HARRISON
Harrison Division
General Motors Corporation
200 Upper Mountain Road
Lockport, New York 14094

July 29, 1994

Mr. Stanley Radon
New York State of Environmental Conservation
270 Michigan Avenue
Buffalo, New York 14203

Dear Mr. Radon:

Please find enclosed the 1994 Annual Report Long-Term Groundwater Monitoring Program Harrison Facility Lockport New York dated July 1994 prepared by GZAGeoenvironmental of New York to indicate ground water monitoring data for the Harrison West Lockport Complex.

Harrison has completed, with the June, 1994 quarterly round, the additional year of groundwater monitoring requested by Ms. Luanne Whitbeck's letter of April 2, 1993.

This report is in lieu of the TSDF Annual Report Addendum I.D. # 002 126 852 due March 1, as agreed in your letter of August 18, 1993 and includes all the 1993 and 1994 data.

Harrison agrees with the GZAGeoenvironmental of New York conclusion stated on page 7 of the enclosed report "that continued monitoring of these wells is not likely to provide additional information on the environmental conditions in the area of the Site." Therefore Harrison is requesting to discontinue monitoring and permission to remove all top-of-rock and bedrock wells used in Site monitoring.

If you have any questions regarding this report, please contact Cathy Ver at 439-2942 or myself at 439-2192.

Sincerely,

Roy D. Knapp
Supervisor -
Environmental Engineering

cc: Mr. P. Counterman - NYSDEC, Albany
Mr. J. DeVald - NCHD

New York State Department of Environmental Conservation
270 Michigan Avenue, Buffalo, New York 14203-2999
(716) 851-7220

Langdon Marsh
Commissioner

August 19, 1994

Mr. Roy D. Knapp
Supervisor
Environmental Engineering
Harrison Division
General Motors Corporation
200 Upper Mountain Road
Lockport, NY 14094

Dear Mr. Knapp:

1994 Annual Report
Long-Term Groundwater
Monitoring

The New York State Department of Environmental Conservation (Department) has reviewed the above referenced report. The following comprise the Department's comments.

The Department has reviewed the groundwater data and has determined that continued groundwater monitoring is not necessary. There is sufficient data that shows that there would be little or no value in continuation of the monitoring program. The post-closure monitoring program is now considered complete.

If you have any questions, please contact me at 716/851-7220.

Sincerely,

Stanley Radon
Engineering Geologist II

SR:vam
cc: Mr. Frank Shattuck
Mr. Robert Wozniak
Mr. Paul Counterman

GZA
GeoEnvironmental
of New York

Engineers and
Scientists

1994 ANNUAL REPORT
LONG-TERM GROUNDWATER MONITORING PROGRAM
HARRISON FACILITY
LOCKPORT, NEW YORK

1994 ANNUAL REPORT
LONG-TERM GROUNDWATER MONITORING PROGRAM
HARRISON FACILITY
LOCKPORT, NEW YORK

PREPARED FOR:
Harrison Division of
General Motors Corporation
Lockport, New York

PREPARED BY:
GZA GeoEnvironmental of New York
Buffalo, New York

July 1994
File: 5805

GZA
GeoEnvironmental
of New York

Engineers and
Scientists

July 28, 1994
File: 5805

Mr. Roy D. Knapp
Harrison Division of
General Motors Corporation
200 Upper Mountain Road
Lockport, New York 14204

364 Nagel Drive
Buffalo, New York
14225
716-685-2300
FAX 716-685-3629

Re: 1994 Annual Report
Long-Term Groundwater Monitoring Program

Dear Mr. Knapp:

This report, prepared by GZA GeoEnvironmental of New York (GZA), summarizes our statistical analysis of the quarterly groundwater monitoring data collected at the Harrison Division of General Motors Corporation site through June 1994. Additionally, representative groundwater flow maps are included for the two water bearing zones monitored (i.e., top of rock and bedrock).

Following your review of this report, please do not hesitate to contact GZA if you have any questions or require additional information.

Very truly yours,

GZA GEOENVIRONMENTAL OF NEW YORK

Robert J. Szustakowski
Project Manager

ERN

Claire G. Quadri
Project Reviewer

Carl Eller/ERN
Carl Eller, P.E.
Associate Principal

RJS/mw
Attachment: Report (6 copies)

TABLE OF CONTENTS

1.00 INTRODUCTION

This document, prepared by GZA GeoEnvironmental of New York (GZA), discusses the groundwater quality upgradient and downgradient of former sludge storage areas at Harrison Division of General Motors Corporation (Harrison) in Lockport, New York. Harrison was formerly known as Harrison Radiator Division of General Motors Corporation. Limitations and other considerations to this report are included in Appendix A.

1.10 BACKGROUND

Between about 1976 and 1985, Harrison stored sludge from their waste water treatment plant in five on-site bermed areas located on their property (see Figure 1, Locus Plan). This sludge and affected underlying soil were removed from these areas and taken off-site between 1985 and 1990 and the sludge areas were closed in accordance with a New York State Department of Environmental Conservation (NYSDEC) approved plan.

Groundwater around the former sludge storage areas is monitored by wells installed in two water bearing units (top-of-rock and bedrock). The top-of-rock wells monitor groundwater at the overburden/fractured bedrock interface. The bedrock wells are deeper, positioned in relatively competent rock and they monitor groundwater within fractures in the rock.

Ten wells are screened in the top-of-rock zone (I-1T through I-5T, I-7T, II-AT, II-BT, II-CT and II-DT) and nine wells are screened in the bedrock zone (I-1R through I-7R; II-AR and II-DR). Group "I" wells designated I-1T, I-7R, etc. serve as sampling and water level monitoring points and Group "II" wells designated II-AR, II-DR, etc. serve as water level monitoring points only. Figures 2-5 show the location of the wells installed on the site.

Additional information on subsurface conditions at the Harrison site and well installation details are included in the following documents prepared by GZA:

- "Groundwater Monitoring Program, Harrison Radiator Division of GMC," April 1989;
- "Long-Term Groundwater Well Installations", May 1990;
- "1992 Annual Report, Long Term Groundwater Monitoring Wells", February 1992; and,

- "1993 Annual Report, Long Term Groundwater Monitoring Wells", February 1993.

A long-term groundwater monitoring program, approved by NYSDEC, began in June 1990 to evaluate the effect of the former sludge piles on groundwater quality. This program included quarterly sampling of all Group I wells and testing for the parameters of concern (i.e., pH, temperature, specific conductance, cadmium, chromium, copper, lead and zinc).

The groundwater monitoring program was modified starting with the August 31-September 1, 1993 sampling round upon recommendations made by NYSDEC in a letter dated April 2, 1993 (Reference 1). NYSDEC was concerned about the elevated chromium levels in well I-6R. The modified program included quarterly sampling of wells I-1T, I-1R, I-2T, I-2R, I-5T, I-5R, I-6R, I-7T and I-7R and testing for chromium, zinc and field parameters (pH, temperature and specific conductance) only. As such, neither historical nor recent data for cadmium, copper or lead are presented herein.

It should be noted that the quarterly sampling scheduled for March 1994 was postponed until April 7, 1994, as many of the wells were frozen throughout the month of March. GZA made weekly attempts to conduct the sampling throughout March 1994, but was unable to sample until April 7, 1994.

The purpose of GZA's work described herein is to determine groundwater flow directions and to evaluate groundwater quality in the wells sampled as part of the long-term monitoring program.

The following scope of work was completed to make this evaluation:

- Water level measurements of the Group I and Group II wells were obtained and used to develop contour maps, depicting groundwater flow direction;

- Group I wells were sampled and these samples were submitted for analytical testing according to the frequencies and schedules stated above;

- Analytical test data were reviewed and statistically analyzed to compare upgradient well locations to downgradient well locations; and

- This report was prepared describing the above work and our interpretation of the data obtained.

2.00 GROUNDWATER CONDITIONS

Groundwater levels were measured in Group I and Group II wells during the 17 quarterly sampling rounds completed from June 1990 to June 1994. Groundwater level data are presented in Appendix B.

Groundwater contour maps, depicting groundwater elevations and flow directions observed in August 1993 and April 1994 for the top-of-rock and bedrock groundwater zones, are included as Figures 2 through 5. These dates were chosen to illustrate the low and high groundwater elevations, respectively, measured during the most recent annual sampling (i.e., between March 1993 and June 1994). As shown on the figures, groundwater flow in both water bearing zones is generally to the east during both the high and low conditions. These flow patterns are generally consistent with historical patterns measured at the site.

Based on the flow directions shown Figures 2 through 5, well clusters I-1 through I-3 represent upgradient positions relative to the former sludge piles for both the top-of-rock and bedrock groundwater zones. (Under the current sampling plan as revised by the NYSDEC, analytical sampling is completed at I-1 and I-2 only.) Thus, the data from these wells will be used in this report as representative of background groundwater quality. Well clusters I-4, I-5 and I-7 and rock well I-6R represent downgradient conditions. As described in the NYSDEC revised plan, well cluster 4 (I-4T and I-4R) has been deleted from the sampling program.

3.00 GROUNDWATER QUALITY

The following sections discuss the results of analytical testing and a statistical review of the data obtained through June 1994.

3.10 ANALYTICAL RESULTS

Group I wells are sampled and tested in accordance to the protocols described in GZA's 1989 report, "Groundwater Monitoring Program, Harrison Radiator Division of GMC", as modified by the NYSDEC. Generally, this involves purging the well and collecting a sample for testing following well recovery. An additional sample is collected from one of the wells as a matrix spike/matrix spike duplicate sample. A trip blank is provided by the laboratory. Following collection, the samples are shipped to Free-Col Laboratories located in Meadville, Pennsylvania for analytical testing. Samples are also tested in the field at the time of sampling for pH, temperature and specific conductance. Field test procedures and equipment

calibration methodologies are presented in GZA's 1989 report. The results of the field testing and laboratory analyses for the period June 1990 through June 1994 are summarized in Appendix B.

3.20 STATISTICAL ANALYSIS

Test results were statistically reviewed in accordance with 40 CFR 264.97 and the procedures outlined in GZA's 1989 submittal to evaluate if the former sludge piles have impacted groundwater quality at the site. This includes a statistical comparison of test results obtained from upgradient and downgradient well locations. The purpose of this analysis was to compare the downgradient groundwater chemical analytical results with those in the upgradient (background) groundwater. Initially, the distribution of the data was assessed to determine whether it was normally distributed. After the distribution was determined, the data from upgradient wells were compared to that in downgradient wells. Data that were normally distributed were evaluated using the student's t-test; data that were not normally distributed were evaluated using the Mann-Whitney test. All statistical analyses were completed at a level of significance of $\alpha = 1$ (as required in 40 CFR 264.97). The level of significance is the probability of rejecting a null hypothesis (i.e., parameter concentrations in the downgradient well are less than or equal to, those in the upgradient wells) when the hypothesis is actually correct. Thus, the level of significance used for this evaluation is 1 percent.

The upgradient locations were grouped together to represent background conditions. Groundwater quality in the upgradient top-of-rock wells was compared to the groundwater quality in the downgradient top-of-rock wells. Likewise, the water quality results in upgradient bedrock wells and downgradient bedrock wells were compared.

As outlined in 40 CFR 264.97, the first step in this evaluation is to determine whether the data follows a normal distribution (i.e., whether the frequency of the distribution follows a "bell" shaped curve). Appendix C contains frequency distribution diagrams of the metal concentrations and pH values, as well as the log of the metal concentrations, measured at the site. (Log values were used in this evaluation since the distribution data visually suggests that these data may follow a log-normal distribution.) The concentration data for the metals tend to be positively skewed (i.e., greater frequencies at the lower concentrations). However, the distribution diagrams of the pH values and the log metal concentrations suggest a normal distribution.

To confirm statistically the normality of the frequency distribution of pH and log metal concentrations, GZA completed a X^2 (chi-square) test on the data. In this test, the average and standard deviation of the data are calculated and a "Z" statistic is computed for each data point using this information (an example of this test is included in Appendix D). Using this methodology, it is possible to predict the number of data points between certain Z values if the data are normally distributed. For this

test, the number of values between selected Z values was determined and compared to the predicted number of values to compute the X^2 statistic. If the X^2 statistic is less than a critical X^2 value (using a level of significance of $\alpha=1\%$), the data are considered normally distributed. Based on these tests, pH values were found to be normally distributed while data for metal and log metal concentrations for chromium and zinc were not normally distributed.

The student t-test (Davis, 1986) was used to compare the upgradient and downgradient concentrations of pH. The version of the test used, presented in Appendix D, compared the mean of two separate sample sets with different standard deviations. A two-sided test (comparison of both high and low values as compared to the upgradient wells) was completed for pH.

Data for chromium and zinc, which were not considered normally distributed by the X^2 test, were analyzed using the Mann-Whitney Test (Davis, 1986), a non-parametric test similar to a t-test but designed for sample data that are not normally distributed. The data from the downgradient well of concern is listed with the upgradient wells and each sample point is individually ranked within the population data base. The general procedure is as follows. For example, using the statistical computation data in Appendix D, the chromium data from the upgradient wells and each downgradient well are given a ranking, 1 being the lowest concentration observed and a ranking of 18 (in this case) being the highest concentration observed. Equal concentrations are given the same ranking. If the data from the upgradient and downgradient positions are statistically similar, the rankings are intermixed, so that no one well has the highest ranking values. If the data are dissimilar, and the downgradient well has higher concentrations, the values associated with the downgradient well will have the higher ranking scores. The analysis for metals concentrations was a one-sided test, that is, only metals concentrations above background were considered.

