

**GROUND-WATER CONTAMINATION BY VOLATILE ORGANIC COMPOUNDS:
SITE CHARACTERIZATION, SPATIAL AND TEMPORAL VARIABILITY**

*Year One Summary Report
for Cooperative Agreement CR815681-01*

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Background

This report is intended to summarize the activities and accomplishments of the first 1¼ year of Cooperative Agreement 815681-01. A meeting was held in Las Vegas with Project Officer Jane Denne (USEPA-EMSL), Doug Bedinger (DRI), Project Manager Allen Wehrmann (ISWS), Tom Starks (UNLV-ERC, statistical consultant), and Mark Varljen (ISWS) in March 1990 at which an oral presentation of the first year's activities was given. This report includes some material which was discussed at that meeting as well as a discussion of work accomplished since then.

A major focus of CR815681-01 is to improve the overall reliability of site characterization methods, particularly as relates to ground-water contamination by volatile organic compounds. Work is being focused on a comparison between the concentrations of volatiles found on aquifer solids samples, in monitoring well water samples, and in water samples collected by hydraulic probe (i.e., HydroPunch®). Major concern regards estimating the contribution of sampling, analytical, and natural (or source) variability to the overall variability of samples collected by these methods. Previous work (Barcelona, et al., 1989) demonstrated how this can be done for the major inorganic and surrogate organic (e.g., TOC, TOX) ground-water quality parameters. Work under this cooperative agreement is deliberately focused on volatile organic compounds.

Another major focus of this cooperative agreement is that of spatial and temporal variability of VOC's in ground water within a "large" setting, i.e., several square miles (as opposed to an individual site covering several square feet to several acres, e.g., Roberts, et al., 1990). The field site chosen is located in Rockford, Illinois (figure 1). The area geology is principally characterized as outwash sand and gravel lying within the Rock Bedrock Valley which trends north-south generally beneath the present Rock River [for further discussion of the geologic setting, see previous progress reports or Wehrmann, et al., 1988]. Background, regional information is being assessed from approximately 25 square miles (figure 2) in the southeast quadrant of the city. The eastern one-third of the study area is characterized as bedrock upland -- depth to bedrock (Silurian dolomite) is often less than 50 feet. As the river is approached, however, the bedrock surface declines sharply and is overlain by up to 250 feet of unconsolidated glacial materials, principally outwash sand and gravel. Land use within the area is mixed residential/industrial -- heavy industry has marked the area for the past century. Historical waste management practices have led to numerous ground-water contamination problems in the area (Colten and Breen, 1986).

Detailed hydrogeologic and chemical data collection activities are being concentrated in an approximate ten square mile area centered within the larger study area boundary. The presence of a variety of VOC's has been documented in numerous private and public water supply wells in the area. The principal components of contamination are trichloroethylene (TCE), trichloroethane (TCA), dichloroethylene (DCE), and dichloroethane (DCA).

Summary of Project Activities

As mentioned in previous progress reports, efforts were being made to collect and assimilate as much previously collected hydrogeologic and chemical data for the study area as possible. Other state and local agencies (i.e., county and state health departments, Illinois EPA, USEPA-Region V, Rockford Water Department) were contacted and a variety of their data have been entered into basically four related databases (figure 3). Obviously, as we and these agencies collect new data, new information

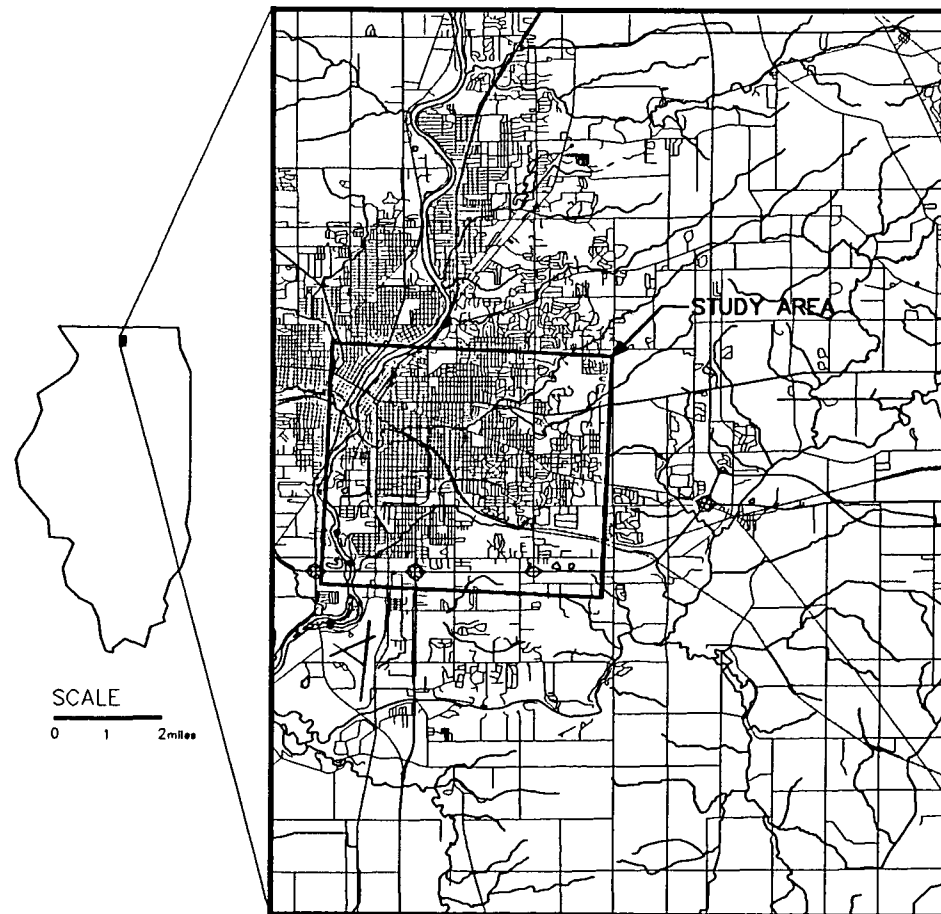


Figure 1. General location of southeast Rockford study area.

SE ROCKFORD STUDY AREA

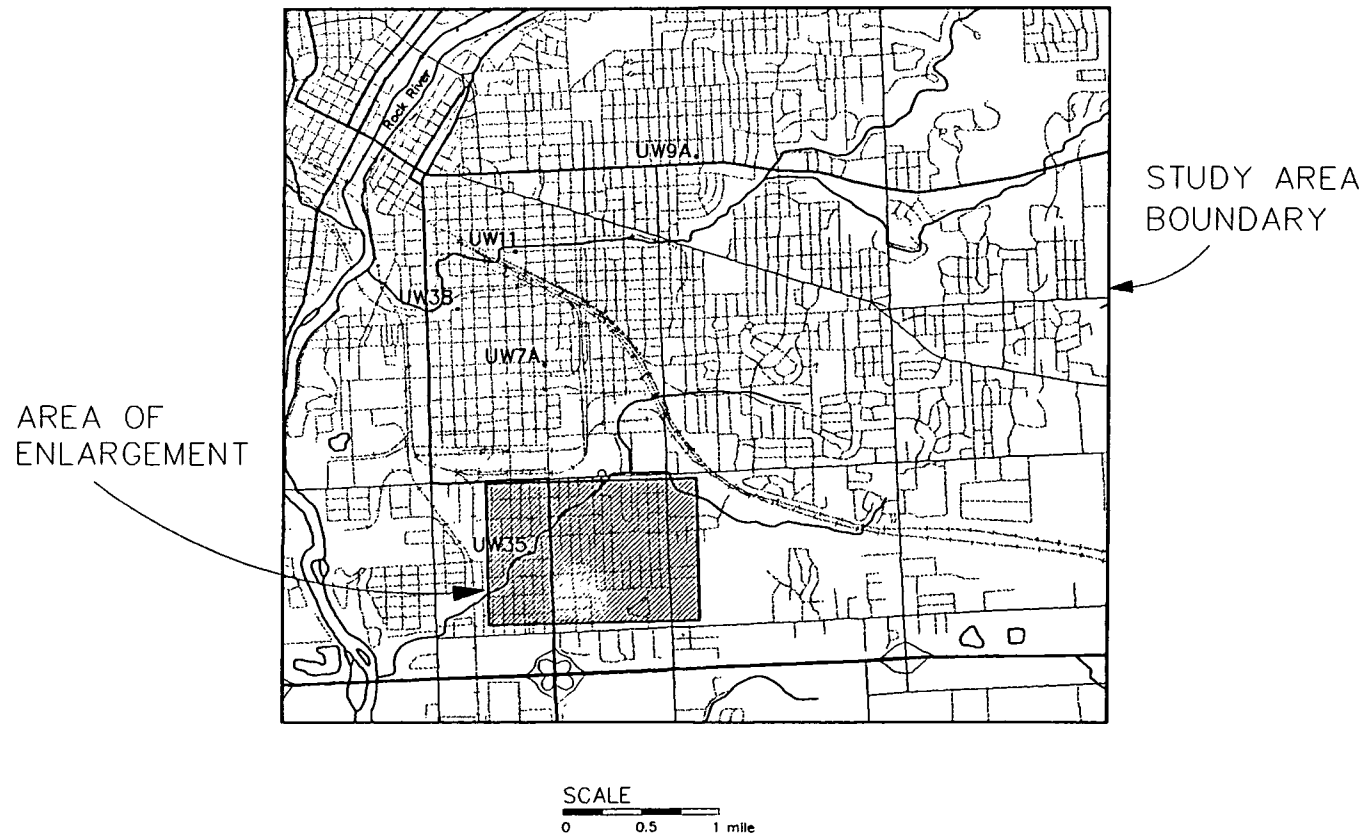


Figure 2. Detailed view of southeast Rockford study area.

will need to be added to the existing databases. Analysis of certain sets of these data have been completed, however, and a summary of an evaluation of the quality of the historic ground-water chemistry data is presented as an appendix. This includes a discussion of the types of chemical data we have assembled and control chart analyses of VOC data collected by the Illinois State Water Survey (ISWS) and the Illinois Department of Public Health (IDPH) in previous studies in Rockford.

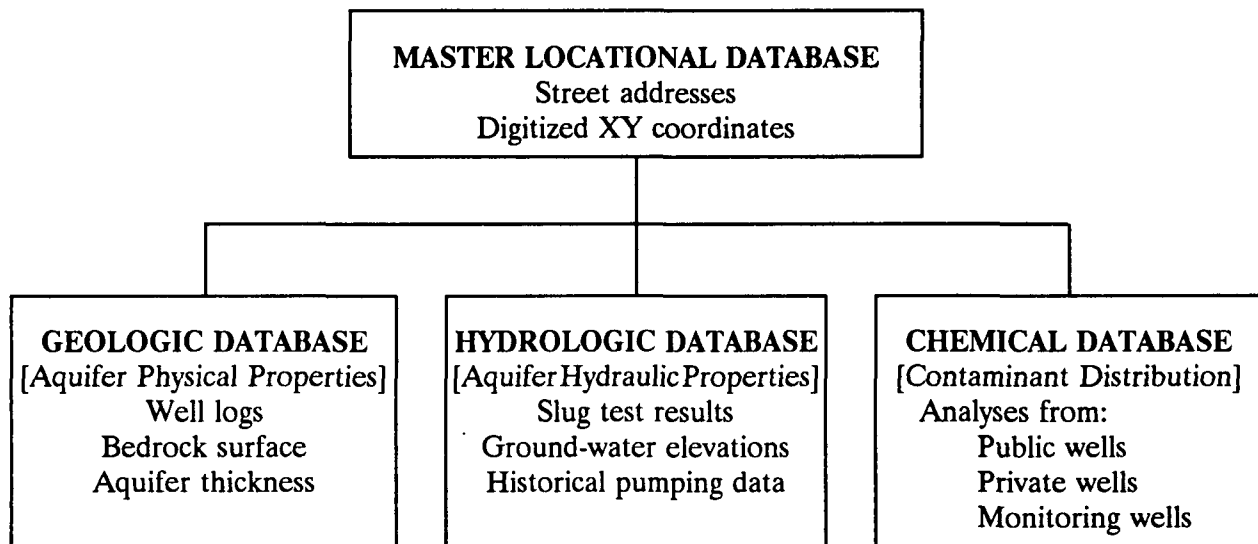


Figure 3. Information contained in Rockford databases

Digitizing of private well sampling locations coupled with the water quality database has allowed us to map VOC concentrations in a portion of the study area. Contour maps of the principal VOC components are presented in a following section entitled *VOC Contaminant Distributions*. In addition, the results of our April sampling of the monitoring wells we drilled last fall are presented in the next section aptly entitled *April Sampling Results*. Other sections of this report also include discussions of geophysical work we conducted in June (and which we hope to continue later this summer), a brief discussion of our summer drilling program, and other project-related activities.

April Sampling Results

The project staff jointly sampled five wells in April which are at the western edge of the known area of contamination. Results of sample analysis on these wells (#2, 4, 7, 8, 12) are summarized in Tables 1 through 3. The data show some evidence of ground-water contamination by a previously detected contaminant, 1,1,1-trichloroethane, although the overall levels of the organic contaminants appear to be quite low.

The apparent dissolved oxygen concentrations shown in Table 1 are clearly at or well above equilibrium-saturation values for the in-situ temperatures. These were determined by iodometric titration by the Winkler method and may be influenced by the presence of other dissolved oxidizing

species acting as interferants, or a systematic error due to the low ambient temperatures experienced in the field. We will explore these possibilities in detail in future sampling operations utilizing both iodometric and electrometric (oxygen-electrode) methods.

Table 1. Results of field chemical measurements for ground water sampled on April 17-18, 1990

Well No.	Temperature (°C)		Eh (volts)	pH	Alkalinity (mg/L as CaCO ₃)	Dissolved Oxygen ^a (mg/L)
	Down-hole	Cell				
2	11.5	13.0	0.433	7.30 - 7.58	301.58	34.83
4	11.5	12.5	0.503	7.34 - 7.60	254.06	45.06
7	13.0	12.0	0.347	7.14 - 7.39	287.90	13.60
8	10.2	11.5	0.502	7.35 - 7.56	303.90	9.11
12	11.4	12.7	0.204	7.62 - 8.02	223.38	22.02

^a Dissolved oxygen concentrations were determined by the Winkler titration method.

