Tibshirani. 1998. An Introduction to the Bootstrap. Chapman & Hall/CRC, Boca Raton.

RMT, Inc. (RMT). 1994. Closure/Post-Closure Care Plan Groundwater Monitoring Network Evaluation. General Motors-Powertrain Division Landfill, Danville, Illinois. January.

Singh, Krishan P., Ramamurthy, G.S., and Seo, Il Won. 1988. 7-Day 10-Year Low Flows of Streams in the Kankakee, Sangamon, Embarras, Little Wabash, and Southern Regions: ISWS Report 441. Illinois State Water Survey; Champaign, IL. February.

United States Environmental Protection Agency (USEPA). 1997. Office of Solid Waste and Emergency Response (OSWER). The Lognormal Distribution in Environmental Applications. EPA/600/R-97/006. December.

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