Appendix D contains further descriptions of the statistical methods and sample calculations. Statistical analysis computations are not included in this report but they are available for review, if required.

The statistical results from the review of historical and the most recent analytical data (1993-1994 sample rounds) for pH, chromium and zinc are summarized on Table 1. This table lists the downgradient wells and values that were found to be statistically different from the upgradient wells, that is, the sample (downgradient well) is not part of the population upgradient wells. The upgradient concentrations and New York State Class GA drinking water standards for these parameters are also presented in this table.

4.00 DISCUSSION

As summarized in Table 1, comparison of the historical (i.e., 1990 through 1992) upgradient and downgradient data indicates that three downgradient top-of-rock wells and one downgradient bedrock well have parameters statistically outside the values measured in the upgradient wells. The parameters of concern and the associated downgradient well include pH (I-7T), chromium (I-6R and I-5T), and zinc (I-6R, I-4T and I-5T).

Comparison of the upgradient and downgradient 1993-1994 data indicates that only one downgradient top-of-rock well and one downgradient bedrock well have parameters statistically outside the values measured in the upgradient wells specifically. The 1993-1994 data indicate statistically elevated values for chromium in I-6R and I-5T and zinc in I-5T.

The available data indicate that downgradient groundwater quality has improved during the period of monitoring. Initially, in 1990 through 1992, one or more downgradient wells had statistically different values for three parameters: pH, chromium, and zinc. Recent data indicate that: (1) pH is not currently statistically different in upgradient and downgradient wells; (2) zinc is elevated in only one well (I-5T) where it had historically been elevated in both I-6R and I-5T; and, (3) while chromium in groundwater from I-6R and I-5T remains statistically elevated, chromium concentrations have been generally decreasing in groundwater from downgradient wells, with the exception of the April sampling round of wells I-5T and I-6R. The most recently measured (June, 1994) chromium concentrations in groundwater from these two wells are below the Class GA standards for chromium.

The statistical variability of pH values of the historic data exhibited in water from I-7T may be due to natural factors. Based upon previous testing, it is known that the sludge previously stored at the site was generally alkaline and that it exhibited elevated pH (i.e., greater than 7.0). Since the pH in I-7T is near neutral pH it is possible that the statistically variant pH values are not related to the former sludge storage area but rather to a natural occurrence. It is also noted that the pH values measured in I-7T are within the Class GA standards for pH (i.e., 6.5 to 8.5) and that elevated pH values were not noted in the recent data.

The statistically elevated zinc concentrations measured in downgradient wells may also be attributable to natural conditions. Although the sludge reportedly contained elevated concentrations of various metals including cadmium, copper, chromium, lead and zinc, available literature indicates that zinc concentrations as high as 300 parts per million (ppm) dry weight (Cannon, H.L., 1955; Whitney, P.R., 1981 - Appendix E) are present within the Lockport Dolomite (the bedrock at the site). This is about 6.5 times the average zinc concentration measured in other sedimentary rocks, such as

limestone (Cannon, H.L., 1955). The possibility of naturally occurring zinc is further supported by the elevated concentrations measured in upgradient well I-1R (historically up to 2,500 μg/l). Due to the natural occurrence of zinc in the bedrock at the Site, as observed in the upgradient wells, it is not possible to determine the relationship between the former sludge piles on the zinc concentrations in downgradient wells, if any.

The statistically elevated concentrations of chromium in I-5T and I-6R may be related to the former sludge storage activities. This is indicated by the increase in concentrations of chromium at these locations compared to background values. It is noted that I-5T and I-6R are located relatively close to each other (i.e., spaced about 500 feet apart). As such, the apparently elevated chromium concentrations could be a localized occurrence. Additionally, the most recent data indicate that, when compared to historical data, the chromium concentrations are generally decreasing in downgradient wells. The only exception was the April 1994 sampling round where the chromium concentrations in I-5T and I-6R were elevated as compared to other recent sampling rounds. The statistical analyses indicate that the downgradient well concentrations still exceed upgradient well concentrations when the data are analyzed without including the April 1994 analytical laboratory data.

5.00 CONCLUSION

The data suggest that chromium concentrations in two downgradient wells statistically exceed those in upgradient wells. Review of historical data indicates that except for the April 1994 sampling round, the concentrations in these wells have steadily decreased and are typically near or below drinking water standards. Based on this information, the former sludge storage area does not appear to be a continual source of chemicals to the groundwater on the Site. Therefore, it is GZA's opinion that continued monitoring of these wells is not likely to provide additional information on the environmental conditions in this area of the Site.

TABLES

TABLE 1

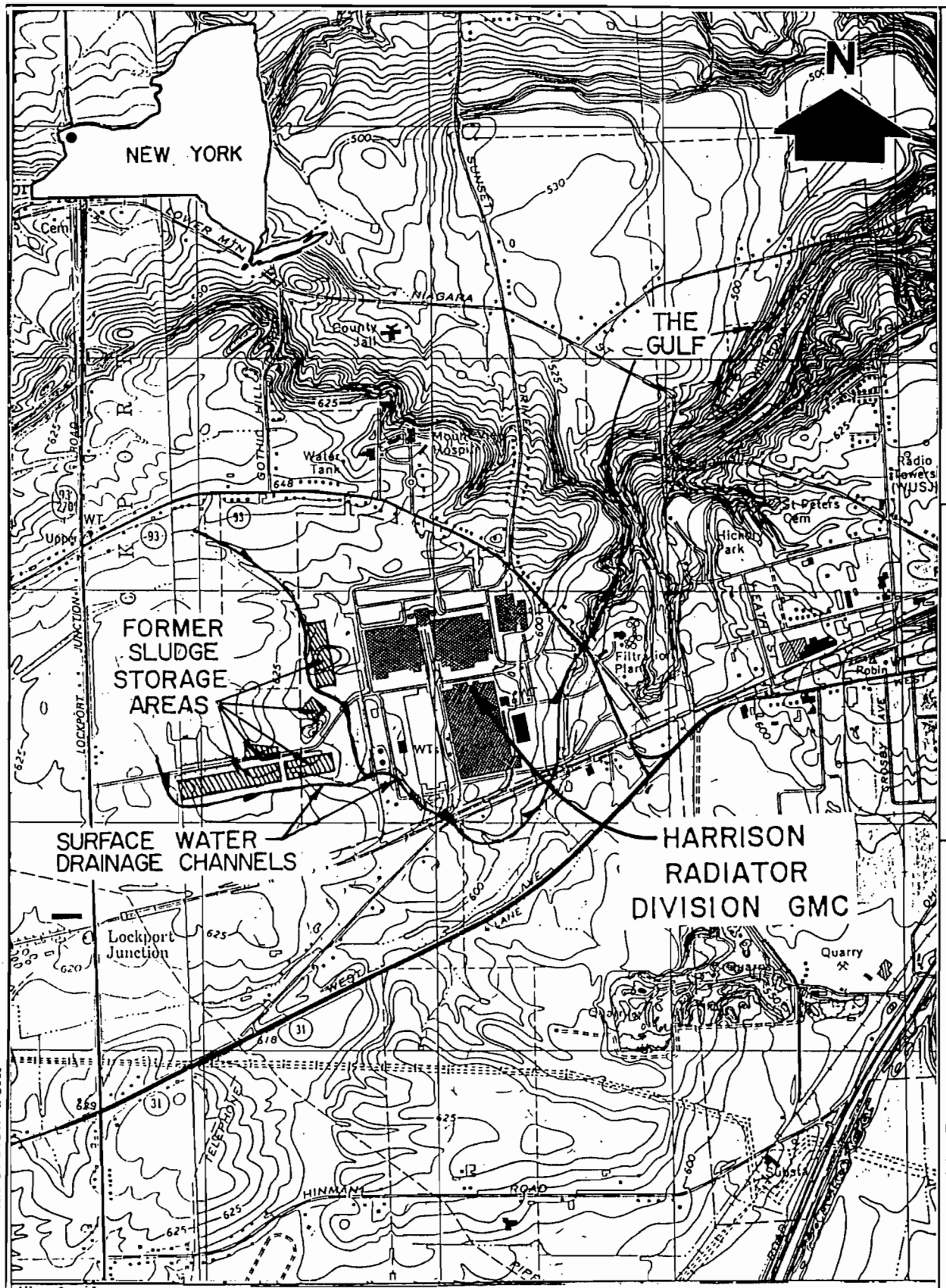
COMPARISON OF UPGRADIENT TO DOWNGRADIENT GROUNDWATER QUALITY

Parameter (units)	BEDROCK WELLS				TOP OF ROCK WELLS				Class GA Standard[2]
	Range of Concentrations/ Values in Upgradient Bedrock Wells		Range of Concentrations/ Values in Downgradient Bedrock Wells Exceeding Upgradient[1]		Range of Concentrations/ Values in Upgradient Top-of-Rock Wells		Range of Concentrations/ Values in Downgradient Top-of-Rock Wells Exceeding Upgradient[1]		
	Historical[3]	'93-94 Data[4]	Historical	'93-94 Data	Historical	'93-94 Data	Historical	'93-94 Data	
pH (S.U.)	6.8 - 7.9	6.8 - 8.5	-[5]	-	6.7 - 8.3	6.8 - 8.1	7.0 - 7.9 (I-7T)	-	6.5 - 8.5
Chromium (μg/l)	1 - 30	1 - 42	10 - 1,250 (I-6R)	5 - 86 (I-6R)	<1 - 14	<1 - 5	1 - 340 (I-5T)	<1 - 760 (I-5T)	50
Zinc (μg/l)	9 - 2,570	5 - 1170	81 - 597 (I-6R)	-	9 - 152	20 - 81	54-167(I-4T) 18 - 248 (I-5T)	65 - 511 (I-5T)	300

Notes:

1. Only concentrations in wells that statistically exceed upgradient locations are shown. These wells are shown in parenthesis.
2. Class GA standards are the most stringent groundwater standards in New York and are designed to protect water supplies (6 NYCRR 703).
3. Historical data includes data from June 1990 to December 1992 sample rounds.
4. '93-94 data inlcudes data from March 1993 to June 1994 sample rounds.
5. - = Water quality in downgradient wells does not statistically exceed water quality in upgradient wells.

FIGURES



NOTE: BASE MAP ADAPTED FROM USGS QUADRANGLE MAPS – LOCKPORT, NY (1980) AND CAMBRIA, NY (1980)

DRAWN BY: DEW

DATE: JULY 1994

GeoEnvironmental of New York

HARRISON
DIVISION OF GENERAL MOTORS CORPORATION
LOCKPORT, NEW YORK

LOCUS PLAN

PROJECT No.
R5805

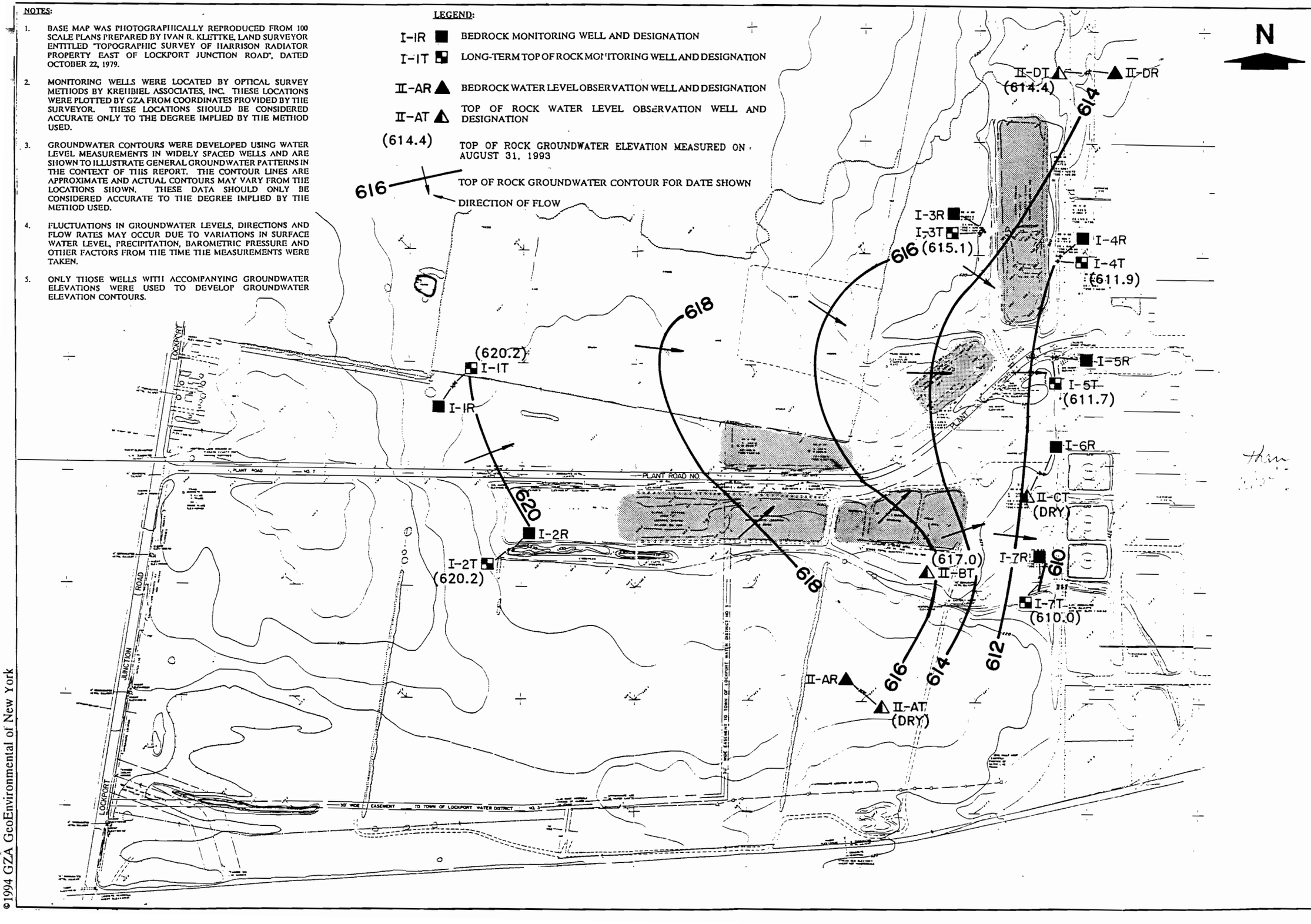
FIGURE No.
1

NOTES:

1. BASE MAP WAS PHOTOGRAPHICALLY REPRODUCED FROM 100 SCALE PLANS PREPARED BY IVAN R. KLETTKE, LAND SURVEYOR ENTITLED "TOPOGRAPHIC SURVEY OF HARRISON RADIATOR PROPERTY EAST OF LOCKPORT JUNCTION ROAD", DATED OCTOBER 22, 1979.
2. MONITORING WELLS WERE LOCATED BY OPTICAL SURVEY METHODS BY KREIBIEL ASSOCIATES, INC. THESE LOCATIONS WERE PLOTTED BY GZA FROM COORDINATES PROVIDED BY THE SURVEYOR. THESE LOCATIONS SHOULD BE CONSIDERED ACCURATE ONLY TO THE DEGREE IMPLIED BY THE METHOD USED.
3. GROUNDWATER CONTOURS WERE DEVELOPED USING WATER LEVEL MEASUREMENTS IN WIDELY SPACED WELLS AND ARE SHOWN TO ILLUSTRATE GENERAL GROUNDWATER PATTERNS IN THE CONTEXT OF THIS REPORT. THE CONTOUR LINES ARE APPROXIMATE AND ACTUAL CONTOURS MAY VARY FROM THE LOCATIONS SHOWN. THESE DATA SHOULD ONLY BE CONSIDERED ACCURATE TO THE DEGREE IMPLIED BY THE METHOD USED.
4. FLUCTUATIONS IN GROUNDWATER LEVELS, DIRECTIONS AND FLOW RATES MAY OCCUR DUE TO VARIATIONS IN SURFACE WATER LEVEL, PRECIPITATION, BAROMETRIC PRESSURE AND OTHER FACTORS FROM THE TIME THE MEASUREMENTS WERE TAKEN.
5. ONLY THOSE WELLS WITH ACCOMPANYING GROUNDWATER ELEVATIONS WERE USED TO DEVELOP GROUNDWATER ELEVATION CONTOURS.

LEGEND:

- I-IR ■ BEDROCK MONITORING WELL AND DESIGNATION
- I-IT ■ LONG-TERM TOP OF ROCK MONITORING WELL AND DESIGNATION
- II-AR ▲ BEDROCK WATER LEVEL OBSERVATION WELL AND DESIGNATION
- II-AT ▲ TOP OF ROCK WATER LEVEL OBSERVATION WELL AND DESIGNATION
- (614.4) TOP OF ROCK GROUNDWATER ELEVATION MEASURED ON AUGUST 31, 1993
- 616 TOP OF ROCK GROUNDWATER CONTOUR FOR DATE SHOWN
- DIRECTION OF FLOW



REV No	DESCRIPTION	BY	DATE

SCALE IN FEET: 0, 200, 400, 800

DRAWN BY: DEW DATE: JULY 1994

GZA GeoEnvironmental of New York

HARRISON
DIVISION OF GENERAL MOTORS CORPORATION
LOCKPORT, NEW YORK

TOP OF ROCK
GROUNDWATER CONTOUR MAP
AUGUST 31, 1993

PROJECT No.
R5805

FIGURE No.
2

NOTES:

1. BASE MAP WAS PHOTOGRAPHICALLY REPRODUCED FROM 100 SCALE PLANS PREPARED BY IVAN R. KLETTKE, LAND SURVEYOR ENTITLED "TOPOGRAPHIC SURVEY OF HARRISON RADIATOR PROPERTY EAST OF LOCKPORT JUNCTION ROAD", DATED OCTOBER 22, 1979.
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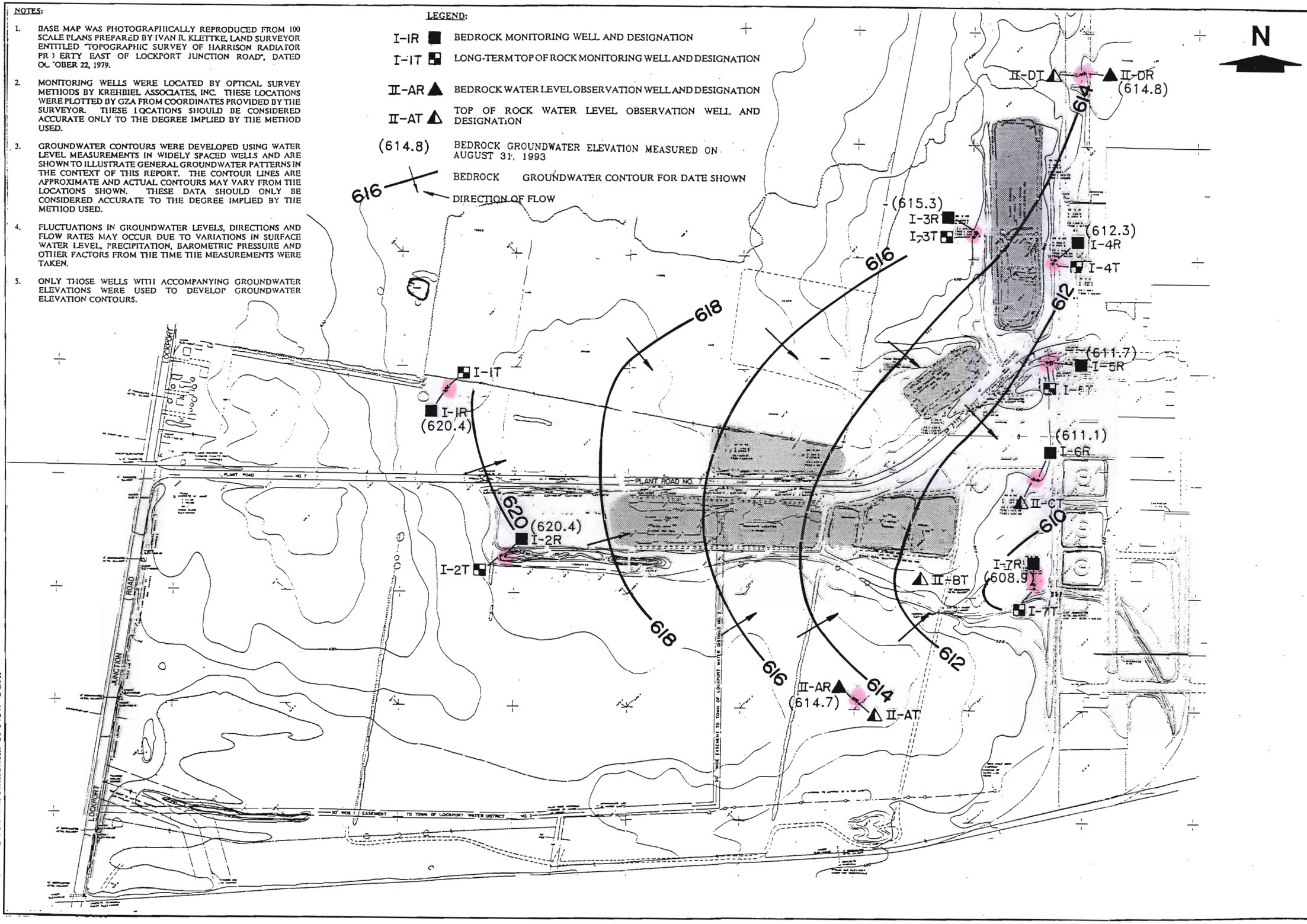
- I-IT ■ LONG-TERM TOP OF ROCK MONITORING WELL AND DESIGNATION
- II-AR ▲ BEDROCK WATER LEVEL OBSERVATION WELL AND DESIGNATION
- II-AT ◭ TOP OF ROCK WATER LEVEL OBSERVATION WELL AND DESIGNATION
- (614.8) BEDROCK GROUNDWATER ELEVATION MEASURED ON AUGUST 31, 1993
- 616 BEDROCK GROUNDWATER CONTOUR FOR DATE SHOWN
- DIRECTION OF FLOW



REV No	DESCRIPTION	BY	DATE

SCALE IN FEET: 0, 200, 400, 800

DRAWN BY: DEW

DATE: JULY 1994

GZA GeoEnvironmental of New York

HARRISON
DIVISION OF GENERAL MOTORS CORPORATION
LOCKPORT, NEW YORK

BEDROCK
GROUNDWATER CONTOUR MAP
AUGUST 31, 1993

PROJECT No.
R5805

FIGURE No.
3

NOTES:

1. BASE MAP WAS PHOTOGRAPHICALLY REPRODUCED FROM 100 SCALE PLANS PREPARED BY IVAN R. KLETTKE, LAND SURVEYOR ENTITLED "TOPOGRAPHIC SURVEY OF HARRISON RADIATOR PROPERTY EAST OF LOCKPORT JUNCTION ROAD", DATED OCTOBER 22, 1979.
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LEGEND:

- I-IR ■ BEDROCK MONITORING WELL AND DESIGNATION
- I-IT ■ LONG-TERM TOP OF ROCK MONITORING WELL AND DESIGNATION
- II-AR ▲ BEDROCK WATER LEVEL OBSERVATION WELL AND DESIGNATION
- II-AT ◭ TOP OF ROCK WATER LEVEL OBSERVATION WELL AND DESIGNATION
- (617.3) TOP OF ROCK GROUNDWATER ELEVATION MEASURED ON APRIL 7, 1994
- 616 TOP OF ROCK GROUNDWATER CONTOUR FOR DATE SHOWN
- DIRECTION OF FLOW

N

II-DT (617.3)
II-DR
I-3R
I-3T (617.8)
I-4R
I-4T (616.5)
I-5R
I-5T (612.9)
I-6R
II-CT (620.0)
I-7R
I-7T (614.1)
(620.4) II-BT
II-AR
II-AT (623.0)
I-IR
(623.8) I-IT
I-2R
I-2T (624.2)
620
622
618
614
616
624

PLANT ROAD NO. 7
LOCKPORT JUNCTION ROAD
30' WIDE EASEMENT TO TOWN OF LOCKPORT WATER DISTRICT NO. 3

REV No	DESCRIPTION	BY	DATE

DRAWN BY: DEW
DATE: JULY 1994

GeoEnvironmental of New York

SCALE IN FEET: 0, 200, 400, 800

HARRISON
DIVISION OF GENERAL MOTORS CORPORATION
LOCKPORT, NEW YORK

TOP OF ROCK
GROUNDWATER CONTOUR MAP
APRIL 7, 1994

PROJECT No.
R5805

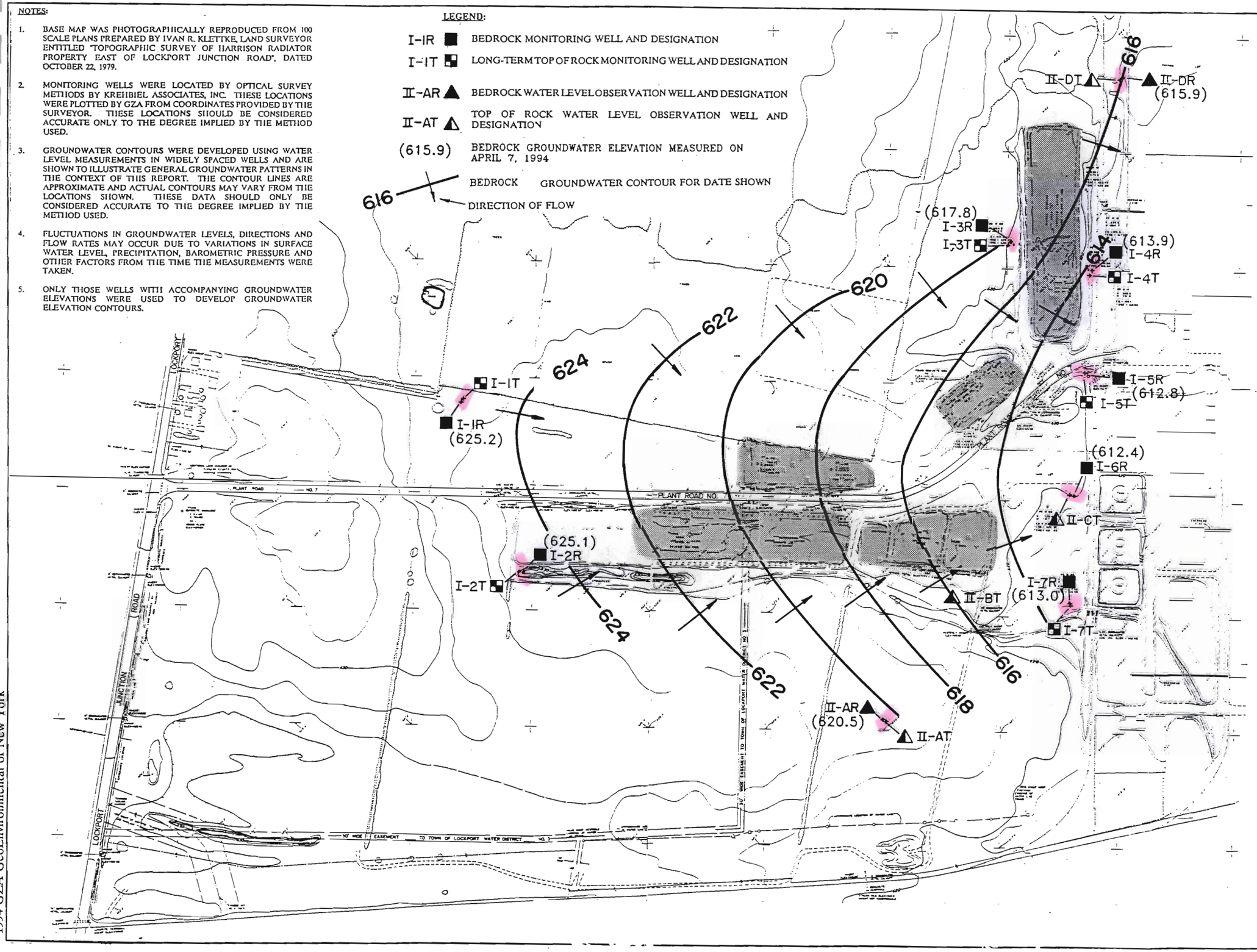
FIGURE No.
4

NOTES:

1. BASE MAP WAS PHOTOGRAPHICALLY REPRODUCED FROM 100 SCALE PLANS PREPARED BY IVAN R. KLETTKE, LAND SURVEYOR ENTITLED "TOPOGRAPHIC SURVEY OF HARRISON RADIATOR PROPERTY EAST OF LOCKPORT JUNCTION ROAD", DATED OCTOBER 22, 1979.
2. MONITORING WELLS WERE LOCATED BY OPTICAL SURVEY METHODS BY KREIHBIEL ASSOCIATES, INC. THESE LOCATIONS WERE PLOTTED BY GZA FROM COORDINATES PROVIDED BY THE SURVEYOR. THESE LOCATIONS SHOULD BE CONSIDERED ACCURATE ONLY TO THE DEGREE IMPLIED BY THE METHOD USED.
3. GROUNDWATER CONTOURS WERE DEVELOPED USING WATER LEVEL MEASUREMENTS IN WIDELY SPACED WELLS AND ARE SHOWN TO ILLUSTRATE GENERAL GROUNDWATER PATTERNS IN THE CONTEXT OF THIS REPORT. THE CONTOUR LINES ARE APPROXIMATE AND ACTUAL CONTOURS MAY VARY FROM THE LOCATIONS SHOWN. THESE DATA SHOULD ONLY BE CONSIDERED ACCURATE TO THE DEGREE IMPLIED BY THE METHOD USED.
4. FLUCTUATIONS IN GROUNDWATER LEVELS, DIRECTIONS AND FLOW RATES MAY OCCUR DUE TO VARIATIONS IN SURFACE WATER LEVEL, PRECIPITATION, BAROMETRIC PRESSURE AND OTHER FACTORS FROM THE TIME THE MEASUREMENTS WERE TAKEN.
5. ONLY THOSE WELLS WITH ACCOMPANYING GROUNDWATER ELEVATIONS WERE USED TO DEVELOP GROUNDWATER ELEVATION CONTOURS.

LEGEND:

- I-IR ■ BEDROCK MONITORING WELL AND DESIGNATION
- I-IT ◪ LONG-TERM TOP OF ROCK MONITORING WELL AND DESIGNATION
- II-AR ▲ BEDROCK WATER LEVEL OBSERVATION WELL AND DESIGNATION
- II-AT ◭ TOP OF ROCK WATER LEVEL OBSERVATION WELL AND DESIGNATION
- (615.9) BEDROCK GROUNDWATER ELEVATION MEASURED ON APRIL 7, 1994
- 616 BEDROCK GROUNDWATER CONTOUR FOR DATE SHOWN
- DIRECTION OF FLOW



REV No.	BY	DATE	DESCRIPTION

SCALE IN FEET: 0 200 400 800

DRAWN BY: DEW

DATE: JULY 1994

GZA GeoEnvironmental of New York

HARRISON
DIVISION OF GENERAL MOTORS CORPORATION
LOCKPORT, NEW YORK

BEDROCK
GROUNDWATER CONTOUR MAP
APRIL 7, 1994

PROJECT No.
R5805

FIGURE No.
5

APPENDIX A

LIMITATIONS

LIMITATIONS

1. The conclusions and recommendations contained in this report are based in part upon the data obtained from a limited number of groundwater samples obtained from widely spaced subsurface explorations. The nature and extent of variations between these explorations may not become evident until further exploration. If variations or other latent conditions then appear evident, it may be necessary to reevaluate the conclusions and recommendations of this report.

2. Water level readings have been made in the monitoring wells at the times and under the conditions stated in the text. However, it must be noted that fluctuations in the level of groundwater may occur due to variations in rainfall and other factors different from those prevailing at the time measurements were made.

3. The conclusions and recommendations contained in this report are based in part upon various types of chemical data and are contingent upon their validity. These data have been reviewed and interpretations made in the report. It should be noted that variations in the types and concentrations of compounds and variations in their flow paths may occur due to seasonal water table fluctuations, past disposal practices, the passage of time, and other factors. Should additional chemical data become available in the future, these data should be reviewed by GZA, and the conclusions and recommendations presented herein modified accordingly.

4. Chemical analyses have been performed for specific parameters during the course of this assessment, as described in the text. However, it should be noted that additional chemical constituents not searched for during the current study may be present in soil and/or groundwater at the site.

5. Surveying (location and elevation) of test borings/monitoring wells was completed by others using optical survey techniques. Various conclusions and recommendations presented in this report were made based upon these survey data and as such are subject to their validity. Should variations become evident, it will be necessary for GZA to reevaluate the conclusions and recommendations presented.

6. This report has been prepared for the exclusive use of Harrison Division of General Motors Corporation for specific application to their site in Lockport, New York. This work was done in accordance with generally accepted geotechnical and groundwater engineering practices for the time period in which this work was completed. No other warranty, expressed or implied, is made.

APPENDIX B

GROUNDWATER ELEVATIONS
AND ANALYTICAL RESULTS

HARRISON LONGTERM GROUNDWATER MONITORING
HISTORICAL SUMMARY OF TESTING RESULTS

Well I.D. I-1R Location 116.88 South
MP Elev 626.20 3772.45 West

Date	Water Elev. (feet)	pH (S.U.)	Specific Conductance (uS/cm)	Temperature (C)	Total Metals Analyses Cadm. (mg/l)	Chrom. (mg/l)	Copper (mg/l)	Lead (mg/l)	Zinc (mg/l)
21-Jun-90	623.6	7.0	800	15	0.0002	0.002	0.007	0.009	0.230
11-Sep-90	619.7	7.0	1300	15	0.0004	0.002	0.012	0.006	1.650
07-Dec-90	623.9	7.2	420	8	< 0.0001	0.003	0.003	0.002	0.084
13-Mar-91	625.2	7.3	500	6	0.0007	0.002	0.006	0.002	0.225
05-Jun-91	623.9	7.3	600	12	0.0076	0.006	0.018	0.009	0.058
04-Sep-91	616.8	7.4	600	18	0.0007	0.030	0.011	0.001	0.408
04-Dec-91	618.4	7.0	1200	8	0.0006	0.005	0.007	0.003	2.570
04-Mar-92	625.0	7.7	600	7	0.0003	0.001	0.006	0.004	0.757
03-Jun-92	623.5	7.5	310	16	0.0015	0.002	0.019	0.002	0.203
02-Sep-92	624.6	7.5	720	19	0.0019	0.003	0.007	0.002	0.079
02-Dec-92	625.1	7.9	600	8	0.0002	0.002	0.004	0.001	0.144
09-Mar-93	624.7	7.9	480	13	0.0006	0.002	0.023	0.010	1.17
02-Jun-93	623.2	8.2	670	12	0.0034	0.003	0.015	0.008	0.410
31-Aug-93	620.4	6.8	750	17	---	0.003	---	---	0.452
01-Dec-93	624.7	7.0	840	13	---	0.001	---	---	0.710
07-Apr-94	625.2	7.2	700	6	---	0.002	---	---	0.178
02-Jun-94	624.0	7.1	400	10	---	0.001	---	---	0.770
Average	623.1	7.4	676		0.0014	0.004	0.011	0.005	0.594
St. Dev.	2.5	0.4	252		0.0020	0.007	0.006	0.003	0.647

Well I.D. I-1T Location 108.75 South
MP Elev 626.35 Feet 3764.24 West

Date	Water Elev. (feet)	pH (S.U.)	Specific Conductance (uS/cm)	Temperature (C)	Total Metals Analyses Cadm. (mg/l)	Chrom. (mg/l)	Copper (mg/l)	Lead (mg/l)	Zinc (mg/l)
21-Jun-90	623.4	7.1	560	19	0.0004	0.004	0.012	0.006	0.041
11-Sep-90	619.9	7.2	700	18	< 0.0001	< 0.001	0.009	0.001	0.029
07-Dec-90	624.1	7.3	440	7	0.0002	0.005	0.008	0.011	0.034
13-Mar-91	624.2	7.4	500	5	0.0004	0.003	0.007	0.006	0.017
05-Jun-91	622.3	7.3	500	16	0.0004	0.001	0.004	< 0.001	0.016
04-Sep-91	DRY	---	---	---	---	---	---	---	---
04-Dec-91	620.4	7.1	325	8	0.0003	0.004	0.012	0.002	0.034
03-Mar-92	624.2	7.3	360	3	0.0013	< 0.001	0.027	0.003	0.045
03-Jun-92	622.8	7.2	500	14	0.0003	< 0.001	0.008	0.002	0.032
02-Sep-92	622.9	7.3	1020	19	0.0019	0.001	0.014	0.002	0.016
02-Dec-92	624.3	8.3	700	6	0.0013	0.001	0.017	0.003	0.029
09-Mar-93	624.1	7.5	675	12	0.0009	0.002	0.021	0.005	0.046
02-Jun-93	623.3	8.1	830	14	0.0006	0.001	0.009	0.010	0.028
31-Aug-93	620.2	6.9	770	18	---	0.001	---	---	0.036
01-Dec-93	624.0	7.0	1000	9	---	0.002	---	---	0.024
07-Apr-94	623.8	7.2	900	5	---	0.005	---	---	0.081
02-Jun-94	622.9	7.0	700	15	---	0.002	---	---	0.052
Average	622.9	7.3	655		0.0007	0.002	0.012	0.004	0.035
St. Dev.	1.4	0.4	207		0.0005	0.001	0.006	0.003	0.016

Note: Values reported as "<" values were given the value of the detection limit for arithmetic calculations.

HARRISON LONGTERM GROUNDWATER MONITORING
HISTORICAL SUMMARY OF TESTING RESULTS

Well I.D. I-2R Location 841.47 South
MP Elev 625.89 Feet 3549.93 West

Date	Water Elev. (feet)	pH (S.U.)	Specific Conductance (uS/cm)	Temperature (C)	Total Metals Analyses Cadmium (mg/l)	Chromium (mg/l)	Copper (mg/l)	Lead (mg/l)	Zinc (mg/l)
21-Jun-90	623.4	7.0	600	16	< 0.0001	0.003	0.002	0.002	0.018
11-Sep-90	619.5	7.2	600	18	0.0003	0.001	0.002	0.002	0.025
11-Dec-90	624.7	7.1	1100	7	< 0.0001	0.003	0.004	0.001	0.079
13-Mar-91	625.0	7.3	500	6	0.0002	0.010	0.005	0.015	0.020
05-Jun-91	623.3	7.3	700	12	0.0015	0.001	0.004	< 0.001	0.015
04-Sep-91	616.7	7.3	800	18	0.0012	0.003	0.010	0.002	0.009
04-Dec-91	618.0	7.1	420	6	0.0005	0.003	0.012	0.004	0.019
03-Mar-92	624.7	7.5	1000	10	0.0003	< 0.001	0.002	< 0.001	0.021
03-Jun-92	623.3	7.6	292	19	0.0009	0.025	0.016	0.002	0.027
02-Sep-92	624.6	7.5	680	18	< 0.0001	0.001	0.004	0.001	0.012
02-Dec-92	624.9	7.6	700	9	0.0002	< 0.001	0.002	< 0.001	0.018
02-Apr-93	625.2	7.6	990	11	0.0001	< 0.001	0.006	0.002	0.015
02-Jun-93	623.4	8.5	580	16	0.0037	0.005	0.010	0.002	0.028
31-Aug-93	620.4	8.0	470	22	---	0.042	---	---	0.017
01-Dec-93	624.6	7.1	800	14	---	0.002	---	---	< 0.005
07-Apr-94	625.1	7.3	940	7	---	0.003	---	---	0.028
02-Jun-94	623.9	7.3	520	11	---	< 0.001	---	---	0.009
Average	623.0	7.4	688		0.0007	0.006	0.006	0.003	0.021
St. Dev.	2.6	0.4	219		0.0010	0.011	0.004	0.004	0.016