The volatile organic compound determinations (Table 2) reflect the area-wide halogenated solvent contamination (i.e., trichloroethane) of the ground water. The levels of approximately 15 µg/L observed in the wells are at the very low end of the range of previously encountered contamination. The observations of other chlorinated compounds and toluene are very near their respective detection limits with the exception of well #2. Well #2 samples showed evidence of contamination with two halogenated methanes as well as tetrachloroethylene though these observations need to be confirmed. The dissolved inorganic and nutrient results (Table 3) reflect the levels commonly observed in the regional sand and gravel aquifer. These preliminary results will require more in-depth future examination in order to correlate major ionic constituents distributions with regional water quality.

Determinations of pH, temperature, redox potential, alkalinity, and dissolved oxygen concentration were all made in the field. Other inorganic and nutrient parameters, and volatile organic compounds were determined in Western Michigan University's (WMU) Water Quality Laboratory. Unfortunately, the planned purchase of new GC and GC-MS equipment has not been completed yet and our current GC with FID and ECD detectors did not allow us to determine the more volatile compounds (e.g., chloromethane, vinyl chloride, chloroethane). This was due mainly to interference from the methanol solvent peak and poor chromatographic resolution. We are improving our instrumental capabilities and hopefully the new GC-MS will arrive in the next month or two. We have taken extra samples which may be used for future analysis under improved analytical conditions.

As part of our vigorous pursuit of the QA/QC program, samples were analyzed in the laboratory together with at least 10% quality control samples consisting of duplicates, blanks, EPA quality control standards and/or laboratory standards. The Water Quality Laboratory at WMU has documented method performance parameters on file and QA/QC procedures for all inorganic constituents analysis. However, improved VOC analytical capability has to be established. We are

in the process of evaluating and incorporating relevant laboratory QA/QC data into our Rockford database in order to be able to estimate the magnitudes of errors introduced in the analytical procedures. We will establish and evaluate the method performance for the VOC analyses soon after our new instruments arrive.

Table 2. Volatile organic compounds detected in ground water sampled on April 17-18, 1990

Well No.	Compound	Concentration ($\mu\text{g/L}$) ^{a,b}
2	1,1,1-trichloroethane	15.2
	tetrachloroethene	12.8
	bromodichloromethane	1.82
	dibromochloromethane	21.2
4	1,1,1-trichloroethane	15.2
	toluene	0.2
7	1,1,1-trichloroethane	16.2/15.3
	1,3-dichlorobenzene	0.82/0.30
8	1,1,1-trichloroethane	15.1
	1,1,1,2-tetrachloroethane	0.15
	ethylbenzene	0.23
12	1,1,1-trichloroethane	14.3

^a Duplicate concentrations indicate results of duplicate analysis.

^b Samples were analysed by the Water Quality Laboratory-WMU using a GC-FID method.

Historic Data Evaluation

We have attempted to collect historic chemical concentration and QC data as well as those from more recent sampling by other agencies. To date, we have gathered data from several sources including the Illinois Department of Public Health (IDPH); the Rockford Water Department; and previous research projects conducted by the Illinois State Water Survey (ISWS). Data quality is unknown for most of these data. Preliminary examination of available QA/QC data from two analytical laboratories have enabled us to assess errors in the analytical procedures. A summary of these data collection and evaluation results is given in the Appendix.

The laboratory QA/QC data appear to suggest varying analytical errors for different compounds depending on a number of factors including method of analysis and detection mechanism (e.g., GC vs. GC-MS; PID vs. ELCD), instrument stability, calibration standard stability and replicate frequency,

*Table 3. Metals and nutrients determined from ground water sampled on April 17-18, 1990
(concentrations in mg/L)*

Well No.	Ca	Mg	Na	K	Mn	Fe	Ba
2	81.2	35.6	26.8	2.38	0.02	0.03	0.04
4	79.1	30.8	28.8	2.96	<0.01	0.01	0.03
7	72.9	45.0	25.2	5.96	0.04	0.04	0.17
8	76.0	35.5	15.6	3.14	0.01	0.01	0.06
12	51.0	17.7	23.2	1.40	0.01	0.53	0.03

Well No.	Cu	Cd	Pb	Zn	Cl	SO ₄	NO ₃ -N
2	0.01	<0.01	0.04	<0.001	50.1	32.1	1.69
4	0.01	<0.01	0.04	0.002	57.2	31.3	8.24
7	0.01	<0.01	0.04	0.003	66.7	44.5	2.42
8	0.01	<0.01	0.04	0.002	23.9	32.9	1.19
12	0.02	<0.01	0.01	<0.001	10.1	9.32	1.07

Well No.	NH ₃ -N	TDS	Si	TC	IC	TOC
2	0.24	465	7.56	90.9	85.9	5.0
4	0.27	475	8.50	78.6	70.9	7.7
7	0.31	495	6.11	89.5	87.2	2.3
8	0.39	460	9.42	90.5	88.0	2.5
12	0.22	290	6.90	73.6	68.1	5.5

TDS: Total Dissolved Solids; TC: Total Carbon; IC: Inorganic Carbon; TOC: Total Organic Carbon

and contamination. For example, private well samples collected in 1986 by the ISWS were analyzed by the Survey's Aquatic Chemistry Section using a GC method with PID (photo-ionization detector) and ELCD (electrolytic conductivity detector) detection. Control chart analyses of laboratory standards recovery data suggest different patterns and magnitudes of variation in the recovery for compounds determined by the ELCD (chlorinated aliphatic compounds) and those by the PID (aromatic compounds). For the aliphatic compounds, control charts show relatively small fluctuations in the percent recovery during the early stage of the two-month analytical project (for typical charts see figure A1 for dichloromethane and figure A8 for trichloroethene in the Appendix). Variation increased during the later stage, suggesting decreased analytical precision. For the aromatic compounds, control charts (e.g., figure A13 for chlorobenzene) show more stable percentage recovery over the entire project, but analysis No. 26 on June 25 had extraordinarily high average results, suggesting it is an outlier. The increasing positive bias of dichloromethane (figure A1) may be due to gradual absorption of dichloromethane, a common solvent in the laboratory, from the laboratory environment by the reagent water and/or standards. While mean recoveries of most standard compounds may be satisfactory (e.g., within $\pm 20\%$ of the true value), precision of the analysis for most chlorinated aliphatic compounds is poor.

Another example is the IDPH/Springfield laboratory which analyzed private well samples in Rockford in the winter of 1989 using a GC-MS method. Laboratory quality assurance data on standard compounds recovery were available. Control charts for the standards recovery are constructed and a typical chart is shown in figure A22 for chloroform. Examination of the control charts suggest no obvious outliers for all compounds. Mean recoveries are within $\pm 20\%$ of the true value and standard deviations of the recovery are less than 15% for all compounds except vinyl chloride and 1,2-dichloroethane which have slightly higher values.

A number of missing data points were present in the 1986 ISWS laboratory standards results, presumably due to failure in recognizing the GC peaks. This problem is solved if a GC-MS method is used, as in the IDPH/Springfield laboratory.

Future Experimental Design: Error Identification and Comparison

There is a critical need in site characterization studies to identify and control major sources of sampling and analytical error. The control of systematic (determinate) error is particularly important since these errors lead to consistently low or high apparent contaminant levels. They may go undetected in routine investigations. Indeed, if site characterization efforts employ a number of sampling personnel, techniques and matrices, systematically-biased results may be interpreted as actual trends in contaminant distributions. In our previous work (Sampling Frequency and Ground-Water Sampling projects), we identified major sources of error and their potential effects on temporal trend analysis. Depending on the duration of the investigation, it may be necessary to increase the level of QA/QC in order to reference our study results to apparent trends in the past ten to fifteen years of data in the Rockford region. With respect to spatial variability, it will also be important to intercompare overall accuracy and precision of replicate synoptic sample analyses from wells, the Hydropunch, soil gas and aquifer solids.

This task, which we will pursue in the next two quarters of the project, will begin with an initial error survey to estimate the magnitude of the errors involved in various sampling and analytical steps. This will be followed by the intercalibration experiment employing sufficient replicates to permit control

Table 4. Error Identification and Control Measures for Ground-Water Sampling and Analysis

	Sample Collection	Sample Handling/ Storage	Analysis	Overall Precision & Accuracy
Error Source	Pumping/ purging Grab sampling	Handling losses/gains Sample matrix effects Storage losses/ gains	Analytical methods	
Control Samples	Replicate samples as a function of pumping or sampling technique	Field standards/ blanks Spiked sample replicates, sample replicates	Lab standards Lab blanks External reference samples	
Precision/ Accuracy	σ_C^* , R_C^{**}	σ_H , R_H	σ_A , R_A	$\sigma_C + \sigma_H + \sigma_A = \sigma_{Total}$ $R_C + R_H + R_A = R_{Total}$

* Precision in units of standard deviation

** Accuracy in units of percent recovery relative to standards (i.e., bias)

over the errors so that techniques can be compared in a statistically significant manner. The sources of errors inherent to steps in sampling and analytical operations are shown in Table 4 with reference to the QA/QC control samples and standards which will be used to estimate accuracy as percent recovery or bias and precision.

Our analysis of the existing organic compound data (provided in the Appendix) disclosed that accuracy and precision may not have been controlled adequately over the entire period of individual investigations. Therefore, our study will employ additional control samples and standards as well as external reference standards for each step in sample collection and analysis. It is also clear that we will have to employ field and lab controls/replicates over a range of concentrations to determine if either accuracy or precision vary with concentration level. We anticipate that the concentration range of interest will extend from the method detection limit (e.g., generally less than 1 $\mu\text{g/L}$) to approximately 1 mg/L for volatile organic compounds in water).

VOC Contaminant Distributions

Figures 4 - 8 present contour maps of several VOC contaminant distributions within the enlarged area shown in figure 2. Total VOC's are shown in figure 4, followed by trichloroethane (figure 5), trichloroethene (figure 6), 1,1-dichloroethene (figure 7), and dichloroethane (figure 8). Asterisks on the maps represent the 220+ private well locations sampled by IDPH. Punctual kriging was performed to interpolate VOC concentrations at the nodes of a 30 \times 20 grid in order to facilitate contouring (kriging was accomplished using GEO-EAS, contouring was accomplished using SURFER®). Note a general lack of sampling points in a corridor starting in the northeast corner of the figures and proceeding southwest to just east of center.

Total VOC's range from nondetectable to over 700 $\mu\text{g/L}$ (figure 4). The plume generally follows the direction of ground-water flow, that is, from east to west. The location of private water wells allows a fairly detailed delineation of the plume especially to the south and in selected zones within the plume itself. However, we are much less confident in the configuration of the plume to the north and east because of the lack of sampling locations in that area (i.e., north and east of the figure). It is important to note that our interpolations indicate three peaks in the plume of total VOC's. Two of these peaks occur in regions where relatively few samples were taken. Therefore, it has yet to be determined if these peaks are real or an artifact of the interpolation/contouring procedure.

One way to express confidence in the kriged estimates is to look at the error or standard deviation of the estimate. The error of the kriged estimate of the total VOC's (i.e., the standard deviation of the kriged, interpolated values) in figure 4 was contoured and is shown in figure 9. Contour values represent the $\ln(\text{total VOC's})$ with a contour interval of 0.1. The greatest error in our kriged estimates will be where we have the least data. This is easily seen in figure 9 to encompass areas outside of our private well sampling locations. Similar uncertainties exist for contours of individual VOC compounds. We intend to use these uncertainty data as a guide for future sampling -- most likely through drilling and hydropunching.

The trichloroethane (TCA) plume (figure 5) appears to be quite similar to the total VOC plume. Peaks in the plume of total VOC's are also strongly evident in the TCA plume. Even though

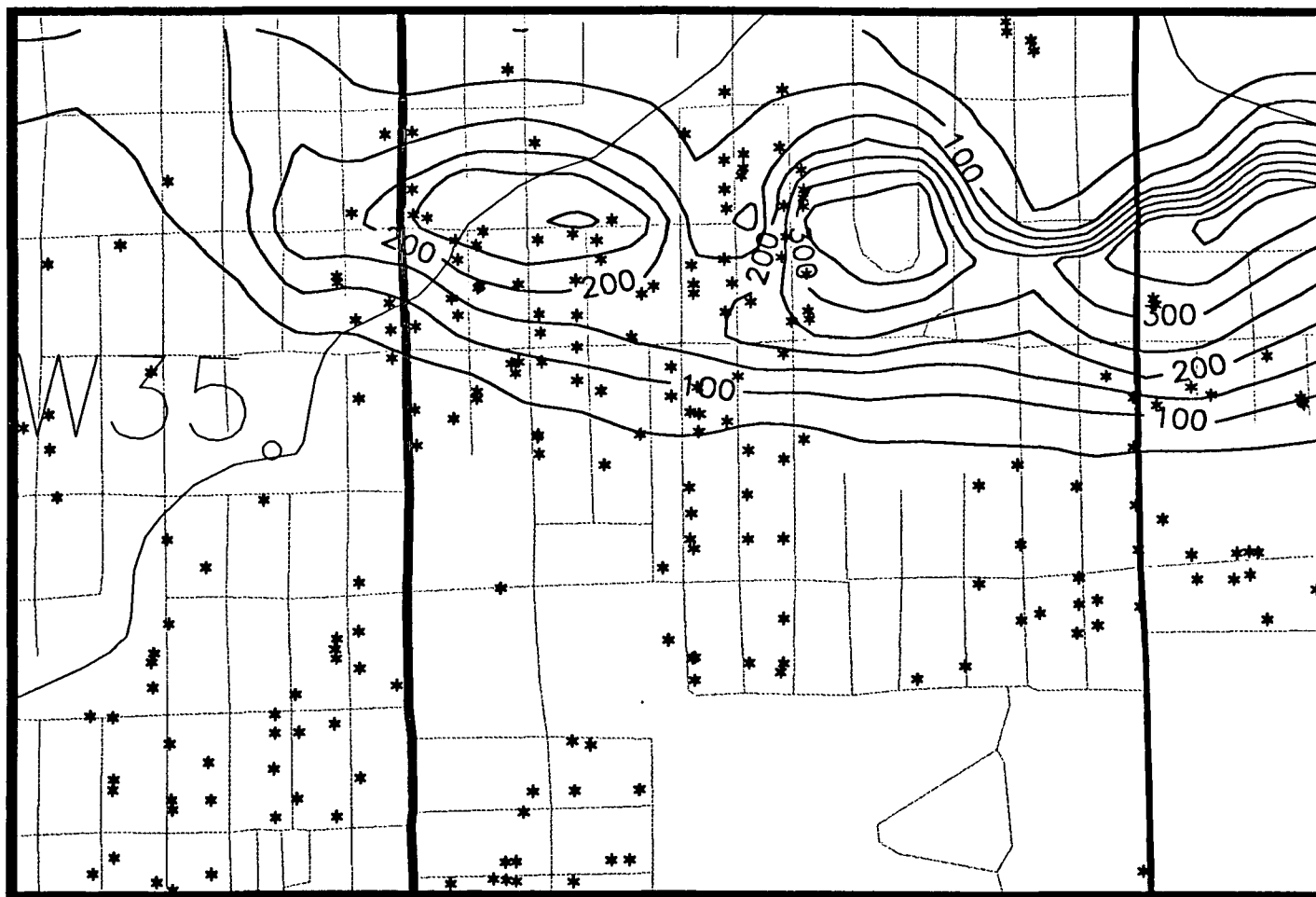


Figure 4. Total VOC concentrations in enlarged map area of figure 2 (scale: 1" = 1000').