Well I.D. I-2T Location 837.90 South
MP Elev 625.33 Feet 3556.60 West

Date	Water Elev. (feet)	pH (S.U.)	Specific Conductance (uS/cm)	Temperature (C)	Total Metals Analyses Cadmium (mg/l)	Chromium (mg/l)	Copper (mg/l)	Lead (mg/l)	Zinc (mg/l)
21-Jun-90	623.2	7.1	710	18	0.0008	0.003	0.008	0.009	0.054
11-Sep-90	619.5	7.3	800	17	0.0005	0.001	0.014	0.004	0.040
07-Dec-90	ND	7.3	800	8	0.0003	0.003	0.010	0.004	0.030
13-Mar-91	624.7	7.4	600	4	0.0004	0.002	0.015	0.007	0.031
05-Jun-91	623.3	7.3	600	15	0.0011	< 0.001	0.002	0.002	0.023
04-Sep-91	616.2	7.2	850	19	0.0006	0.002	0.009	< 0.001	0.009
04-Dec-91	618.2	7.1	550	6	0.0004	0.002	0.007	0.002	0.020
03-Mar-92	623.6	7.2	900	9	0.0028	0.003	0.012	0.004	0.021
03-Jun-92	622.9	7.1	730	15	0.0005	0.002	0.016	0.002	0.023
02-Sep-92	623.2	7.3	1150	19	0.0025	0.001	0.007	0.002	0.032
02-Dec-92	624.3	7.3	700	6	0.0011	< 0.001	0.005	0.002	0.023
02-Apr-93	624.8	7.4	1200	11	0.0004	0.001	0.014	0.005	0.028
02-Jun-93	622.9	7.8	780	17	0.0003	< 0.001	0.015	0.003	0.027
01-Sep-93	620.2	6.8	850	22	---	0.001	---	---	0.020
01-Dec-93	623.7	7.1	760	7	---	0.002	---	---	0.029
07-Apr-94	624.2	7.2	810	6	---	0.003	---	---	0.025
02-Jun-94	623.5	7.4	700	16	---	0.002	---	---	0.026
Average	622.4	7.2	793		0.0009	0.002	0.010	0.004	0.027
St. Dev.	2.4	0.2	172		0.0008	0.001	0.004	0.002	0.009

Notes:
1. Values reported as "<" values were given the value of the detection limit for arithmetic calculations.
2. ND - Frozen conditions, no water level taken. Sample collected from beneath ice and ice level may not have been true water level.

HARRISON LONGTERM GROUNDWATER MONITORING
HISTORICAL SUMMARY OF TESTING RESULTS

Well I.D. I-3R Location 621.20 North
MP Elev 622.46 Feet 1490.30 West

Date	Water Elev. (feet)	pH (S.U.)	Specific Conductance (uS/cm)	Temperature (C)	Total Metals Analyses Cadmium (mg/l)	Chromium (mg/l)	Copper (mg/l)	Lead (mg/l)	Zinc (mg/l)
21-Jun-90	616.4	6.8	900	14	0.0013	0.010	0.022	0.036	0.187
11-Sep-90	615.3	6.8	900	18	0.0003	0.001	0.008	0.003	0.040
10-Dec-90	617.2	6.8	700	8	< 0.0001	0.002	0.010	0.006	0.049
13-Mar-91	617.2	7.2	700	7	0.0002	0.002	0.006	0.007	0.025
05-Jun-91	616.1	7.2	800	12	0.0004	0.006	0.023	0.002	0.033
04-Sep-91	612.8	7.0	820	18	0.0015	0.002	0.008	0.002	0.013
04-Dec-91	610.8	6.8	700	7	0.0003	0.0015	0.003	0.001	0.020
04-Mar-92	616.5	7.3	800	7	0.0003	< 0.001	0.004	0.00	0.015
03-Jun-92	616.1	6.8	630	13	< 0.0001	0.002	0.021	0.00	0.018
02-Sep-92	617.3	7.1	1280	20	0.0004	< 0.001	0.004	0.00	0.021
02-Dec-92	617.4	7.5	800	8	0.0024	< 0.001	0.007	0.00	0.034
09-Mar-93	617.6	7.0	880	16	0.0008	< 0.001	0.005	0.00	0.058
02-Jun-93	616.1	7.7	970	12	0.0016	< 0.001	0.012	0.00	0.016
31-Aug-93	615.3	---	---	---	---	---	---	---	---
01-Dec-93	617.7	---	---	---	---	---	---	---	---
07-Apr-94	617.8	---	---	---	---	---	---	---	---
02-Jun-94	616.5	---	---	---	---	---	---	---	---
Average	616.1	7.1	837		0.0007	0.002	0.010	0.006	0.041
St. Dev.	1.8	0.3	159		0.0007	0.003	0.007	0.009	0.044

Well I.D. I-3T Location 1497.95 South
MP Elev 622.48 Feet 622.48 West

Date	Water Elev. (feet)	pH (S.U.)	Specific Conductance (uS/cm)	Temperature (C)	Total Metals Analyses Cadmium (mg/l)	Chromium (mg/l)	Copper (mg/l)	Lead (mg/l)	Zinc (mg/l)
21-Jun-90	616.4	6.7	930	15	0.0007	0.007	0.022	0.016	0.098
11-Sep-90	615.4	6.8	930	18	0.0007	0.014	0.027	0.034	0.152
10-Dec-90	617.1	6.8	700	9	< 0.0001	0.002	0.010	0.006	0.049
13-Mar-91	617.2	7.0	700	7	0.0003	0.003	0.017	0.004	0.031
05-Jun-91	616.1	7.2	800	12	0.0005	0.002	0.012	0.004	0.040
04-Sep-91	612.8	6.9	910	18	0.0014	0.008	0.030	0.009	0.068
04-Dec-91	612.3	6.8	706	7	0.0003	0.001	0.009	< 0.001	0.022
04-Mar-92	616.5	7.1	800	7	0.0002	0.002	0.020	0.005	0.034
03-Jun-92	616.1	6.9	440	13	0.0002	0.002	0.015	0.002	0.028
02-Sep-92	617.3	7.0	1380	19	0.0010	0.002	0.012	0.002	0.018
02-Dec-92	617.3	7.7	850	8	0.0022	< 0.001	0.007	0.002	0.124
09-Mar-93	617.7	7.0	830	14	0.0004	0.001	0.014	0.00	0.036
02-Jun-93	616.1	7.6	980	14	0.0018	0.001	0.007	0.001	0.026
31-Aug-93	615.1	---	---	---	---	---	---	---	---
01-Dec-93	617.7	---	---	---	---	---	---	---	---
07-Apr-94	617.8	---	---	---	---	---	---	---	---
02-Jun-94	616.4	---	---	---	---	---	---	---	---
Average	616.2	7.1	836		0.0008	0.003	0.015	0.006	0.052
St. Dev.	1.6	0.3	213		0.0007	0.004	0.007	0.009	0.041

Note: Values reported as "<" values were given the value of the detection limit for arithmetic calculations.

HARRISON LONGTERM GROUNDWATER MONITORING
HISTORICAL SUMMARY OF TESTING RESULTS

Well I.D. I-4R Location 524.50 North
MP Elev 620.01 Feet 1158.86 West

Date	Water Elev. (feet)	pH (S.U.)	Specific Conductance (uS/cm)	Temperature (C)	Total Metals Analyses Cadm. (mg/l)	Chrom. (mg/l)	Copper (mg/l)	Lead (mg/l)	Zinc (mg/l)
21-Jun-90	612.3	6.8	1100	14	0.0012	0.011	0.023	0.023	0.368
11-Sep-90	611.5	6.8	1100	17	0.0005	0.003	0.010	0.005	0.264
10-Dec-90	613.0	6.7	900	8	0.0002	0.003	0.009	0.004	0.037
13-Mar-91	613.4	6.8	900	7	0.0003	0.008	0.013	0.008	0.065
05-Jun-91	611.9	7.0	900	12	0.0016	0.001	0.010	0.002	0.145
04-Sep-91	610.4	7.3	1100	19	0.0024	0.004	0.023	0.003	0.161
04-Dec-91	608.7	6.7	800	8	0.0008	0.004	0.005	0.003	0.151
04-Mar-92	613.0	7.2	1000	8	0.0015	< 0.001	0.012	0.003	0.058
03-Jun-92	612.4	6.8	680	13	0.0003	0.002	0.008	0.003	0.126
02-Sep-92	613.1	7.2	1980	17	0.0001	0.001	0.004	0.001	0.016
02-Dec-92	613.4	7.6	1200	8	0.0008	0.001	0.007	0.002	0.089
09-Mar-93	614.0	7.0	1350	6	0.0005	0.001	0.005	0.002	0.098
02-Jun-93	612.3	7.5	1460	12	0.0014	0.003	0.007	0.002	0.052
31-Aug-93	612.3	---	---	---	---	---	---	---	---
01-Dec-93	612.9	---	---	---	---	---	---	---	---
07-Apr-94	613.9	---	---	---	---	---	---	---	---
02-Jun-94	612.4	---	---	---	---	---	---	---	---
Average	612.4	7.0	1113		0.0009	0.003	0.010	0.005	0.125
St. Dev.	1.3	0.3	325		0.0007	0.003	0.006	0.006	0.094

Well I.D. I-4T Location 517.37 North
MP Elev 619.93 Feet 1158.84 West

Date	Water Elev. (feet)	pH (S.U.)	Specific Conductance (uS/cm)	Temperature (C)	Total Metals Analyses Cadm. (mg/l)	Chrom. (mg/l)	Copper (mg/l)	Lead (mg/l)	Zinc (mg/l)
21-Jun-90	613.8	6.9	1300	14	0.0003	0.003	0.008	0.007	0.085
11-Sep-90	612.2	6.6	1400	19	0.0001	0.001	0.008	0.013	0.054
10-Dec-90	614.7	6.7	1000	9	0.0001	0.001	0.014	0.002	0.107
13-Mar-91	615.2	6.8	900	5	0.0001	0.005	0.023	0.011	0.167
05-Jun-91	612.9	7.0	900	12	0.0006	0.004	0.006	0.002	0.093
04-Sep-91	610.8	7.2	1090	20	0.0010	0.013	0.140	0.006	0.129
04-Dec-91	610.4	6.6	900	7	0.0003	0.002	0.018	0.001	0.142
04-Mar-92	614.5	7.1	1100	7	0.0005	< 0.001	0.008	0.003	0.106
03-Jun-92	613.8	6.6	860	14	0.0004	0.002	0.018	0.001	0.119
02-Sep-92	615.1	7.1	2280	19	0.0001	0.001	0.004	0.002	0.126
02-Dec-92	615.6	7.6	1300	7	0.0022	< 0.001	0.007	0.002	0.124
09-Mar-93	615.2	7.0	1650	16	0.0002	0.001	0.004	< 0.001	0.206
02-Jun-93	613.4	7.3	1800	13	0.0016	0.002	0.007	0.001	0.092
31-Aug-93	611.9	---	---	---	---	---	---	---	---
01-Dec-93	615.5	---	---	---	---	---	---	---	---
07-Apr-94	616.5	---	---	---	---	---	---	---	---
02-Jun-94	614.2	---	---	---	---	---	---	---	---
Average	613.9	7.0	1268		0.0006	0.003	0.020	0.004	0.119
St. Dev.	1.7	0.3	409		0.0006	0.003	0.035	0.004	0.037

Note: Values reported as "<" values were given the value of the detection limit for arithmetic calculations.

HARRISON LONGTERM GROUNDWATER MONITORING
HISTORICAL SUMMARY OF TESTING RESULTS

Well I.D. I-5R Location 62.93 North
MP Elev 617.50 Feet 1160.63 West

Date	Water Elev. (feet)	pH (S.U.)	Specific Conductance (uS/cm)	Temperature (C)	Total Metals Analyses Cadmium (mg/l)	Chromium (mg/l)	Copper (mg/l)	Lead (mg/l)	Zinc (mg/l)
21-Jun-90	612.3	7.2	1200	17	0.0001	0.003	0.004	0.006	0.058
11-Sep-90	611.2	6.8	1400	21	0.0006	0.002	0.009	0.001	0.028
10-Dec-90	612.4	6.9	900	9	0.0001	0.001	0.006	0.006	0.032
13-Mar-91	612.4	7.0	900	5	0.0001	0.005	0.007	0.002	0.029
05-Jun-91	611.3	7.0	900	15	0.0017	0.001	0.010	< 0.001	0.039
04-Sep-91	609.6	7.2	1200	19	0.0003	0.002	0.014	0.001	0.067
04-Dec-91	609.0	6.8	1200	6	0.0002	0.001	0.002	< 0.001	0.029
04-Mar-92	612.5	7.4	1250	8	0.0012	0.005	0.016	0.010	0.038
03-Jun-92	612.3	7.1	840	15	0.0003	0.002	0.011	0.002	0.034
02-Sep-92	612.5	7.4	1950	20	0.0004	0.003	0.003	< 0.001	0.045
02-Dec-92	612.6	7.4	1100	7	0.0004	< 0.001	0.006	0.002	0.044
09-Mar-93	613.4	7.2	1470	12	0.0009	< 0.001	0.005	0.001	0.056
02-Jun-93	612.3	7.6	620	14	0.0009	0.001	0.004	0.001	0.029
31-Aug-93	611.7	6.5	1200	22	---	0.001	---	---	0.029
01-Dec-93	612.8	6.7	1720	13	---	< 0.001	---	---	0.020
07-Apr-94	612.8	7.0	1400	9	---	0.006	---	---	0.045
02-Jun-94	612.0	7.2	1800	15	---	0.002	---	---	0.041
Average	611.9	7.1	1238		0.0006	0.002	0.007	0.003	0.039
St. Dev.	1.1	0.3	349		0.0005	0.002	0.004	0.003	0.012