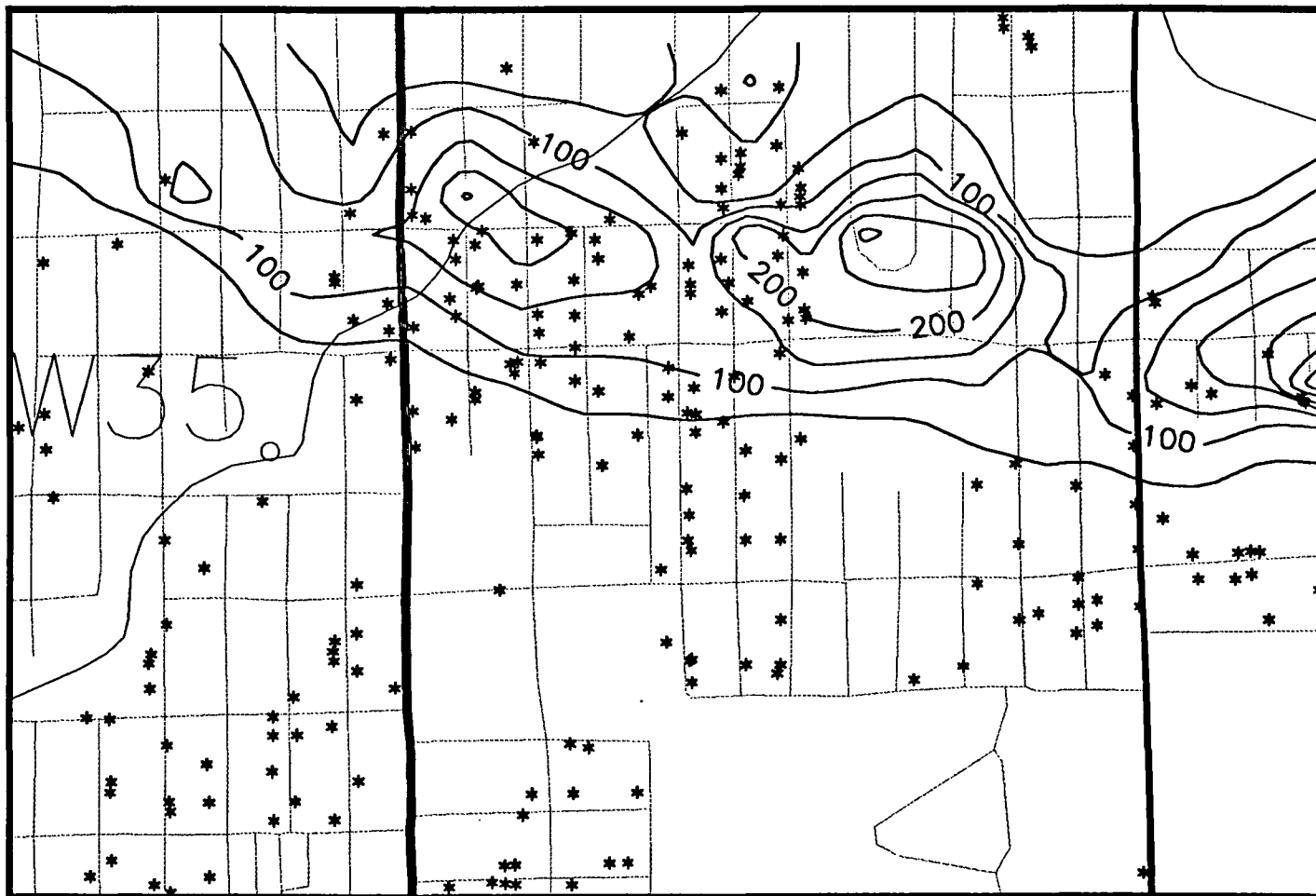


Figure 5. Trichloroethane (TCA) concentrations in enlarged map area of figure 2 (scale: 1" = 1000').

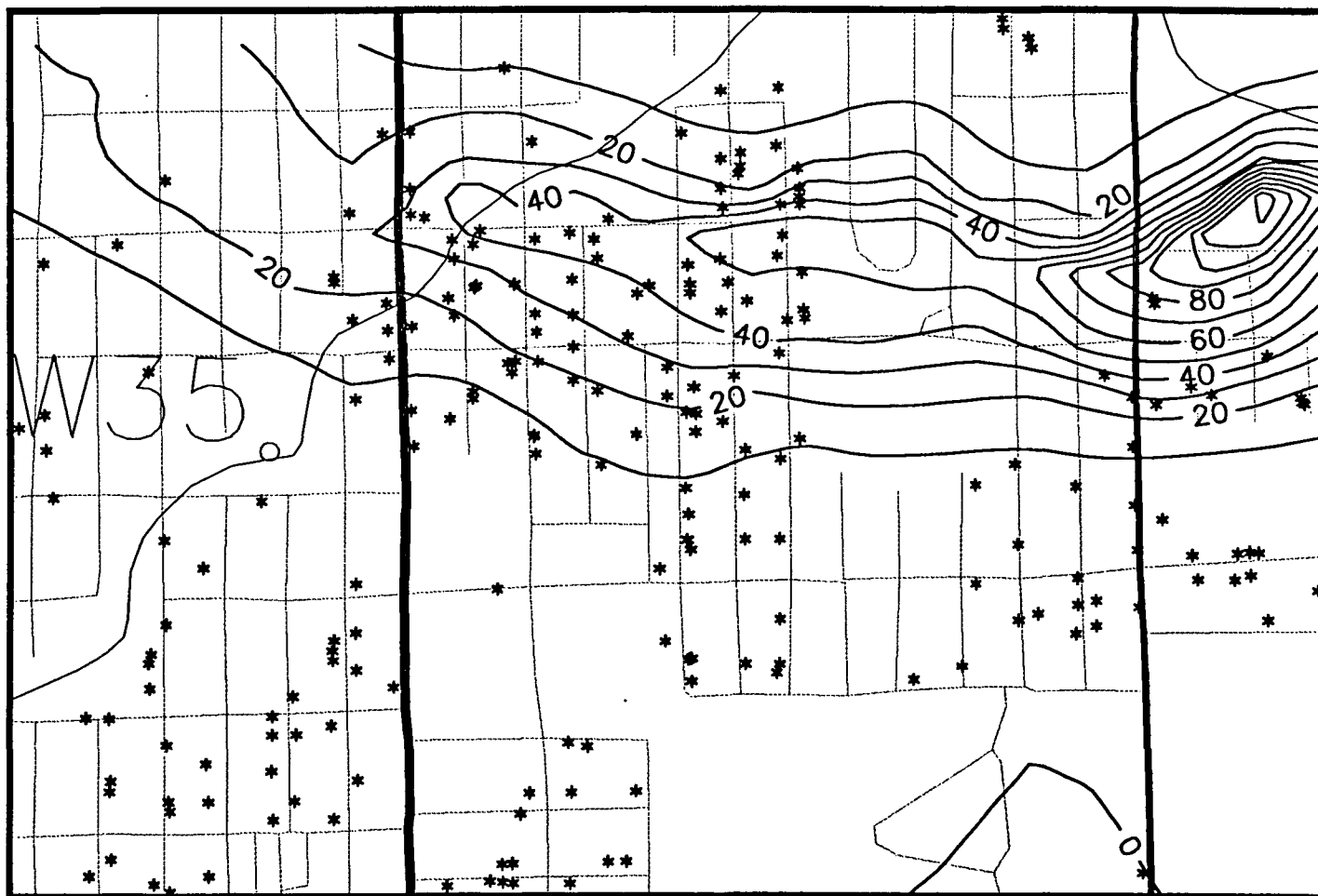


Figure 6. Trichloroethene (TCE) concentrations in enlarged map area of figure 2 (scale: 1" = 1000').



Figure 7. 1,1-Dichloroethene (DCE) concentrations in enlarged map area of figure 2 (scale: 1' = 1000').



Figure 8. Dichloroethane (DCA) concentrations in enlarged map area of figure 2 (scale: 1" = 1000').



Figure 9. Standard deviation of the kriged estimate of $\ln[\text{TVOC}]$, contour interval = $0.1(\ln[\text{TVOC}])$ (scale: $1'' = 1000'$).

some portions of the peaks occur in areas where there are few samples, other portions occur where there are many samples (i.e., we have more confidence in the interpolations). Interestingly, the separation distance between peaks figures to approximately a one year travel time assuming a ground-water flow velocity of one foot per day (Wehrmann et al., 1988).

The spatial distributions of the compounds trichloroethene (TCE) and 1,1-dichloroethene (DCE), figures 6 and 7, respectively, are much different than for the TCA plume. The TCE plume appears to look like the "classic" point source plume with the highest concentrations in an upgradient location and lower concentrations fanning out downgradient. Again, however, the contoured plot shows the highest concentration in an area where no actual data exists and care should be exerted when examining the contour map.

On the other hand, confidence in the DCE plume (figure 7) is quite high, as there are many sampling points equally distributed throughout the plume. No DCE appears to exist within the eastern portion of the volatile plume. DCE concentrations increase in the downgradient direction. This manifestation is consistent with the production of DCE from the degradation of TCE and TCA (Olsen and Davis, 1990). The compound dichloroethane (DCA) is also present (figure 8). Compound identification was more uncertain for this compound than many of the others and, therefore, the contoured concentrations are less well behaved -- the pattern exhibited is similar to that of the TCE plume.

Incidentally, the graphical overlaying of concentration contours, sample locations, and cultural information (e.g., roads, etc.) was accomplished using a desktop geographic information system (GIS) developed for this project. The concept of this desktop GIS, which is based on the computer aided drafting program AutoCAD® was the topic of a paper presented by Mark Varljen last June in San Francisco at the ASTM International Symposium on Mapping and Geographic Information Systems. A paper using some of the figures in this report as examples will be published as part of the ASTM Special Technical Publications (STP) series -- the paper was reviewed by Bedinger and C.O. Morgan.

Geophysics

As part of the hydrogeological investigation, a good conceptual model of ground-water flow behaviour across the study area is needed. In particular, we feel more effort is needed to determine where the sand and gravel aquifer pinches out along the eastern bedrock valley wall of the Rock Bedrock Valley. Not only does the sand and gravel thickness decrease as the elevation of the valley wall rises, the thickness is decreased from above as a sequence of till overlies the sand and gravel along the eastern flank of the valley. Some surface resistivity may be done this fall to help define the existence of the till overburden; however, last June with the assistance of the State Geological Survey, we spent 1½ days conducting a series of seismic refraction lines to better define the depth to the bedrock valley wall in eastern portions of the study area. The locations of the general areas of investigation are shown in figure 10.

Six 600-foot lines were run with shots placed at both ends of the lines. One 1200-foot line was laid out but not completed because of difficulties with the detonator. More work will be done later this year in the locations indicated. Preliminary results indicate the depth to bedrock in some areas was from 60 to 80 feet and in others over 200 feet. A detailed analysis will be

LOCATIONS OF GEOPHYSICAL INVESTIGATIONS

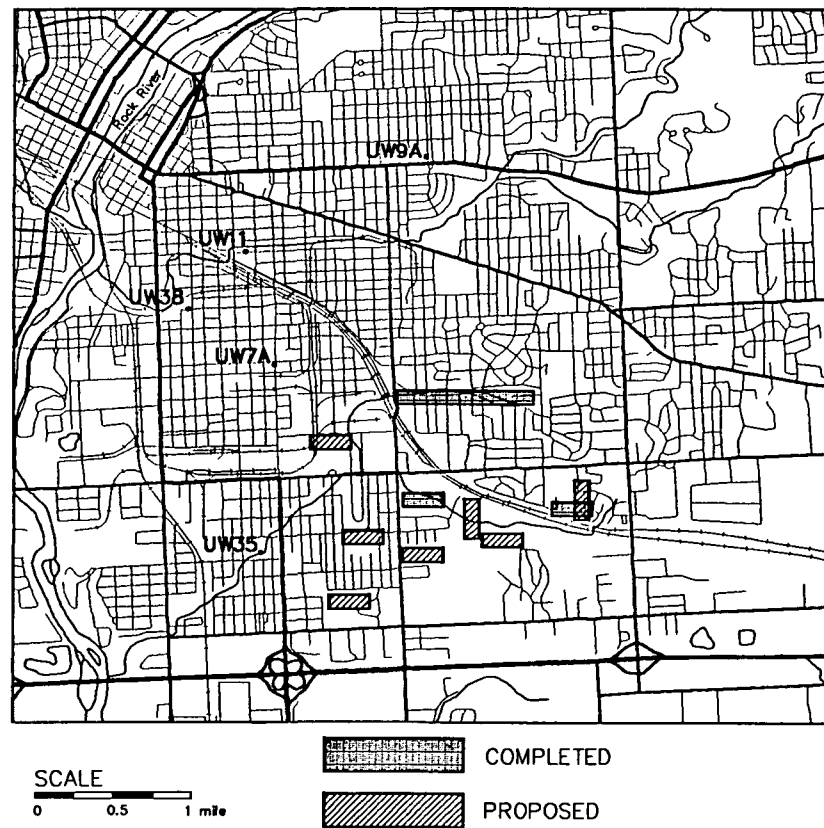


Figure 10. Locations of seismic refraction lines for geophysical investigations in SE Rockford.

forthcoming in future reports.

Upcoming Project Activities

Drilling/Sampling

Just as this progress report was being finished, another group of monitoring wells was being installed in Rockford. In conjunction with this drilling program, Kent Cordry (QED Technical Consultant on the HydroPunch) assisted with the collection of several HydroPunch samples. The next progress report will detail the results of this preliminary work. Figure 11 shows the location of all our monitoring wells (20 total). Wells 13-20 were drilled most recently. The location of most of our monitoring wells in relation to the VOC plume is shown in figure 12.

As the drilling progressed, Mike Barcelona and Western Michigan University staff with the assistance of IDPH personnel, collected 80+ samples for VOC analysis from a selected group of homes within the affected area. All of the wells at these homes will be abandoned because City water has been extended to the area through Superfund Emergency Response. Sampling was deemed highly desirable as a last chance to secure high-density coverage of the plume to evaluate temporal changes in the plume configuration. Again, a more detailed discussion of the results of this effort will follow in our next progress report.

Budget

As of 7/20/90 accounting, the project is operating within budget for the first two budget increments totaling \$300,000. Progress on the WMU subcontract work had been substantially slowed due to the inordinately long delay in processing the budget revision submitted in December 1989. It appears that the negotiations over equipment transfers slowed the processing somewhat, yet the successive four month delay resulted from office difficulties at Agency Headquarters. As of this writing, the subcontractual agreement with the University of Illinois should be in the final stages of approval. It is clear that avoidance of future delays will be necessary to keep their work on schedule. Submission for an \$85,000 third increment was made last April. We have not received any word of the status of this funding.

The status of budget line items within the \$300,000 limit of the first two increments is shown on the next page. Outstanding obligations exist in the amount of approximately \$11,000 which have not yet cleared accounting (principally drilling costs). The subcontractual line of \$126,490 will be obligated when final subcontract arrangements have been made (Barcelona does have a letter of intent from the U of I which basically allows him to spend against this amount). As you can see, while we are within budget, once the \$126,490 is obligated, our balance is only \$7,333. Considering the \$11,000 outstanding, the \$85,000 increment is sorely needed, particularly to balance out our travel and supply lines. These lines are especially hard-hit during our summer field work. Frankly, an additional increment will be needed to get us through the remainder of the field season this fall.

	<u>Budgeted</u>	<u>Balance</u>
Personnel	\$ 60,362	\$ -1,347
Fringe Benefits	7,908	838
Travel	7,197	-2,114
Equipment	18,405	10,973
Supplies	11,615	-3,120
Contractual	13,836	3,978
Subcontractual (WMU)	126,490	126,490
Other	2,279	1,265
Indirect Costs	<u>51,908</u>	<u>-3,128</u>
Total Budget	\$300,000	\$133,823

Project Staff

There have been no major changes in project staff during the past quarter. Mark Varljen was added to the staff of the Water Survey as a full-time permanent employee upon graduation last June. He has been involved with the project from the start as a graduate assistant working part-time during the school year and full-time last summer (1989). Mark is responsible for the geostatistical interpretation and most of the hydrologic, geologic, and master locational database development.

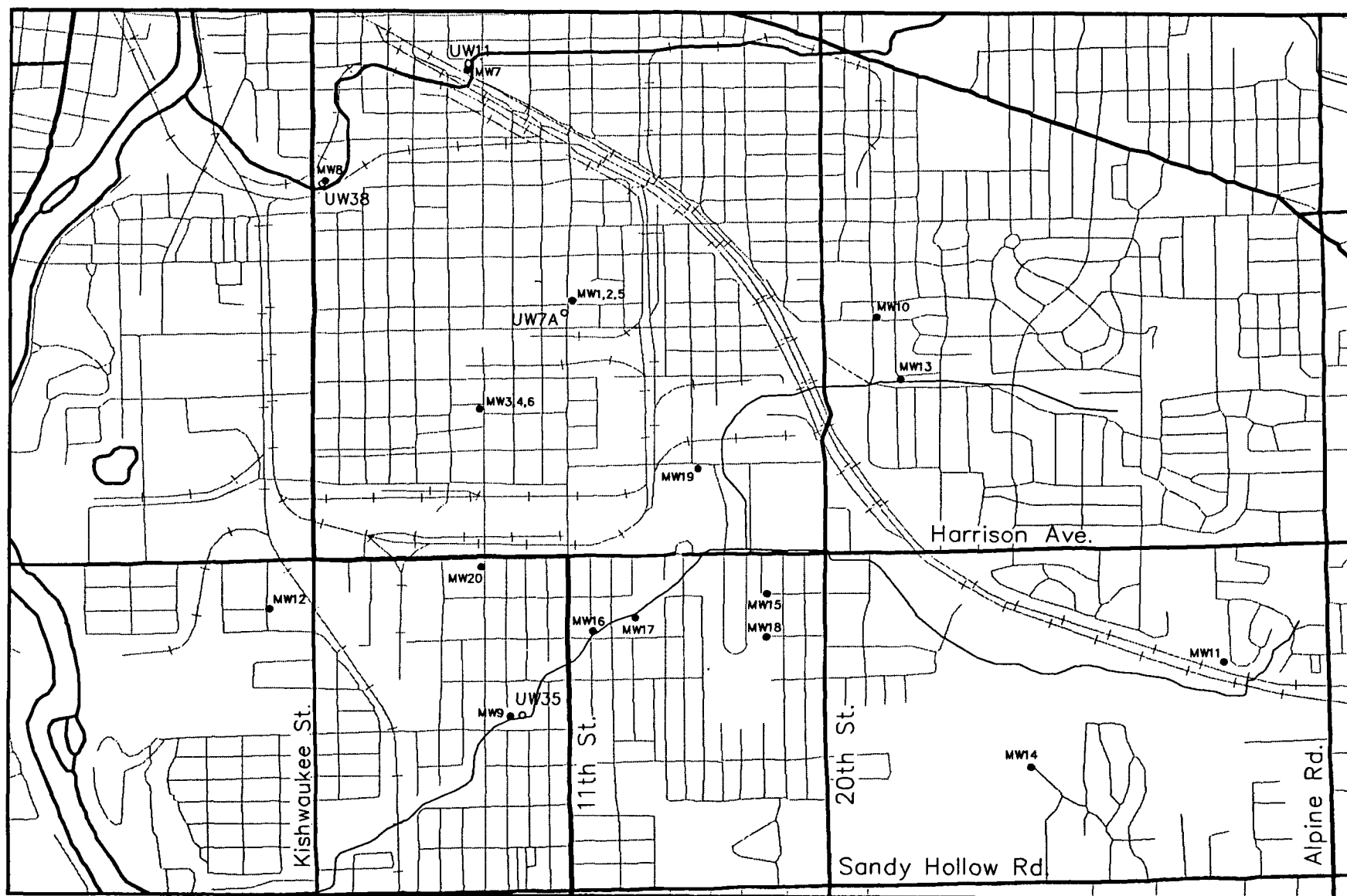


Figure 11. Location of 4 municipal and 20 monitoring wells in SE Rockford study area.

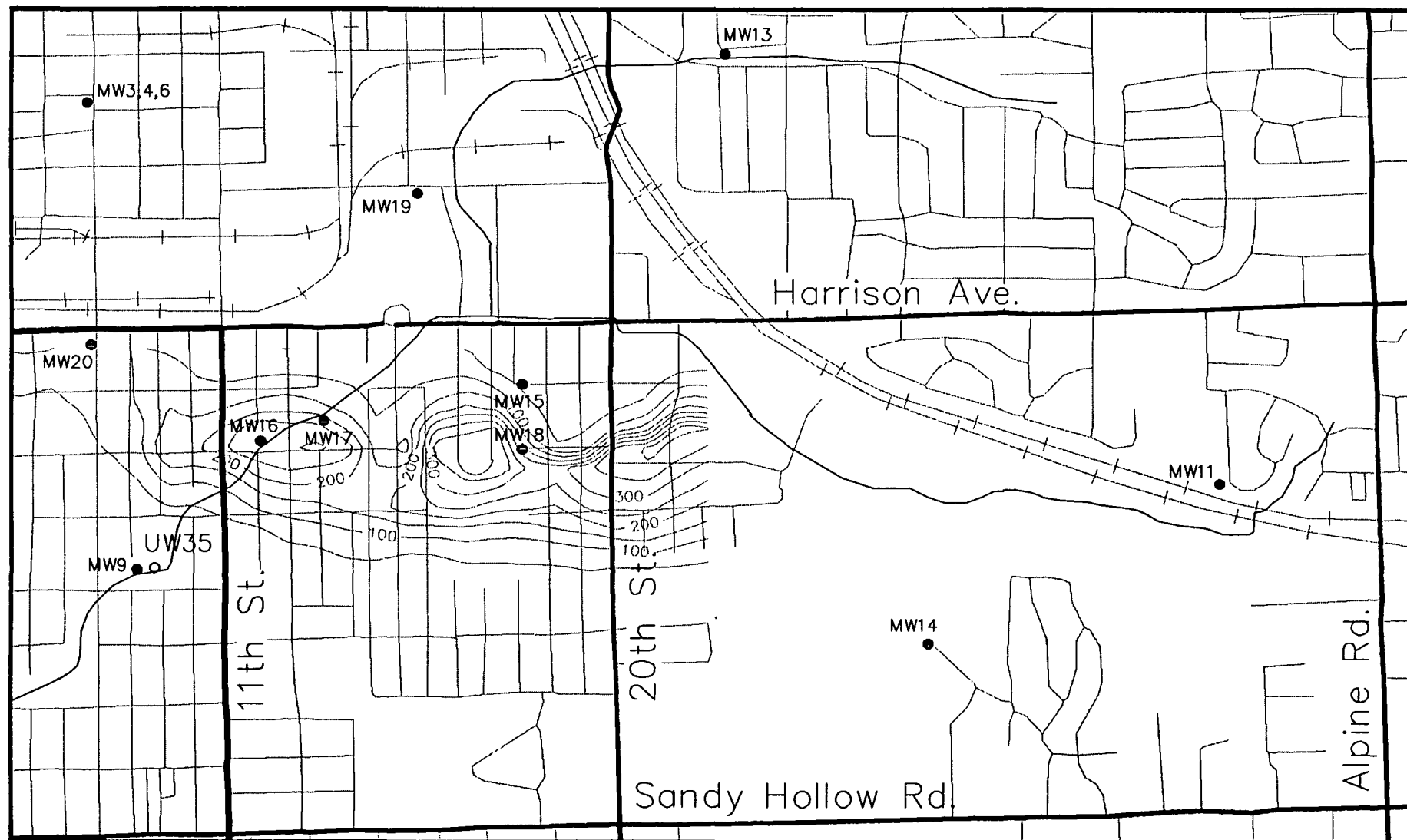


Figure 12. Location of monitoring wells in relation to known VOC plume in SE Rockford study area.

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APPENDIX
Summary of Collection and Evaluation of Historic Data on Rockford Groundwater Chemistry
May 28, 1990

A. Historic Data Collection

Historic data on Rockford ground water chemistry are available as a result of several previous sampling and monitoring efforts made by the Illinois Department of Public Health (IDPH), the Illinois State Water Survey (ISWS), and other state and municipal agencies. To date, we have collected a considerable amount of data from these sources on a number of chemical parameters.

Historic samplings were undertaken for a variety of reasons. Each set of data sources generally had a different set of chemical parameters which were determined under different field and analytical conditions. In certain cases, samples from one sampling event were analyzed by more than one laboratory and no external reference or inter-laboratory calibration data were available. These problems have resulted in data incompleteness and data quality inconsistencies. In most cases, data quality estimations (analytical precision and bias) were not supplied. We were successful, however, in obtaining relevant raw QA/QC data from some analytical laboratories.

Original data were supplied to us in hard copy and all have been through a preliminary examination. In some cases this involved data reduction before manual entry into a PC-based database in the form of ten Lotus spreadsheets. Table A1 lists the Lotus spreadsheets and their contents. Codes and/or abbreviations used in the database are provided in Table A2.

The data collected fall into either organic (volatile organic compounds or VOC) or inorganic categories. The following list shows specific parameters for which we have data for at least one sample:

Inorganic Parameters: pH, alkalinity, SO_4^{2-} , NH_4^+ , Ag, Al, As, B, Ba, Ca, Cd, CN^- , Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb, Se, Sr, Zn.

Organic (VOC) Parameters: vinyl chloride, bromoform, bromodichloromethane, chlorodibromomethane, dichloromethane, trans-1,2-dichloroethene, 1,1-dichloroethane, 1,1-dichloroethene, cis-1,2-dichloroethene, chloroform, 1,2-dichloroethane, trichloroethane, carbon tetrachloride, trichloroethene, 1,1,2-trichloroethane, tetrachloroethene, benzene, toluene, chlorobenzene, ethylbenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, and 1,2-dichlorobenzene

B. Inorganic Data

Inorganic data collected are stored in file MASTER1.WK1. A major portion of the data was from the 1986 private well sampling by the ISWS. Data from various other sources also are included with sampling dates back to 1955 (1984, '82, '79, '78, '74, etc.).

C. Organic (VOC) Data

Organic data are contained in file MASTER2.WK1. These are primarily from the following sampling events:

a. Private Well Sampling by IDPH. Sampling was conducted in Fall and Winter, 1989. Samples were analyzed in two laboratories, IDPH/Springfield Laboratory and IDPH/Chicago Laboratory.

The Springfield Laboratory analyzed samples collected on: 11/06/89, 12/05/89, 12/12/89, for the following (quantitative) parameters (using capillary GC-MS method): vinyl chloride, 1,1-dichloroethene, chloroform, 1,2-dichloroethane, 1,1,1-trichloroethane, carbon tetrachloride, bromodichloromethane, trichloroethene, benzene, dibromochloromethane, 2-chloro vinyl ether, and 1,4-dichlorobenzene.