Well I.D. I-5T Location 65.88 North
MP Elev 617.21 Feet 1169.19 West

Date	Water Elev. (feet)	pH (S.U.)	Specific Conductance (uS/cm)	Temperature (C)	Total Metals Analyses Cadmium (mg/l)	Chromium (mg/l)	Copper (mg/l)	Lead (mg/l)	Zinc (mg/l)
21-Jun-90	612.4	7.4	2450	19	0.0008	0.010	0.010	0.007	0.074
21-Jun-90	612.4	7.4	2450	19	0.0010	0.011	0.008	0.001	0.102
11-Sep-90	611.4	7.1	1900	22	0.0008	0.022	0.025	0.003	0.128
10-Dec-90	612.7	7.0	1400	8	0.0006	0.011	0.013	0.005	0.123
13-Mar-91	612.6	7.0	1700	5	0.0005	0.007	0.009	0.002	0.135
05-Jun-91	611.2	7.0	1800	12	0.0017	0.120	0.033	0.022	0.248
04-Sep-91	609.6	7.4	2200	19	0.0010	0.340	0.027	< 0.001	0.143
04-Dec-91	609.0	7.0	1200	6	0.0007	0.021	0.014	< 0.001	0.054
04-Mar-92	612.9	7.5	1800	8	0.0011	0.033	0.010	< 0.010	0.124
03-Jun-92	612.5	7.0	1300	15	0.0009	0.030	0.022	0.002	0.102
02-Sep-92	612.6	7.2	2680	21	0.0009	0.022	0.007	0.001	0.018
02-Dec-92	612.8	7.3	1700	6	0.0009	0.021	0.014	0.002	0.131
09-Mar-93	614.1	7.2	2070	12	0.0009	0.005	0.050	< 0.001	0.128
02-Jun-93	612.5	7.4	2730	15	0.0017	0.004	0.010	0.0017	0.097
31-Aug-93	611.7	6.9	2650	22	---	0.013	---	---	0.065
01-Dec-93	613.0	7.0	2890	11	---	0.015	---	---	0.137
07-Apr-94	612.9	7.1	2600	8	---	0.760	---	---	0.511
02-Jun-94	612.2	7.4	2000	17	---	0.012	---	---	0.112
Average	612.1	7.2	2084		0.0010	0.081	0.018	0.004	0.135
St. Dev.	1.2	0.2	508		0.0003	0.182	0.012	0.006	0.102

Note: Values reported as "<" values were given the value of the detection limit for arithmetic calculations.

HARRISON LONGTERM GROUNDWATER MONITORING
HISTORICAL SUMMARY OF TESTING RESULTS

Well I.D. I-6R Location 476.04 South
MP Elev 622.51 Feet 1222.99 West

Date	Water Elev. (feet)	pH (S.U.)	Specific Conductance (uS/cm)	Total Metals Analyses: Temperature (C)	Cadmium (mg/l)	Chromium (mg/l)	Copper (mg/l)	Lead (mg/l)	Zinc (mg/l)
21-Jun-90	611.5	6.5	860	16	0.0018	0.284	0.008	0.007	0.335
21-Jun-90	611.5	6.5	860	16	0.0017	0.219	0.006	0.004	0.322
11-Sep-90	610.9	6.5	1200	16	0.0027	0.278	0.016	0.007	0.518
10-Dec-90	611.8	7.1	800	9	0.0003	0.034	0.007	0.001	0.081
13-Mar-91	612.1	7.1	800	9	0.0014	0.162	0.013	0.005	0.314
05-Jun-91	611.4	7.2	800	15	0.0005	0.100	0.008	0.002	0.285
04-Sep-91	609.3	7.4	920	17	0.0030	1.250	0.015	0.012	0.597
04-Dec-91	611.8	7.2	800	8	0.0024	1.050	0.010	0.006	0.556
04-Mar-92	611.5	7.6	800	11	0.0025	0.170	0.008	< 0.001	0.142
03-Jun-92	611.6	7.2	536	12	0.0010	0.274	0.032	0.002	0.246
02-Sep-92	611.9	7.7	954	15	0.0009	0.190	0.005	0.002	0.159
02-Dec-92	612.1	7.9	800	8	0.0011	0.010	0.006	< 0.001	0.215
09-Mar-93	614.9	7.3	680	16	0.0010	0.037	0.036	0.002	0.228
02-Jun-93	611.6	8.1	780	12	0.0002	0.033	0.008	0.002	0.277
31-Aug-93	611.1	6.7	730	17	---	0.069	---	---	0.364
01-Dec-93	612.1	6.9	950	14	---	0.005	---	---	0.212
07-Apr-94	612.4	7.1	900	9	---	0.086	---	---	0.350
02-Jun-94	611.3	7.3	740	13	---	0.012	---	---	0.416
Average	611.7	7.2	828		0.0015	0.237	0.013	0.004	0.312
St. Dev.	1.0	0.5	133		0.0009	0.338	0.009	0.003	0.137

Well I.D. I-7R Location 942.94 South
MP Elev 617.38 Feet 1222.65 West

Date	Water Elev. (feet)	pH (S.U.)	Specific Conductance (uS/cm)	Total Metals Analyses: Temperature (C)	Cadmium (mg/l)	Chromium (mg/l)	Copper (mg/l)	Lead (mg/l)	Zinc (mg/l)
21-Jun-90	611.5	7.5	610	15	0.0001	0.001	0.002	0.001	0.011
11-Sep-90	609.6	7.2	800	18	0.0009	0.002	0.020	0.003	0.026
11-Sep-90	609.6	7.2	800	18	0.0001	0.002	0.003	0.002	0.030
10-Dec-90	612.1	7.2	600	8	0.0002	0.002	0.010	0.004	0.026
13-Mar-91	612.0	7.4	500	6	0.0001	0.003	0.010	0.005	0.013
05-Jun-91	611.2	7.3	500	15	0.0012	< 0.001	0.004	0.002	0.018
04-Sep-91	607.6	7.2	680	16	0.0180	0.004	0.010	0.003	0.048
04-Dec-91	610.6	7.0	600	8	0.0006	0.002	0.005	< 0.001	0.020
04-Mar-92	613.4	7.8	700	9	0.0005	0.002	0.006	0.001	0.020
03-Jun-92	611.5	7.4	407	14	0.0005	0.003	0.017	0.001	0.021
02-Sep-92	611.8	7.7	1100	17	0.0002	0.001	0.004	0.001	0.019
02-Dec-92	612.2	7.6	750	8	0.0007	0.001	0.002	0.001	0.020
09-Mar-93	613.2	7.6	730	14	0.0002	0.002	0.002	0.001	0.029
02-Jun-93	611.2	8.4	770	12	< 0.0001	0.001	0.003	0.002	0.020
31-Aug-93	608.9	7.0	740	17	---	0.001	---	---	0.010
01-Dec-93	612.4	7.2	990	14	---	0.001	---	---	< 0.005
07-Apr-94	613.0	7.2	800	8	---	0.002	---	---	0.029
02-Jun-94	611.4	7.5	620	13	---	0.004	---	---	0.022
Average	611.3	7.4	705		0.0017	0.002	0.007	0.002	0.022
St. Dev.	1.5	0.3	164		0.0045	0.001	0.006	0.001	0.009

Note: Values reported as "<" values were given the value of the detection limit for arithmetic calculations.

HARRISON LONGTERM GROUNDWATER MONITORING
HISTORICAL SUMMARY OF TESTING RESULTS

Well I.D. I-7T Location 950.66 South
MP Elev 616.96 Feet 1223.51 West

Date	Water Elev. (feet)	pH (S.U.)	Specific Conductance (uS/cm)	Temperature (C)	Total Metals Analyses				
					Cadmium (mg/l)	Chromium (mg/l)	Copper (mg/l)	Lead (mg/l)	Zinc (mg/l)
21-Jun-90	611.4	7.7	600	14	0.0003	0.004	0.018	0.006	0.066
11-Sep-90	609.4	7.4	600	19	0.0009	0.001	0.010	0.001	0.028
11-Sep-90	609.4	7.4	600	19	0.0014	0.005	0.012	0.003	0.038
10-Dec-90	613.9	7.5	470	8	0.0009	0.001	0.009	0.002	0.019
13-Mar-91	613.6	7.4	400	5	0.0002	0.003	0.013	0.003	0.031
05-Jun-91	611.1	7.3	500	12	0.0014	0.002	0.006	0.001	0.031
04-Sep-91	606.4	7.7	580	17	0.0009	0.006	0.024	0.005	0.057
04-Dec-91	610.0	7.0	450	8	0.0005	0.001	0.018	0.005	0.016
04-Mar-92	611.2	7.6	600	9	0.0018	0.002	0.021	0.004	0.043
03-Jun-92	609.5	7.4	470	14	0.0003	0.001	0.014	0.001	0.010
02-Sep-92	613.4	7.9	920	19	0.0024	0.003	0.012	< 0.001	0.018
02-Dec-92	613.5	7.8	650	6	0.0013	0.001	0.020	0.003	0.017
09-Mar-93	613.2	7.5	640	13	0.0004	< 0.001	0.002	< 0.001	0.040
02-Jun-93	611.3	8.4	790	12	0.0003	0.002	0.011	0.004	0.044
31-Aug-93	610.0	7.0	670	18	---	0.006	---	---	0.030
01-Dec-93	613.6	7.2	820	11	---	0.001	---	---	0.007
07-Apr-94	614.1	7.2	760	10	---	0.003	---	---	0.030
02-Jun-94	611.7	7.6	580	15	---	0.002	---	---	0.022
Average	611.5	7.5	617		0.0009	0.003	0.014	0.003	0.030
St. Dev.	2.0	0.3	134		0.0006	0.002	0.006	0.002	0.015

Note: Values reported as "<" values were given the value of the detection limit for arithmetic calculations.

HARRISON LONGTERM GROUNDWATER MONITORING
HISTORICAL SUMMARY OF WATER LEVELS

Well I.D. II–AR Location 1447.58 South
MP Elev 627.90 Feet 1991.06 West

Date	Water Elev. (feet)
07–Mar–90	621.4
04–Apr–90	622.4
21–Jun–90	618.5
11–Sep–90	614.7
10–Dec–90	616.3
13–Mar–91	618.0
05–Jun–91	617.9
04–Sep–91	614.2
03–Dec–91	615.1
03–Mar–92	615.7
02–Jun–92	619.8
02–Sep–92	618.6
02–Dec–92	619.1
09–Mar–93	617.3
01–Jun–93	614.9
31–Aug–93	614.7
30–Nov–93	617.3
07–Apr–94	620.5
31–May–94	615.6

Well I.D. II–AT Location 1449.35 South
MP Elev 628.62 Feet 1986.12 West

Date	Water Elev. (feet)
07–Mar–90	620.5
04–Apr–90	621.2
21–Jun–90	619.8
11–Sep–90	616.6
10–Dec–90	618.0
13–Mar–91	622.3
05–Jun–91	619.6
04–Sep–91	DRY
03–Dec–91	DRY
03–Mar–92	619.8
02–Jun–92	615.7
02–Sep–92	620.8
02–Dec–92	622.7
09–Mar–93	614.5
01–Jun–93	616.7
31–Aug–93	DRY
30–Nov–93	617.1
07–Apr–94	623.0
31–May–94	616.9

HARRISON LONGTERM GROUNDWATER MONITORING
HISTORICAL SUMMARY OF WATER LEVELS

Well I.D. II–BT Location 940.97 South
MP Elev 624.9 Feet 1721.07 West

Date	Water Elev. (feet)
07–Mar–90	619.1
04–Apr–90	619.8
21–Jun–90	617.9
11–Sep–90	617.6
10–Dec–90	619.4
13–Mar–91	620.0
05–Jun–91	617.8
04–Sep–91	615.7
03–Dec–91	621.8
03–Mar–92	619.4
02–Jun–92	619.4
02–Sep–92	619.7
02–Dec–92	619.4
09–Mar–93	620.0
01–Jun–93	617.7
31–Aug–93	617.0
30–Nov–93	619.9
07–Apr–94	620.4
31–May–94	617.7

Well I.D. II–CT Location 476.23 South
MP Elev 622.70 Feet 1230.63 West

Date	Water Elev. (feet)
07–Mar–90	617.3
04–Apr–90	617.8
21–Jun–90	613.7
11–Sep–90	613.2
10–Dec–90	615.6
13–Mar–91	619.1
05–Jun–91	613.6
04–Sep–91	613.2
03–Dec–91	613.6
03–Mar–92	617.7
02–Jun–92	DRY
02–Sep–92	616.9
02–Dec–92	617.4
09–Mar–93	617.4
01–Jun–93	613.3
31–Aug–93	DRY
30–Nov–93	619.0
07–Apr–94	620.0
31–May–94	613.8