The Chicago Laboratory analyzed samples collected on: 09/12/89, 09/19/89, 09/26/89, 10/17/89, 10/25/89, 11/06-07/89, 11/28/89, 12/04/89, and 12/11/89.

b. Private Well Sampling by ISWS, 1986 (Wehrmann/Holm principal investigators). Sampling was conducted in the Summer of 1986 and all samples were analyzed by ISWS Aquatic Chemistry Section using capillary GC-ELCD/PID. Parameters determined were as follows: dichloromethane, trans-1,2-dichloroethene, 1,1-dichloroethane, cis-1,2-dichloroethene, chloroform, 1,2-dichloroethane plus trichloroethane (coeluting on GC column), carbon tetrachloride, trichloroethene, 1,1,2-trichloroethane, tetrachloroethene, benzene, toluene, chlorobenzene, ethylbenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, and 1,2-dichlorobenzene.

c. ISWS 1988 Pump Test on Municipal Well 7A and VOC Sampling from Observation Wells. Samples were analyzed by ISWS for five compounds: chloroform, benzene, toluene, trichloroethene and tetrachloroethene. Limited data.

d. Miscellaneous Sources. These include data from municipal well sampling conducted by the Rockford Department of Water and others.

D. Data Quality Evaluation

A major problem encountered with the historic data are the data quality unknowns. In most cases, no error limits were given in the original data reports supplied to us. We are unaware of any vigorous QA/QC programs carried out with the sampling procedures (except limited data on travel blanks) and cannot evaluate overall data quality. However, by direct contact with the analytical laboratories involved in the sample analysis, we were able to obtain some specific analytical information and laboratory quality assurance data, which would allow us to estimate analytical uncertainties. The discussion below is restricted to the VOC analysis in two laboratories of which we have so far obtained relatively complete sets of QA/QC data.

a. 1986 ISWS VOC Analysis. Samples from the 1986 ISWS private well sampling were analyzed in the Aquatic Chemistry Section, ISWS between June 6 and August 5, 1986. Laboratory quality assurance data on standard compound recovery are available for this period (file QAQC2.WK1).

According to laboratory records, at least one laboratory standard sample was analyzed on any day Rockford samples were analyzed. Concentration levels of the laboratory standards included 5, 20, but mostly 10 $\mu\text{g/L}$.

The analytical facility consisted of an HP 19395A static headspace sampler, a Varian 3700 gas chromatograph equipped with a HNU PID and an Hall ELCD in tandem, and a Vista 401 data system. The facility was automated with the auto-injection feature of the sampler and a custom-made timing/relay circuit which, upon sample injection, activates acquisition by the data system and temperature programming on the GC. All compounds were identified based on comparison of the retention time with that of standard compounds. 1,4-Dichlorobutane was used as the internal quantitation standard for chlorinated aliphatic hydrocarbons detected by the ELCD, and α,α,α -trifluorotoluene as the internal standard for the aromatic compounds detected by the PID.

Percent recoveries of each standard compound have been calculated and the complete data set is contained in file QAQC2.WK1. Summary statistics on the recovery data, subgrouped by compound concentrations and as a whole data set, are shown in Table A3. X-Control charts for each compound are plotted in figures A1 to A17.

As indicated in Table A3, we have data from a total of 4 determinations at the 5 $\mu\text{g/L}$ level. All compounds appear to have been recognized and quantified. There are 33 determinations at the 10 $\mu\text{g/L}$ level and 8 determinations at the 20 $\mu\text{g/L}$ level. At the latter two concentration levels, several missing values are present for certain compounds presumably because these compounds were not recognized in the analysis. The missing data points were excluded from statistical analysis (Table A3).

The majority of compounds have a mean recovery within $\pm 20\%$ of the true value. Positively biased compounds exceeding 120% recovery include dichloromethane (5, 10, 20 $\mu\text{g/L}$ and overall), trans-1,2-dichloroethene (10, 20 $\mu\text{g/L}$ and overall), 1,1-dichloroethane (10, 20 $\mu\text{g/L}$ and overall), 1,1,2-trichloroethane (20 $\mu\text{g/L}$), and carbon tetrachloride (20 $\mu\text{g/L}$). Negatively biased compounds with a recovery lower than 80% include cis-1,2-dichloroethane (5 $\mu\text{g/L}$) and carbon tetrachloride (5 $\mu\text{g/L}$).

Standard deviations of percentage recovery are significantly large for most compounds in the 10, 20 $\mu\text{g/L}$ and the all standards sub-data sets (Table A3). In contrast, the 5 $\mu\text{g/L}$ standards show small standard deviations. No obvious analytical relationships, however, can be derived between the standard deviation and the mean of the recovery. Indeed, the 5 $\mu\text{g/L}$ standards were analyzed only in the early stage of the project (prior to June 13). Determination of other standards spanned over a wider period of time when other factors may have caused greater analytical variances as illustrated in the control chart analysis discussed next.

In general, control charts for the halogenated aliphatic compounds (figures A1 to A10) show relatively small fluctuations in the early stage of the analysis period (prior to June 17). Variation increased during the later stages. For aromatic compounds (except 1,2-dichlorobenzene), control charts show more stable percentage recovery over the entire analysis period, but analysis no. 26 on June 25 had extraordinarily high concentration results, suggesting a possible outlier. After removal of analysis no. 26, statistical analysis of both the 10 $\mu\text{g/L}$ sub-data set and the all-standards data set gives considerably smaller values in standard deviations for the aromatic compounds (Table A3). The larger errors in the aliphatic compound analyses compared to the aromatic may be due to the different detection mechanisms. Furthermore, larger errors for the aliphatic compound analyses experienced in the later stage of the analysis period may be due to increased detector or laboratory

standard instability.

The control chart for dichloromethane (figure A1) shows a significant increasing trend with time starting from approximately June 16. The highest recovery reached 710.4%. This increasing positive bias may be attributed, at least in part, to the gradual absorption of dichloromethane, a common solvent in the laboratory, from the laboratory environment by the reagent water and/or standards.

Based on the statistics for the 5 $\mu\text{g/L}$ standards, Method Detection Limit (MDL) and Method Quantitation Limit (MQL) are estimated (Table A4). As the 5 $\mu\text{g/L}$ standards were all analyzed at a period of best analytical performance, these estimates should be considered as the lowest possible limits. Estimation of the 95% confidence interval for the overall percentage recovery is also given in Table A4.

In summary, accuracy and precision of VOC analysis by ISWS in 1986 can be assessed from the quality assurance data on the standard compound recovery. While mean recoveries of most standard compounds may be satisfactory (e.g., within $\pm 20\%$ of the true value), precision of the analysis for most chlorinated aliphatic compounds is poor. Control chart analyses suggest greater analytical variability for the chlorinated aliphatic hydrocarbons during the later stage of the analytical season. For the chlorinated aromatic hydrocarbons, precision is satisfactory if a highly likely outlier sample is removed. A number of factors may have influenced the analytical accuracy and precision, including detection mechanisms, instrument stability, calibration standard stability and replicate frequency, and contamination.

b. IDPH/Springfield Laboratory VOC Analysis. IDPH/Springfield Laboratory provided raw data on GC-MS calibration check standards which were analyzed together with the Rockford samples in the winter of 1989. These raw QA data were reduced and entered into Lotus files QAQC3.WK1 and QAQC4.WK1. Limited QA/QC data for travel blanks and laboratory duplicates were also available on the Springfield Laboratory analysis.

Data from a total of 18 determinations on standard samples were supplied to us, most of which are 2 $\mu\text{g/L}$ standards (Table A7). Other concentration levels were 0.4, 4, 8, and 20 $\mu\text{g/L}$ but the number of data points is insufficient for subgroup statistical analysis. For this reason, statistics are only obtained on percentage recovery data of all standards (Table A5).

As shown in Table A5, the mean recovery of all compounds are within $\pm 20\%$ of the true value. Standard deviations of recovery for all compounds are less than 15% except vinyl chloride and 1,2-dichloroethane which have slightly higher values.

Examination of control charts (figures A18 through A29) suggests no obvious outliers for all compounds. However, short term (hours) drifts are obvious for most of the compounds (e.g., figure A19, vinyl chloride; figure A20, bromoform). It would appear that the analytical/instrumental condition was not sufficiently stable (not unusual for GC-MS quantitation) but well maintained calibration/quality assurance procedures have ensured satisfactory results.

Table A1. Directory of Lotus Spreadsheets for Rockford Ground-Water Quality Data

MASTER1	- Inorganic chemistry master database
MASTER2	- Organic chemistry master database
PUMPTTEST	- VOC results from ISWS 1988 pump test on Municipal Well 7A
INQAQC1	- Inorganic QA/QC data for 1986 private well sampling conducted by Wehrmann/Holm
QAQC1	- Organic QA/QC results and calculations of % recovery for 1988 pump test
QAQC2	- Organic QA/QC data for 1986 private well sampling conducted by Wehrmann/Holm
QAQC3	- Organic QA/QC data for 12/5/89 private well sampling - IDPH Springfield
QAQC3A	- Percent recovery calculations for lab standards - IDPH Springfield, 12/5/89
QAQC4	- Organic QA/QC data for 12/12/89 private well sampling - IDPH Springfield
QAQC4A	- Percent recovery calculations for lab standards - IDPH Springfield, 12/12/89

Table A2. Codes Used in Rockford Ground-Water Quality Databases

Well Type	SP	=	Sand Point
	D	=	Drilled
Use	P	=	Private
	C	=	Commercial
	PWS	=	Public Water Supply
	M	=	Monitoring
Aquifer Type	S-G	=	Sand & Gravel
	B	=	Bedrock
Site	RG.#	=	Rockford Group Well
	R.#	=	Rockford Unit Well
	LP.#	=	Loves Park
Data Source	SWS	=	State Water Survey
	IDPH-C	=	Dept. Pub. Health/Chicago Laboratory
	IDPH-S	=	Dept. Pub. Health/Springfield Laboratory
Concentration	#	=	Compound detected but not quantified
	ND	=	Not detected

**Table A3. Summary Statistics of Percentage Recovery of Laboratory Standards, ISWS
(June to August, 1986)^{1,2}**

Compound	Number of Observations	Minimum	Maximum	Mean	Standard Deviation
<u>5 pbb standards (4 analyses)</u>					
dichloromethane	4	115.8	124.4	120.4	4.64
trans-1,2-dichloroethene	4	77.4	87.6	82.7	5.06
1,1-dichloroethane	4	82.0	99.2	91.0	7.04
cis-1,2-dichloroethene	4	73.2	81.4	77.5	3.40
chloroform	4	83.4	99.8	93.0	6.89
1,2-dichloroethane + trichloroethane	4	83.1	95.4	90.4	5.25
carbon tetrachloride	4	64.8	77.2	72.2	5.79
trichloroethene	4	73.6	88.2	82.6	6.47
1,1,2-trichloroethane	4	76.0	85.0	81.3	3.79
tetrachloroethene	4	75.6	85.6	80.3	4.66
benzene	4	99.0	102.2	101.0	1.47
toluene	4	87.0	91.2	89.5	1.77
chlorobenzene	4	96.2	103.8	98.6	3.50
ethylbenzene	4	90.8	96.0	94.4	2.42
1,3-dichlorobenzene	4	95.6	100.4	97.5	2.10
1,4-dichlorobenzene	4	91.6	106.2	96.0	6.84
1,2-dichlorobenzene	4	98.6	100.4	99.4	0.90
<u>10 ppb standards (33 analyses)</u>					
dichloromethane	32	15.1	710.4	316.6	173.82
trans-1,2-dichloroethene	32	83.1	294.5	128.7	40.34
1,1-dichloroethane	29	86.5	226.3	135.9	35.43
cis-1,2-dichloroethene	31	45.6	177.5	98.5	27.06
chloroform	28	65.3	222.3	116.0	32.75
1,2-dichloroethane + trichloroethane	33	18.4	374.5	119.0	59.74
carbon tetrachloride	28	83.3	200.3	120.7	31.35
trichloroethene	33	53.8	128.1	100.9	16.20
1,1,2-trichloroethane	31	71.9	131.2	106.5	11.54
tetrachloroethene	32	58.7	122.8	95.9	13.04
benzene	33	89.9	244.9	108.0	26.46
	(32)		(149.4)	(103.7)	(9.96)
toluene	33	63.0	193.5	88.6	20.99
	(32)		(107.9)	(85.3)	(9.42)

(continued)

(Table A3. continued)

Compound	Number of Observations	Minimum	Maximum	Mean	Standard Deviation
chlorobenzene	33 (32)	74.8	207.5 (104.4)	98.1 (94.7)	20.96 (7.43)
ethylbenzene	33 (32)	67.4	182.2 (109.6)	98.7 (96.1)	17.76 (9.67)
1,3-dichlorobenzene	33 (32)	66.5	177.2 (105.1)	92.8 (90.2)	17.40 (8.71)
1,4-dichlorobenzene	33 (32)	66.3	155.2 (104.4)	92.4 (90.5)	14.60 (9.44)
1,2-dichlorobenzene	29	73.0	151.8	93.9	13.61
<u>20 ppb standards (8 analyses)</u>					
dichloromethane	8	97.7	397.3	235.1	135.23
trans-1,2-dichloroethene	8	88.2	166.7	122.2	29.89
1,1-dichloroethane	8	90.3	157.8	120.7	26.16
cis-1,2-dichloroethene	8	90.5	133.7	109.4	14.51
chloroform	8	94.4	139.7	111.6	16.36
1,2-dichloroethane + trichloroethane	8	91.3	146.4	114.0	20.17
carbon tetrachloride	8	86.3	169.9	124.6	31.22
trichloroethene	8	91.6	139.9	112.4	19.38
1,1,2-trichloroethane	8	102.2	155.6	123.4	18.09
tetrachloroethene	8	88.9	131.6	106.8	15.91
benzene	8	96.1	113.2	104.8	6.46
toluene	8	91.8	98.5	94.1	2.69
chlorobenzene	8	101.5	107.7	104.2	2.29
ethylbenzene	8	105.0	118.0	112.9	5.10
1,3-dichlorobenzene	8	94.8	107.4	100.8	3.99
1,4-dichlorobenzene	8	95.7	110.2	102.6	5.12
1,2-dichlorobenzene	7	97.5	109.0	103.9	4.47
<u>All standards (45 analyses)</u>					
dichloromethane	44	15.1	710.4	284.0	168.8
trans-1,2-dichloroethene	44	77.4	294.5	123.3	38.7
1,1-dichloroethane	41	82.0	226.3	128.6	34.6
cis-1,2-dichloroethene	43	45.6	177.5	98.5	25.0
chloroform	40	65.3	222.3	112.8	29.0
1,2-dichloroethane + trichloroethane	45	18.4	374.5	115.5	52.2
carbon tetrachloride	40	64.8	200.3	116.6	32.9
trichloroethene	45	53.8	139.9	101.3	17.5

(continued)

(Table A3. concluded)

Compound	Number of Observations	Minimum	Maximum	Mean	Standard Deviation
1,1,2-trichloroethane	43	71.9	155.6	107.3	16.3
tetrachloroethene	44	58.7	131.6	96.5	14.5
benzene	45	89.9	244.9	106.8	22.8
	(44)		(149.4)	(103.7)	(8.91)
toluene	45	63.0	193.5	89.7	18.1
	(44)		(107.9)	(87.3)	(8.79)
chlorobenzene	45	74.8	207.5	99.2	18.1
	(44)		(107.7)	(96.8)	(7.44)
ethylbenzene	45	67.4	182.2	100.8	16.4
	(44)		(118.0)	(99.0)	(10.8)
1,3-dichlorobenzene	45	66.5	177.2	94.6	15.3
	(44)		(107.4)	(92.8)	(8.75)
1,4-dichlorobenzene	45	66.3	155.2	94.6	13.3
	(44)		(110.2)	(93.2)	(9.71)
1,2-dichlorobenzene	40	73.0	151.8	96.2	12.3

1. Missing data were excluded from the statistical analysis.
2. Values in parentheses are statistics of data sub-set obtained by removal of the outlier (analysis no. 26).