HARRISON LONGTERM GROUNDWATER MONITORING
HISTORICAL SUMMARY OF WATER LEVELS

Well I.D.	II–DR	Location	1344.65 North
MP Elev	620.49 Feet		1030.80 West

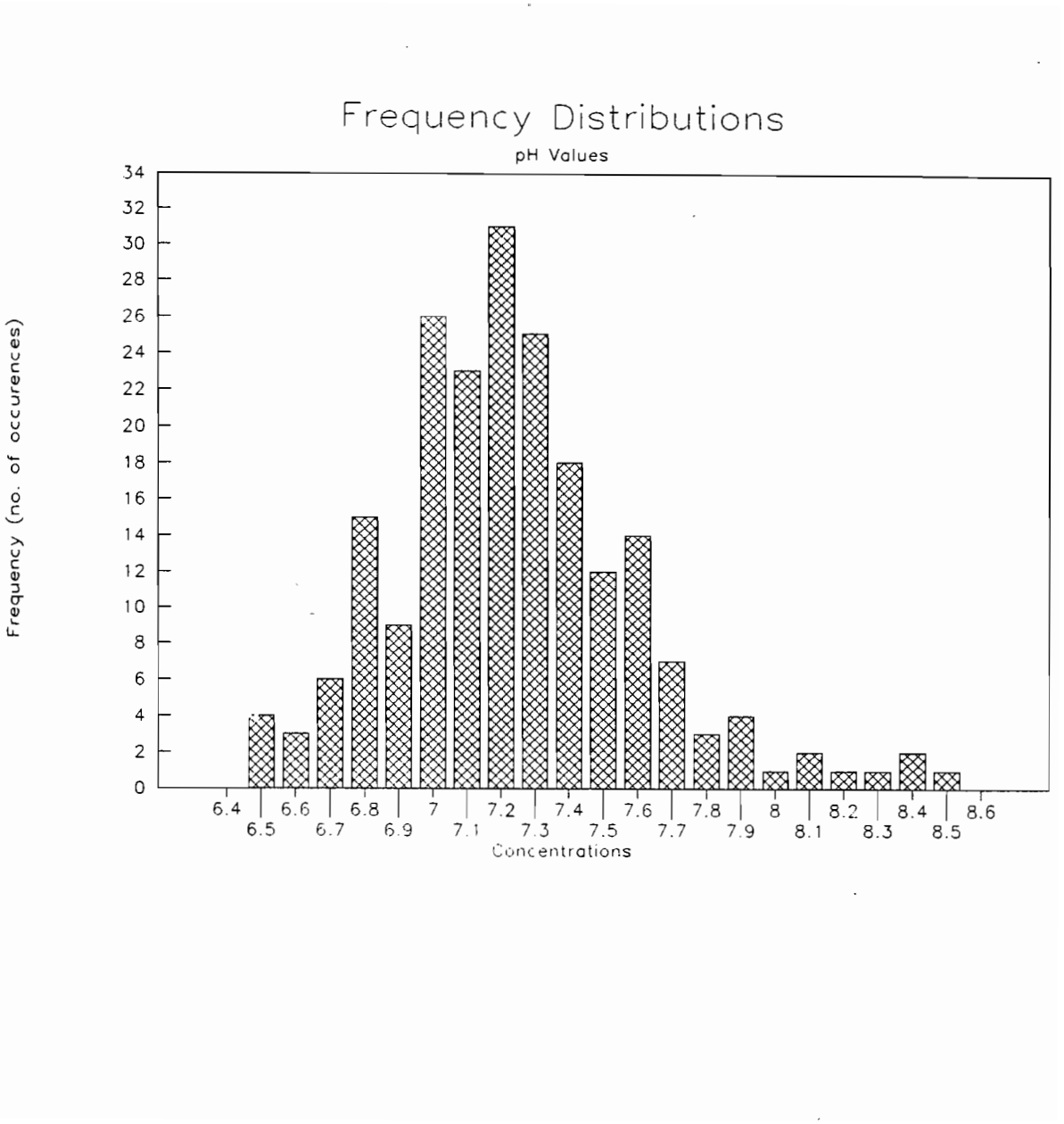
Date	Water Elev. (feet)
07–Mar–90	618.6
04–Apr–90	619.2
21–Jun–90	615.4
11–Sep–90	614.7
10–Dec–90	615.1
13–Mar–91	616.0
05–Jun–91	614.9
04–Sep–91	613.9
03–Dec–91	614.6
03–Mar–92	616.0
02–Jun–92	616.0
02–Sep–92	616.3
02–Dec–92	616.6
09–Mar–93	616.7
01–Jun–93	615.7
31–Aug–93	614.8
30–Nov–93	615.9
07–Apr–94	615.9
31–May–94	615.4

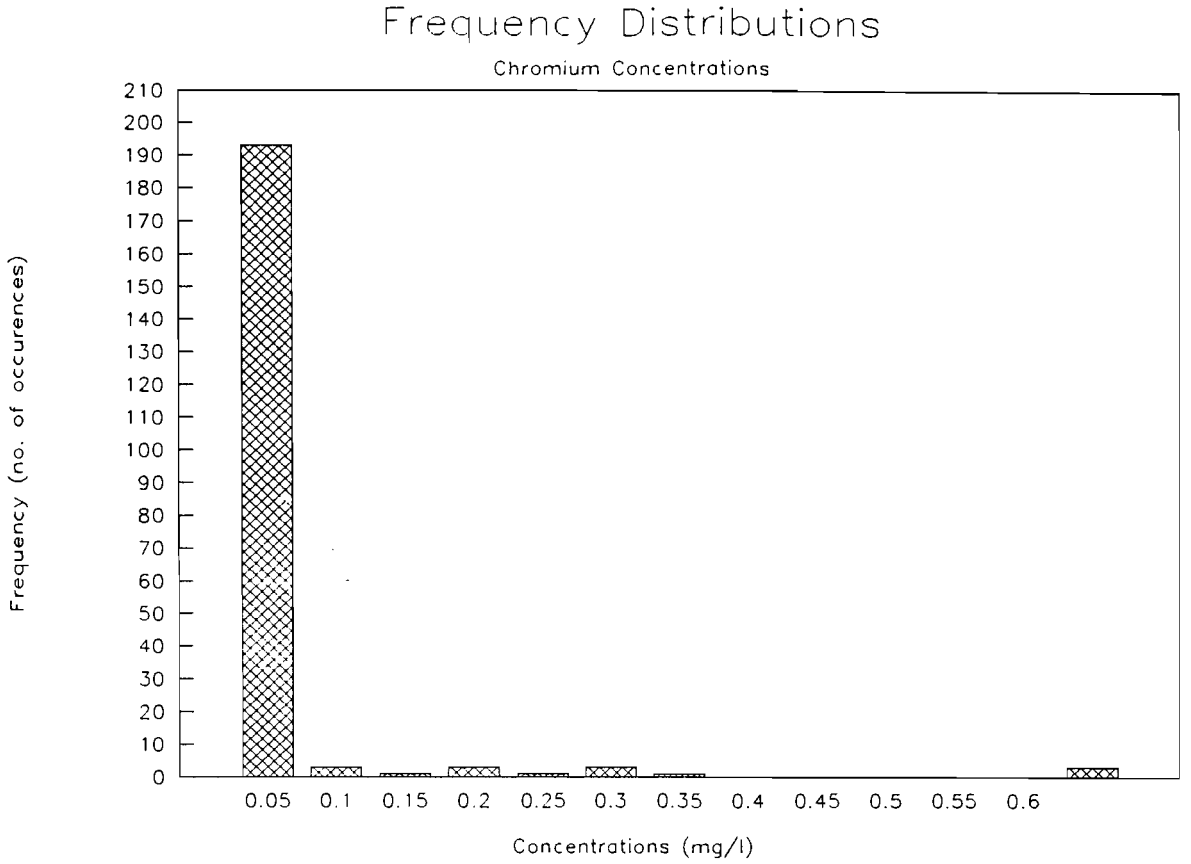
Well I.D.	II–DT	Location	1343.71 North
MP Elev	621.76 Feet		1041.30 West

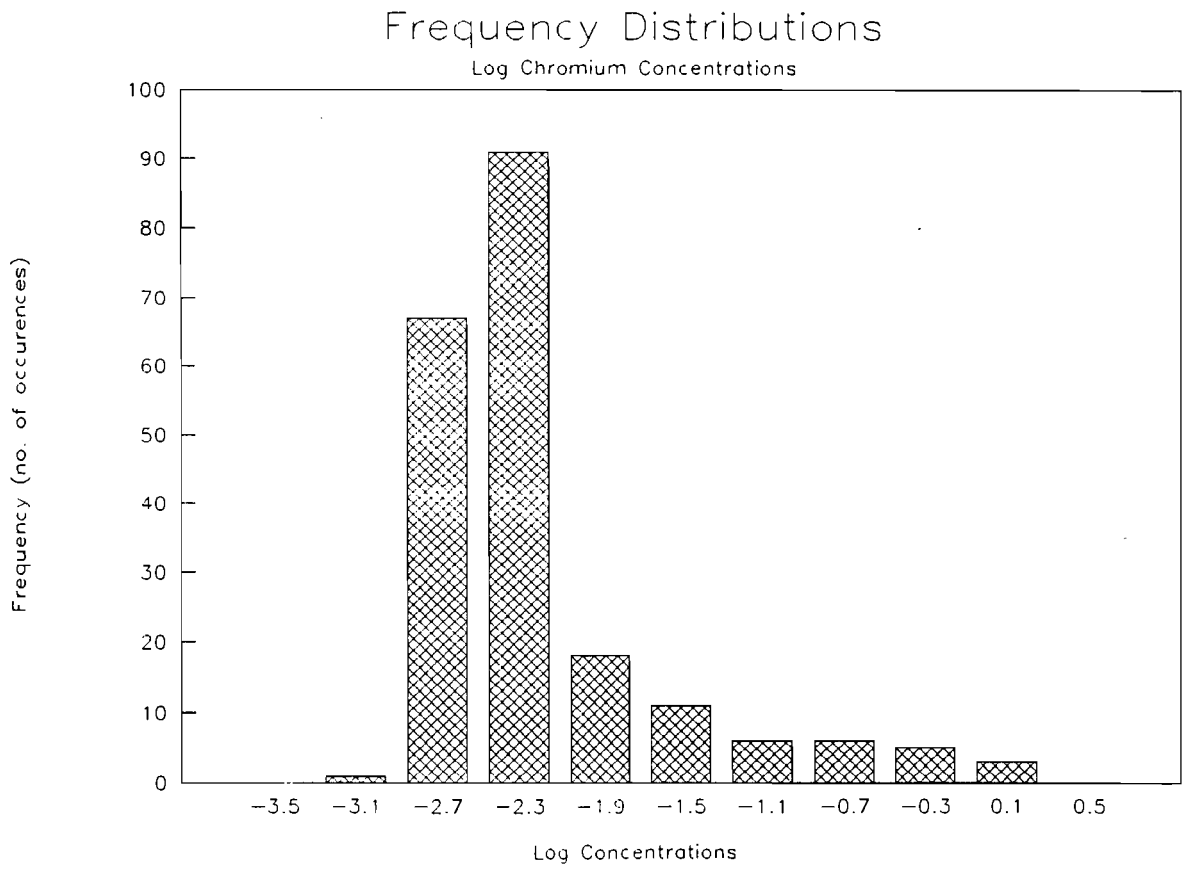
Date	Water Elev. (feet)
07–Mar–90	616.0
04–Apr–90	617.5
21–Jun–90	615.5
11–Sep–90	614.7
10–Dec–90	617.1
13–Mar–91	616.9
05–Jun–91	615.4
04–Sep–91	614.1
03–Dec–91	619.5
03–Mar–92	616.9
02–Jun–92	616.9
02–Sep–92	616.3
02–Dec–92	616.8
09–Mar–93	616.7
01–Jun–93	615.2
31–Aug–93	614.4
30–Nov–93	617.0
07–Apr–94	617.3
31–May–94	615.4