**Table A4. Method Detection Limit (MDL), Quantitation Limit (MQL), and
95% Confidence Interval for Percent Recovery of VOC Analysis, ISWS
(June to August, 1986)**

Compound	MDL ¹ (µg/L)	MQL ¹ (µg/L)	95% Confidence Interval ^{2,3}	
			From (%)	To (%)
dichloromethane	1.1	2.3	-222.4	790.3
trans-1,2-dichloroethene	1.1	2.5	7.3	239.3
1,1-dichloroethane	1.6	3.5	24.9	232.3
cis-1,2-dichloroethene	0.8	1.7	23.6	173.5
chloroform	1.6	3.4	25.8	199.9
1,2-dichloroethane	2.4	5.3	-41.2	272.3
+ trichloroethane				
carbon tetrachloride	1.3	2.9	17.8	215.4
trichloroethene	1.5	3.2	48.7	154.0
1,1,2-trichloroethane	0.9	1.9	58.4	156.2
tetrachloroethene	1.1	2.3	53.0	139.9
benzene	0.3	0.7	38.4	175.3
			(77.0)	(130.4)
toluene	0.4	0.9	35.5	143.8
			(60.9)	(113.7)
chlorobenzene	0.8	1.8	45.0	153.4
			(74.4)	(119.1)
ethylbenzene	0.6	1.2	51.7	149.9
			(66.6)	(131.3)
1,3-dichlorobenzene	0.5	1.1	48.8	140.5
			(66.5)	(119.0)
1,4-dichlorobenzene	1.6	3.4	54.6	134.5
			(64.1)	(122.3)
1,2-dichlorobenzene	0.2	0.5	59.3	133.2

1. Estimation of MDL and MQL are based on statistics on the 5 ppb standards (Table A3), where:

$$\text{MDL} = 4.541 \times (5\sigma)$$

$$\text{MQL} = 10 \times (5\sigma)$$

where, σ = standard deviation of recovery

2. Estimation of 95% confidence interval is based on statistics on all standards (Table A3), from Mean - 3 σ to Mean + 3 σ .
3. Values in parentheses are estimates based on statistics after removal of the outlier, analysis no. 26.

**Table A5. Summary Statistics of Percentage Recovery of Laboratory Standards,
IDPH/Springfield (December, 1989)**

Compound	Number of Observations	Minimum	Maximum	Mean	Standard Deviation
carbon tetrachloride	18	74.5	114.0	93.8	12.80
vinyl chloride	18	56.6	111.9	83.2	16.03
bromoform	18	89.1	130.5	110.3	11.14
bromodichloromethane	18	75.0	113.2	95.0	11.99
chloroform	18	71.6	103.2	90.9	9.86
chlorodibromomethane	18	89.2	113.9	102.1	8.15
1,2-dichloroethane	18	63.0	112.4	91.7	15.95
1,1,1-trichloroethane	18	72.8	114.1	91.7	11.02
benzene	18	82.3	104.3	93.7	6.98
1,4-dichlorobenzene	18	90.9	123.5	106.8	9.65
1,1-dichloroethene	18	60.8	102.4	81.3	13.34
tetrachloroethene	18	80.8	107.7	95.9	7.81

**Table A6. Analysis Sequence Number, Date of Analysis, and Laboratory Standard Concentration
Plotted in Control Charts in Figures A1 to A17 (ISWS 1986 Data)**

Analysis Sequence Number	Analysis Date (1986)	Laboratory Standard Concentration ($\mu\text{g/L}$)	Analysis Sequence Number	Analysis Date (1986)	Laboratory Standard Concentration ($\mu\text{g/L}$)
1	06/06	20	24	06/25	10
2	06/06	20	25	06/25	10
3	06/09	10	26	06/25	10
4	06/09	10	27	06/25	10
5	06/10	5	28	06/27	10
6	06/10	5	29	06/27	10
7	06/11	20	30	07/28	10
8	06/11	20	31	07/28	10
9	06/12	5	32	07/29	20
10	06/12	5	33	07/29	20
11	06/13	10	34	07/30	10
12	06/13	10	35	07/30	10
13	06/16	10	36	07/31	20
14	06/16	10	37	07/31	20
15	06/16	10	38	08/01	10
16	06/17	10	39	08/01	10
17	06/17	10	40	08/04	10
18	06/23	10	41	08/04	10
19	06/23	10	42	08/04	10
20	06/24	10	43	08/04	10
21	06/24	10	44	08/05	10
22	06/24	10	45	08/05	10
23	06/24	10			

Table A7. Analysis Sequence Number, Time of Analysis, and Laboratory Standard Concentrations Plotted in Control Charts in Figures A18 to A29 (IDPH/Springfield 1989 Data)

Analysis Sequence Number	Time of Analysis		Compound Concentration ($\mu\text{g/L}$)
	Date (1989)	Hour	
1	12/04	9	0.4
2	12/04	10	2
3	12/04	11	4
4	12/04	13	8
5	12/04	14	20
6	12/05	13	2
7	12/05	14	2
8	12/06	9	2
9	12/06	22	2
10	12/07	20	2
11	12/08	0	4
12	12/08	3	8
13	12/08	7	20
14	12/15	20	2
15	12/16	7	2
16	12/16	15	2
17	12/17	5	2
18	12/17	9	2

Figures A1 to A17. \bar{X} -Control Charts of Percentage Recovery Data of Laboratory Standards, ISWS (June to August, 1986). Dashed lines indicate mean and mean $\pm 3\sigma$.

Symbol code:

- 5 $\mu\text{g/L}$ Standard
- 10 $\mu\text{g/L}$ Standard
- ▲ 20 $\mu\text{g/L}$ Standard

Dichloromethane---ISWS

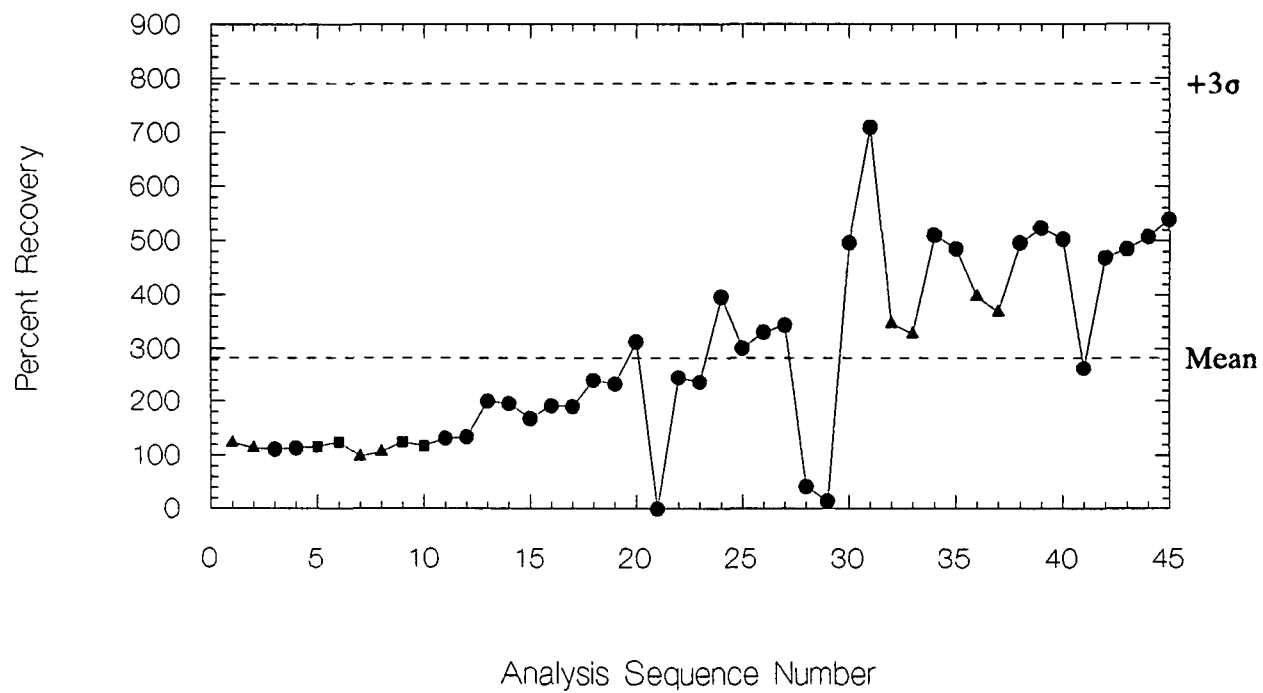


Figure A1. Dichloromethane Control Chart

trans-1,2-Dichloroethene---ISWS

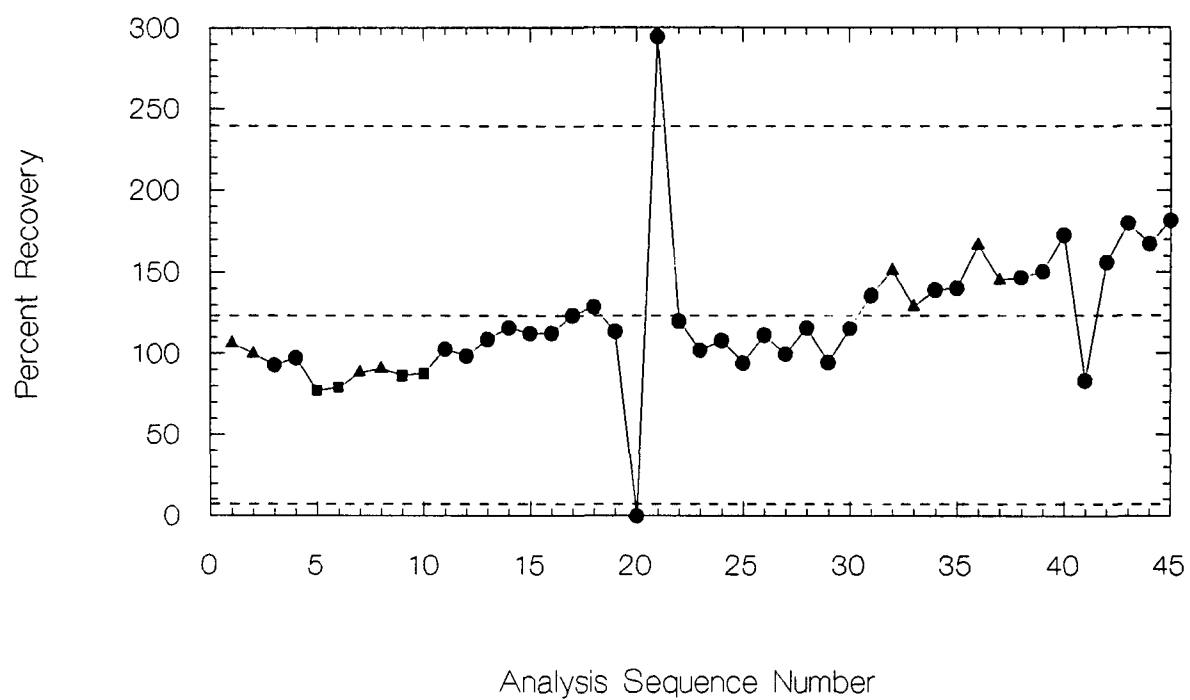


Figure A2. Trans-1,2-Dichloroethene Control Chart

1,1-Dichloroethane---ISWS

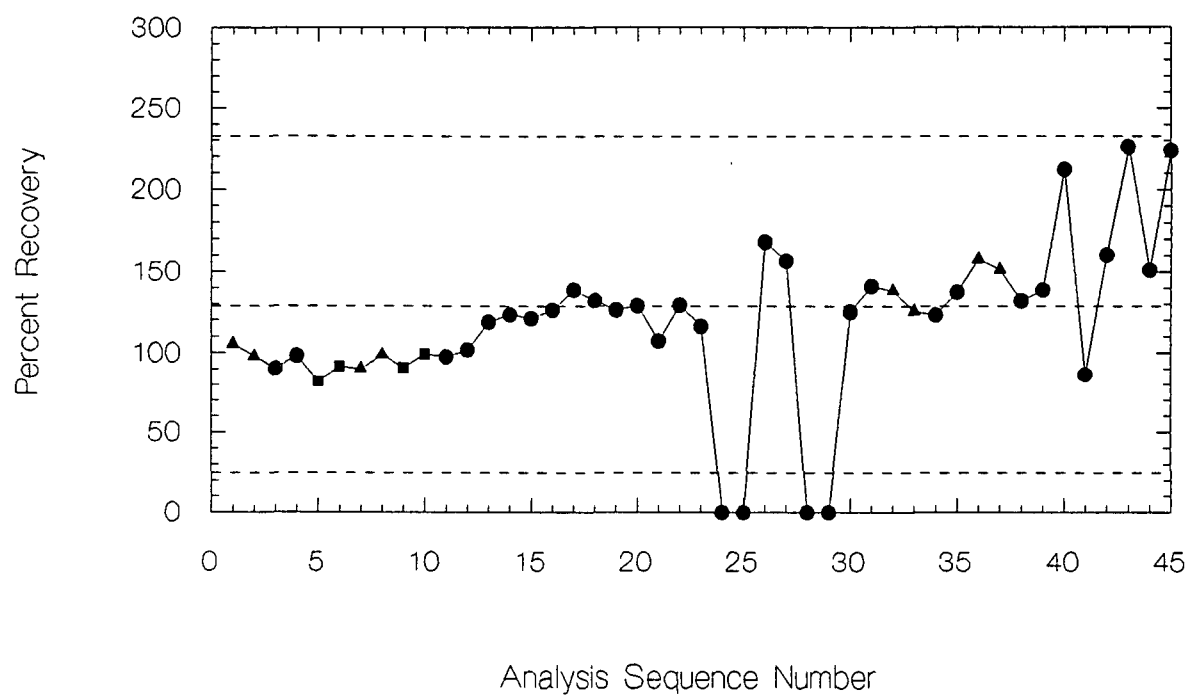


Figure A3. 1,1-Dichloroethane Control Chart

cis-1,2-Dichloroethene---ISWS

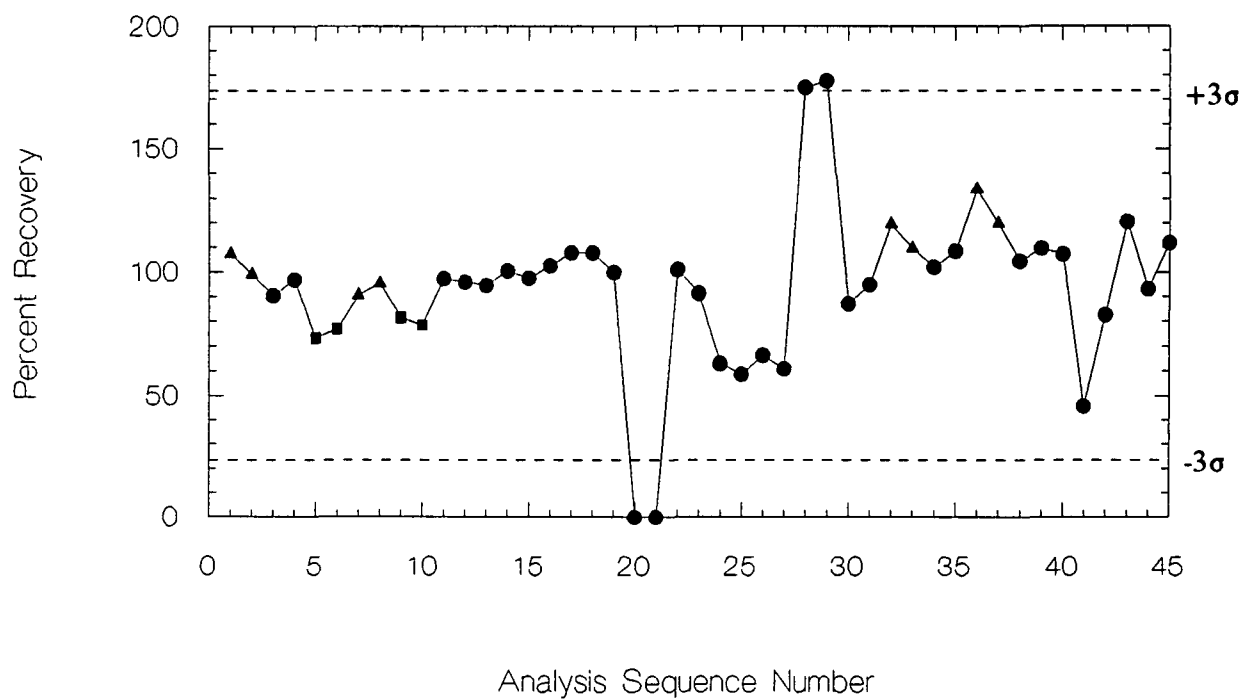


Figure A4. Cis-1,2-Dichloroethene Control Chart

Chloroform---ISWS

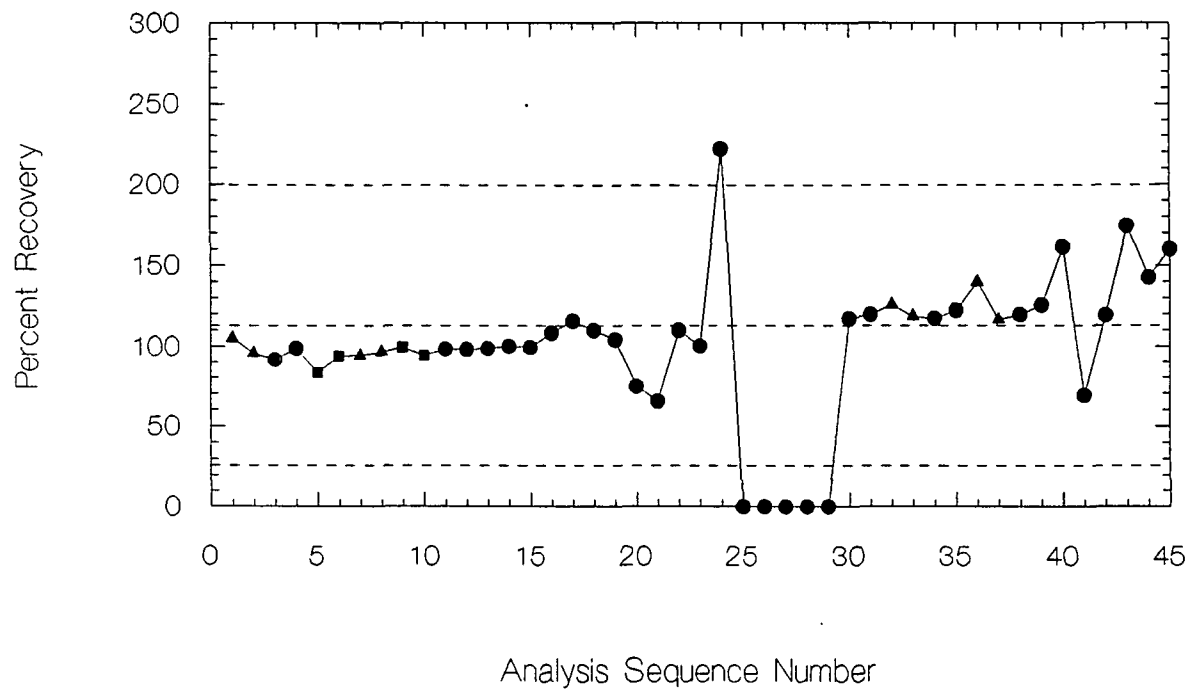


Figure A5. Chloroform Control Chart

1,2-Dichloroethane & Trichloroethane---ISWS

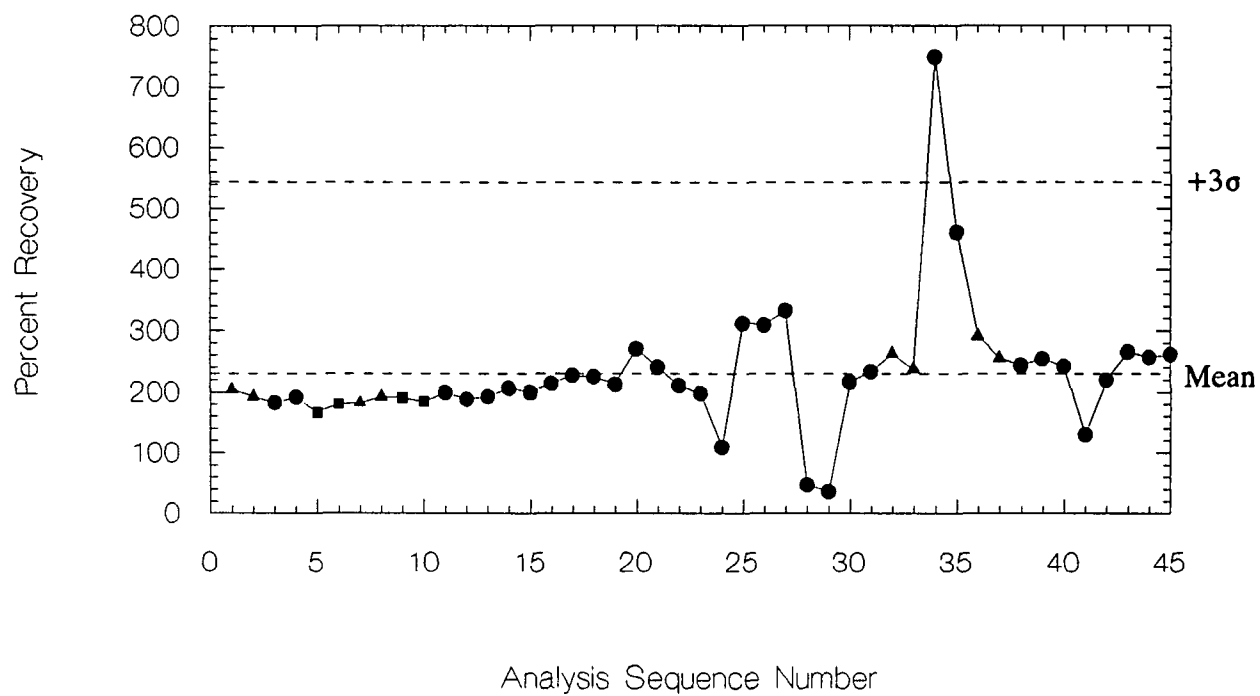


Figure A6. 1,2-Dichloroethane and Trichloroethane Control Chart

Carbon Tetrachloride---ISWS