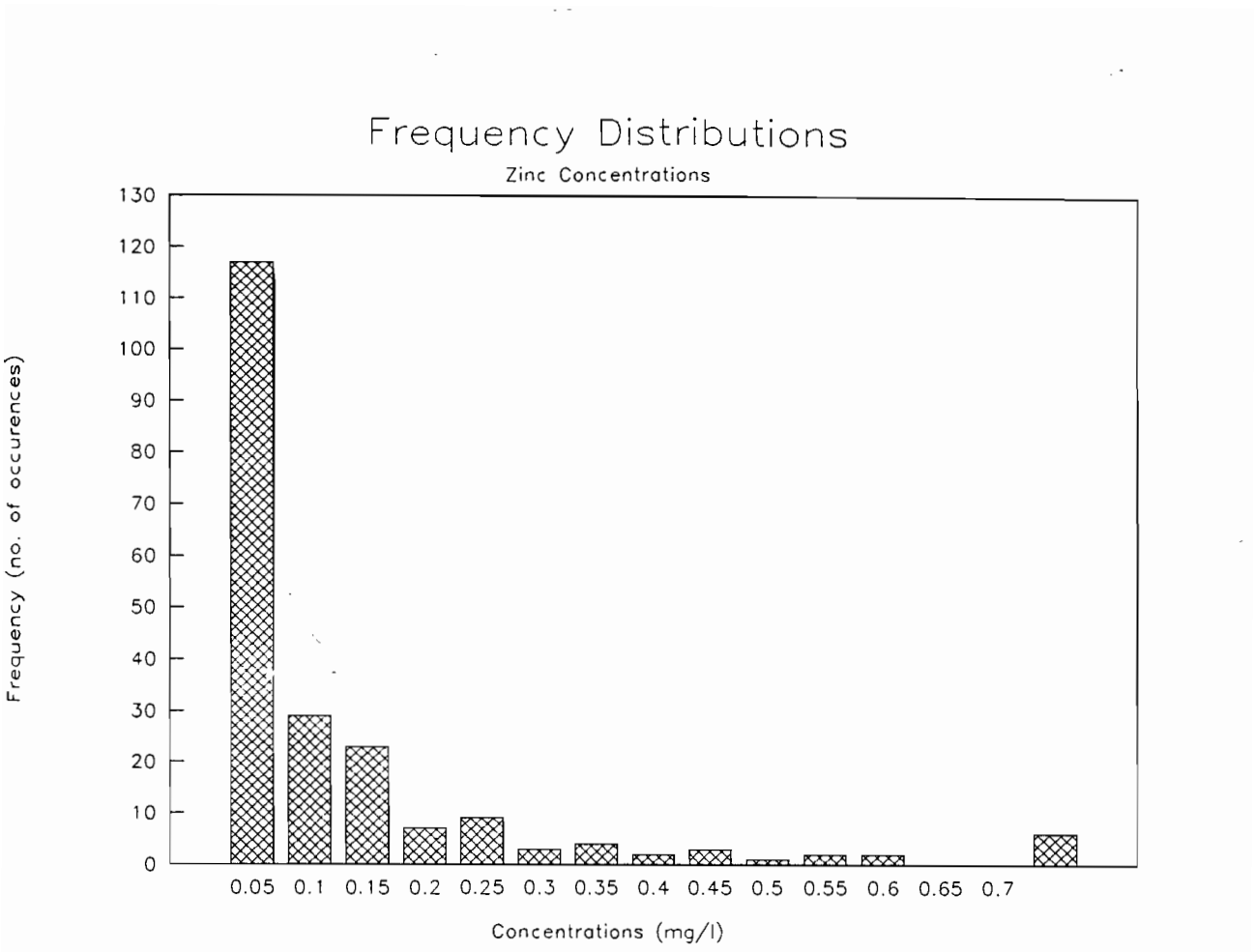
APPENDIX C

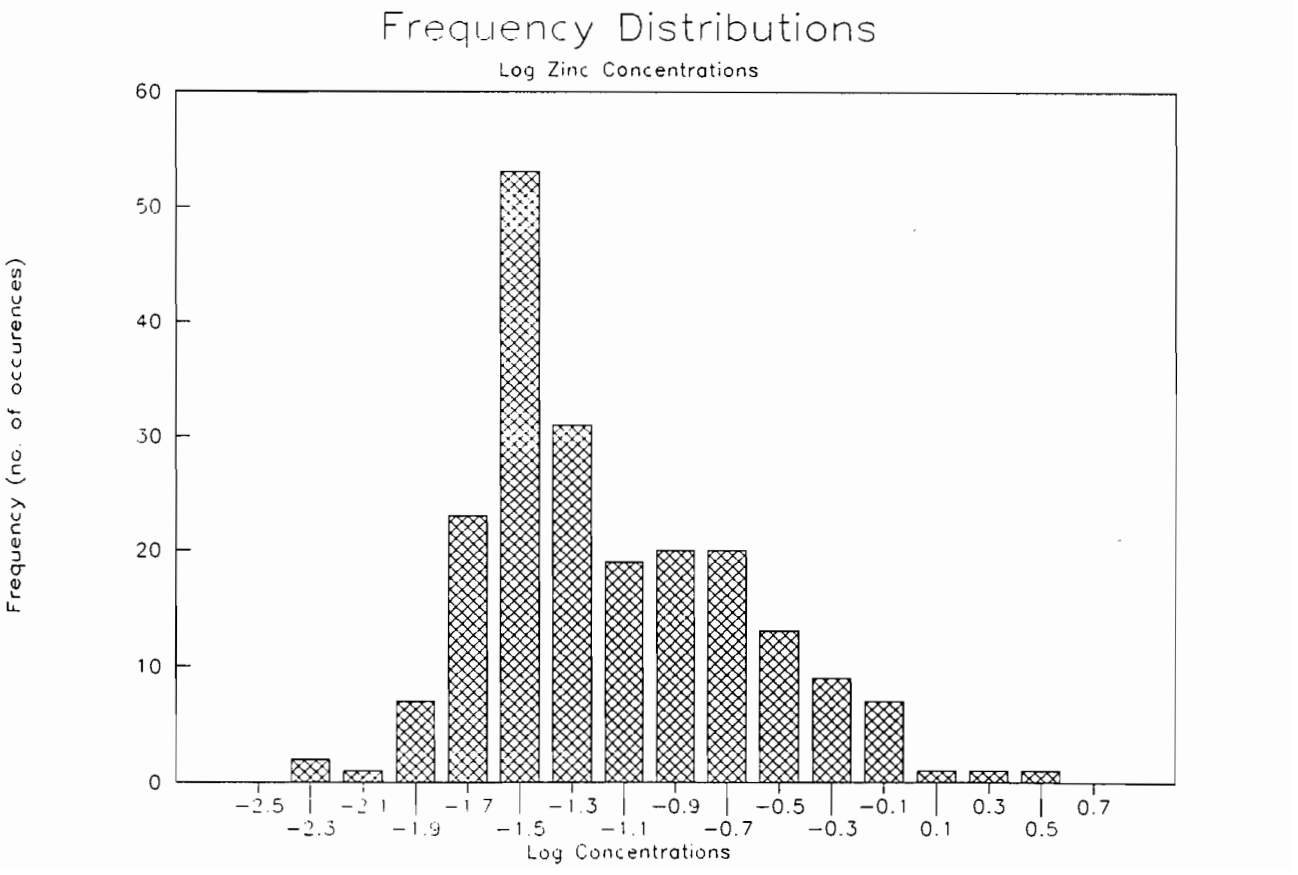
FREQUENCY - DISTRIBUTION DIAGRAMS


Frequency Distributions
pH Values
Frequency (no. of occurences)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
6.4
6.5
6.6
6.7
6.8
6.9
7
7.1
7.2
7.3
7.4
7.5
7.6
7.7
7.8
7.9
8
8.1
8.2
8.3
8.4
8.5
8.6
Concentrations


Frequency Distributions
Chromium Concentrations
Frequency (no. of occurences)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
Concentrations (mg/l)


Frequency Distributions
Log Chromium Concentrations
Frequency (no. of occurences)
100
90
80
70
60
50
40
30
20
10
0
−3.5
−3.1
−2.7
−2.3
−1.9
−1.5
−1.1
−0.7
−0.3
0.1
0.5
Log Concentrations


Frequency Distributions
Zinc Concentrations
Frequency (no. of occurences)
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6 0.65 0.7
Concentrations (mg/l)


Frequency Distributions
Log Zinc Concentrations
Frequency (no. of occurences)
60
50
40
30
20
10
0
−2.5 −2.3 −2.1 −1.9 −1.7 −1.5 −1.3 −1.1 −0.9 −0.7 −0.5 −0.3 −0.1 0.1 0.3 0.5 0.7
Log Concentrations

APPENDIX D

EXAMPLE OF STATISTICAL COMPUTATIONS

EXAMPLE OF STATISTICAL COMPUTATIONS

This appendix gives examples of the calculations used for the statistical analyses completed as part of this study. GZA can provide additional specific calculations, if desired. The source for these tests is Davis, J.C. (1986) Statistics and Data Analysis in Geology, 2nd edition, John Wiley & Sons, New York and Taylor, P.J.(1977) Quantitative Methods in Geography, Houghton Mifflin Company, Boston.

X^2 test

This test is designed to assess the distribution of the data. In this case, this test was used to determine whether the data, or the log of the data, were normally distributed. Generally, this method reviews the distribution of data and compare it to an expected distribution.

All the data, both upgradient and downgradient wells, are examined together. The mean and standard deviation are calculated and each data point is assigned a "Z" value:

$$Z = \frac{x - \bar{x}}{s}$$

where x = data value
$\bar{x}$ = mean of all data values
s = standard deviation of all data values

The Z values will fall within the range of $-\infty$ to $+\infty$. If the data were normally distributed, the Z values would be evenly distributed within the following ranges based on value that separate equal areas of a standard curve:

$-\infty$ to -0.67
-0.67 to 0
0 to +0.67
+0.67 to $+\infty$

The X^2 statistic is:

$$X^2 = \Sigma \frac{(O_j - E_j)^2}{E_j}$$

where O_j = observed number of data points in a particular range
E_j = expected number of data points in a particular range

For example, the Z values of the zinc concentrations were calculated and were grouped accordingly:

Z Range	# Observations
$-\infty$ to -0.67	0
-0.67 to 0	152
0 to +0.67	36
+0.67 to $+\infty$	20

Since there were a total of 208 points, if the data were normally distributed, about 52 data points should be in each range. The X^2 statistic is:

$$X^2 = \frac{(0-52)^2 + (152-52)^2 + (36-52)^2 + (20-52)^2}{52}$$

$$= 269$$

The number of degrees of freedom (v) is the number of ranges minus 3 = 4-3 = 1. For α = 0.01, the critical X^2 value is 6.63 (Davis, 1986, table 2.18). Since 269 > 6.63, the data do not appear to not be normally distributed.

t - test

This is a common test used to compare values which are normally distributed. Generally, this method uses the average and standard deviation of two sample sets are compared to assess whether the two sample sets come from one population. The method used allows comparisons of data sets with different standard deviations.

Hypothesis - The average value of the downgradient well(s) is less than or equal (for metals) or is not equal to (for pH) the average value of the upgradient well, i.e.;

$$H_o : \bar{x}_{up} = \bar{x}_{dn}$$

where $\bar{x}_{up}$ = mean value of upgradient wells

$\bar{x}_{dn}$ = mean value of downgradient well

The governing equation is:

$$t = \frac{\bar{x}_{up} - \bar{x}_{dn}}{Se}$$

where S_e = standard error = $\dfrac{sp}{\sqrt{\frac{1}{n_{up}} + \frac{1}{n_{dn}}}}$

n_{up} = number of data points upgradient
n_{dn} = number of data points downgradient
and S_p is a pooled estimate of the standard deviation -

$$S_p^2 = \frac{(n_{up} - 1)\, S_{up}^2 + (n_{dn} - 1)\, S_{dn}^2}{n_{up} + n_{dn} - 2}$$

where S_{up} = standard deviation of upgradient wells
S_{dn} = standard deviation of downgradient well

Sample Calculation:
for pH values between upgradient top of rock wells (I-1T, I-2T, I-3T) and downgradient well I-7T

$\bar{x}_{up} = 7.18$ $\bar{x}_{dn} = 7.52$
$S_{up} = 0.29$ $S_{dn} = 0.23$
$S_p = 0.28$
$S_e = 0.09$

t- statistic = -3.62

degrees of freedom (v) = $n_{up} + n_{dn} - 2 = 45 - 2 = 43$
For $\alpha = 0.005$ (that is, 1% divided between two side of the bell curve), and v = 43,
Critical value of t = $\pm$ 2.697 (Davis, 1986, table 2.11)

since -3.62 < -2.697 the upgradient means are not equal to the downgradient means (i.e., from different populations).

Mann-Whitney Test

This method is similar to the t-test in that it compares means of two sample sets to determine whether the sets come from the same population. It is designed for non-parametric data.

Hypothesis - The chromium concentration of the downgradient well(s) [E(X)] is less than or equal to the value of the upgradient well [E(Y)] i.e.,

$$H_o: E(X) \leq E(Y); H_1: E(X) > E(Y)$$

The governing equation is:

$$T = \Sigma_{i=1}^{n} R(X_i) - \frac{n(n+1)}{2} \qquad \text{(Davis, 1986; Eg 2.50)}$$

or using the upgradient wells:

$$T = \Sigma_{i=1}^{n} R(Y_i) - \frac{m(m+1)}{2}$$

Where, in the following example,

T	=	critical value
$R(X_i)$	=	rank of observation X_i
n	=	sample size of upgradient wells
	=	2 wells x 6 samples = 12
m	=	sample size of downgradient wells
	=	1 well x 6 samples = 6

For	α	= 0.01
	T_α	= lower critical value of T = 12 (Davis, 1986; Table 2.22)
	$T_{1-\alpha}$	= upper critical value of T = nm - T_α = (12 x 6) - 12 = 60

That is, T values greater than 60 indicates the downgradient well is significantly different from the upgradient.

An example of the rankings and calculations are shown below:

Ranking of I-1T, I-2T & I-7T	
Well I.D.	Chromium Concentration in ppb (rank)
I-1T	1 (3.5) 2 (10) 2 (10) 2 (10) 3 (15) 5 (17)
I-2T	1 (3.5) 1 (3.5) 1 (3.5) 2 (10) 2 (10) 3 (15)
I-7T	1 (3.5) 1 (3.5) 2 (10) 2 (10) 3 (15) 6 (18)

Calculation (using upgradient wells):

$$T = (3.5 + 10 + 10 + 10 + 15 + 17 + 3.5 + 3.5 + 3.5 + 10 + 10 + 15) - \frac{12(12+1)}{2} =$$

$$= 111-78=33$$

Since 33 < 60, accept null hypothesis,
H_o: $E(X) \leq E(Y)$.

For sample sets with more than 20 samples, the Mann-Whitney statistic was calculated as follows (Taylor, P.J., 1977):

$$U = n(m) + n(n+1)/2 - \Sigma_{i=1}^{n} R(X_i)$$

Z value of U is then calculated as:

$$Z_u = [(U-nm/2)/((nm(n+m+1))/12)]$$

The critical value of Z_u is based on the probabilities of a normal bell-shaped curve. If the probability of Z is greater than $\alpha = 1\%$, then the upgradient and downgradient wells are from different populations.

APPENDIX E

REFERENCES

REFERENCES

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