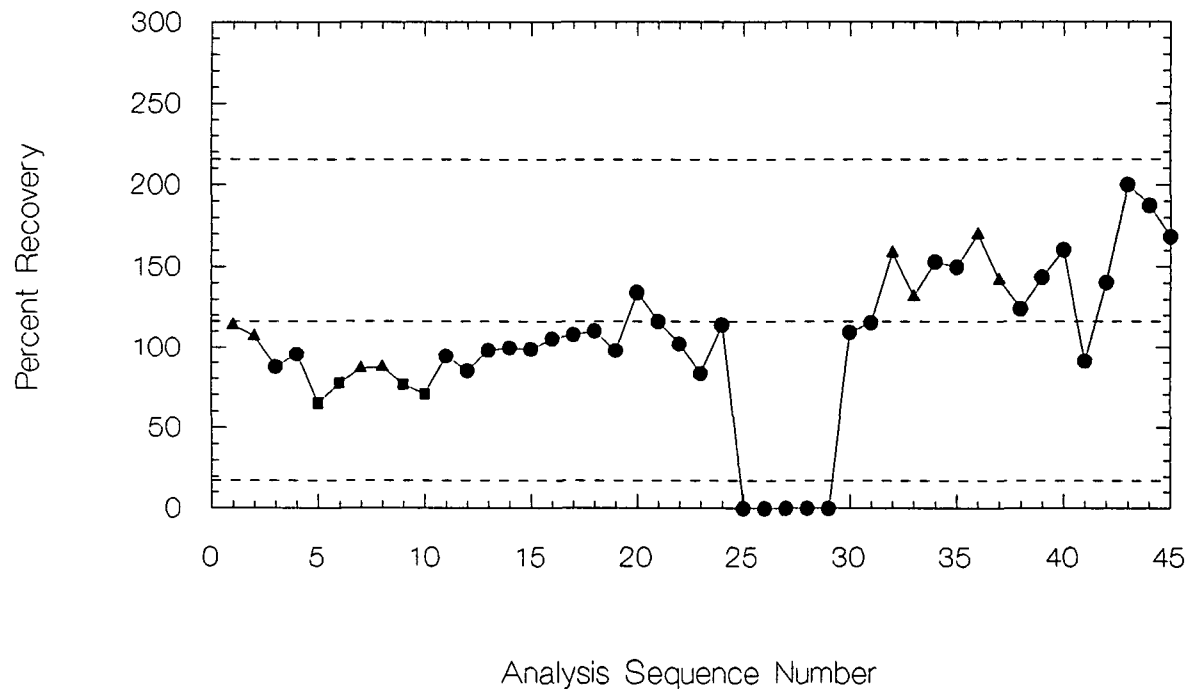


Figure A7. Carbon Tetrachloride Control Chart

Trichloroethene---ISWS

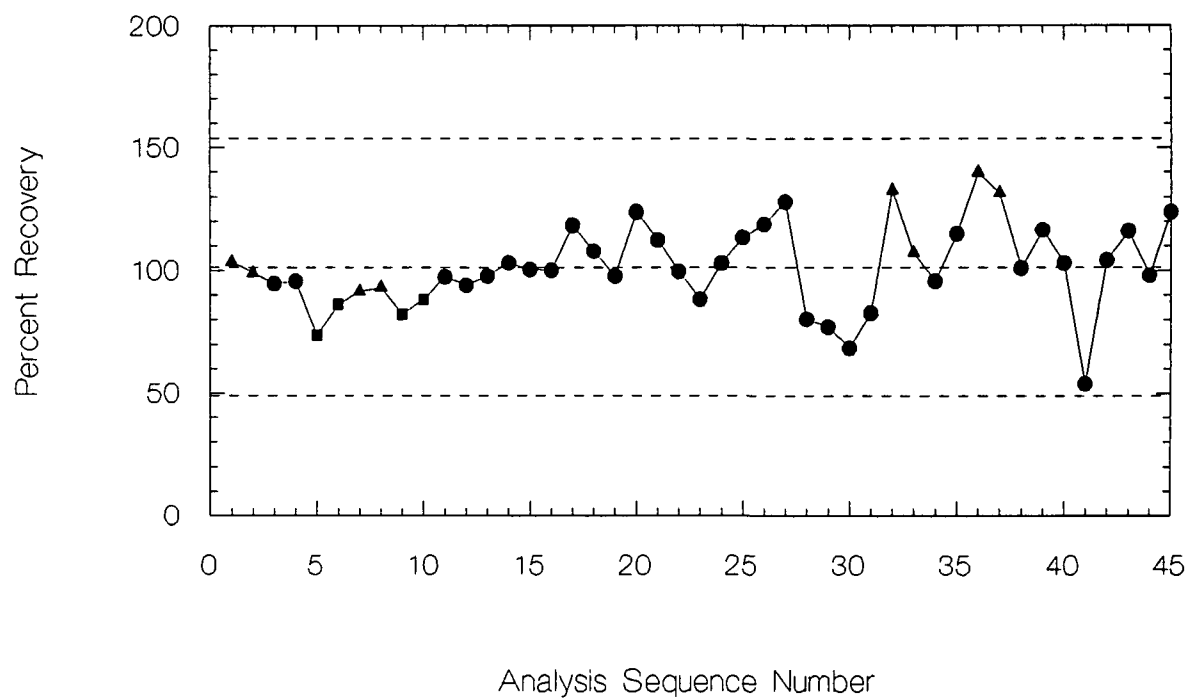


Figure A8. Trichloroethene Control Chart

1,1,2-Trichloroethane---ISWS

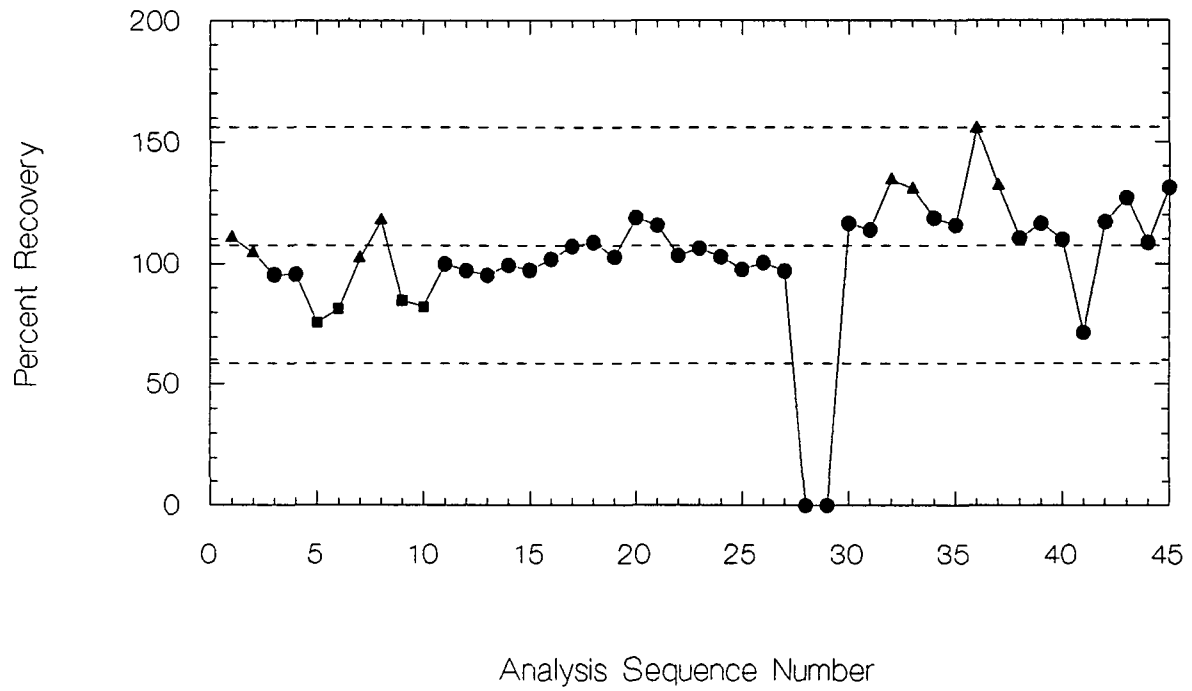


Figure A9. 1,1,2-Trichloroethane Control Chart

Tetrachloroethene---ISWS

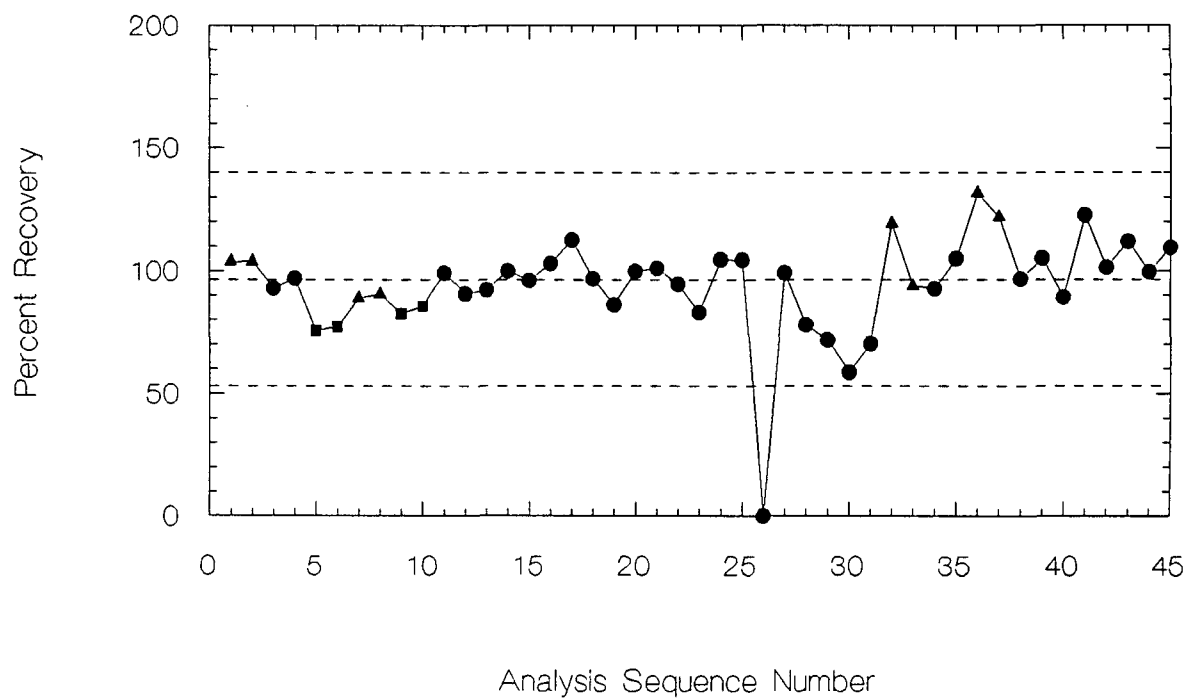


Figure A10. Tetrachloroethene Control Chart

Benzene---ISWS

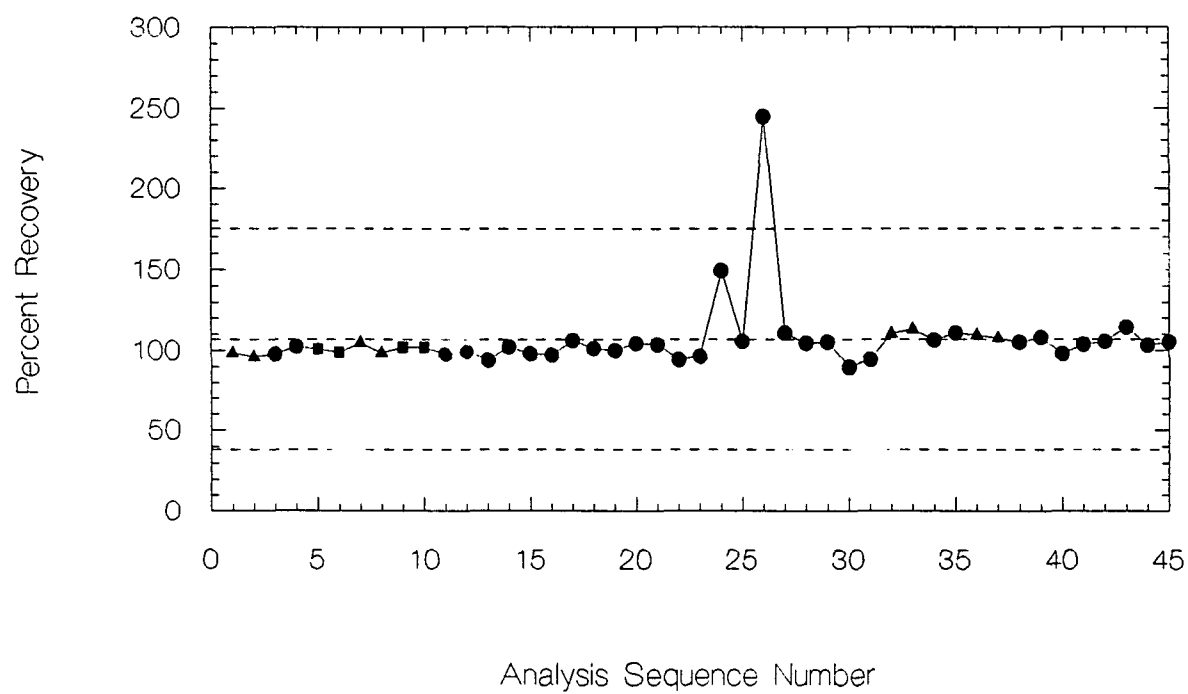


Figure A11. Benzene Control Chart

Toluene---ISWS

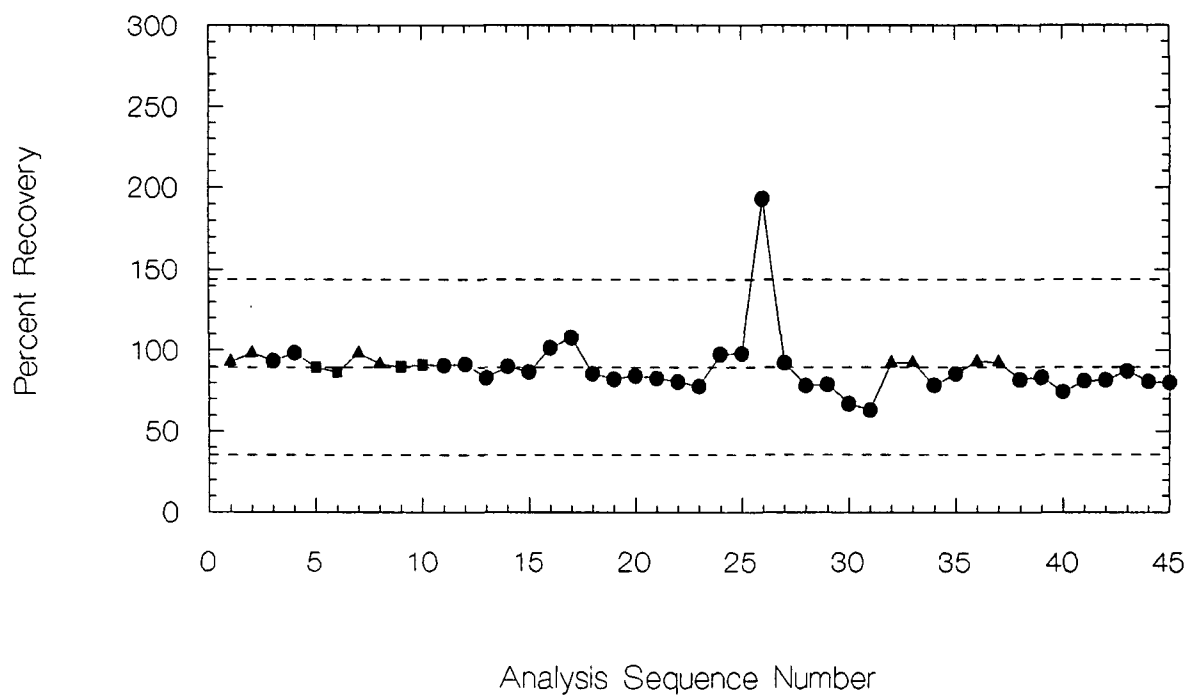


Figure A12. Toluene Control Chart

Chlorobenzene---ISWS

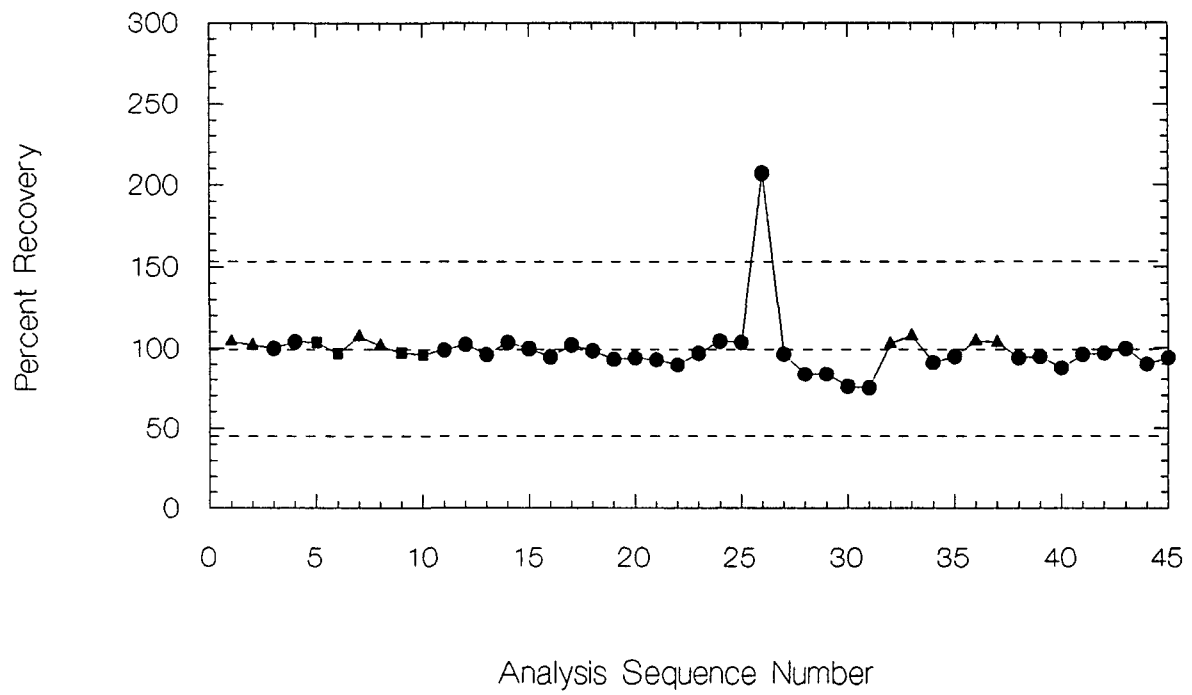


Figure A13. Chlorobenzene Control Chart

Ethylbenzene---ISWS

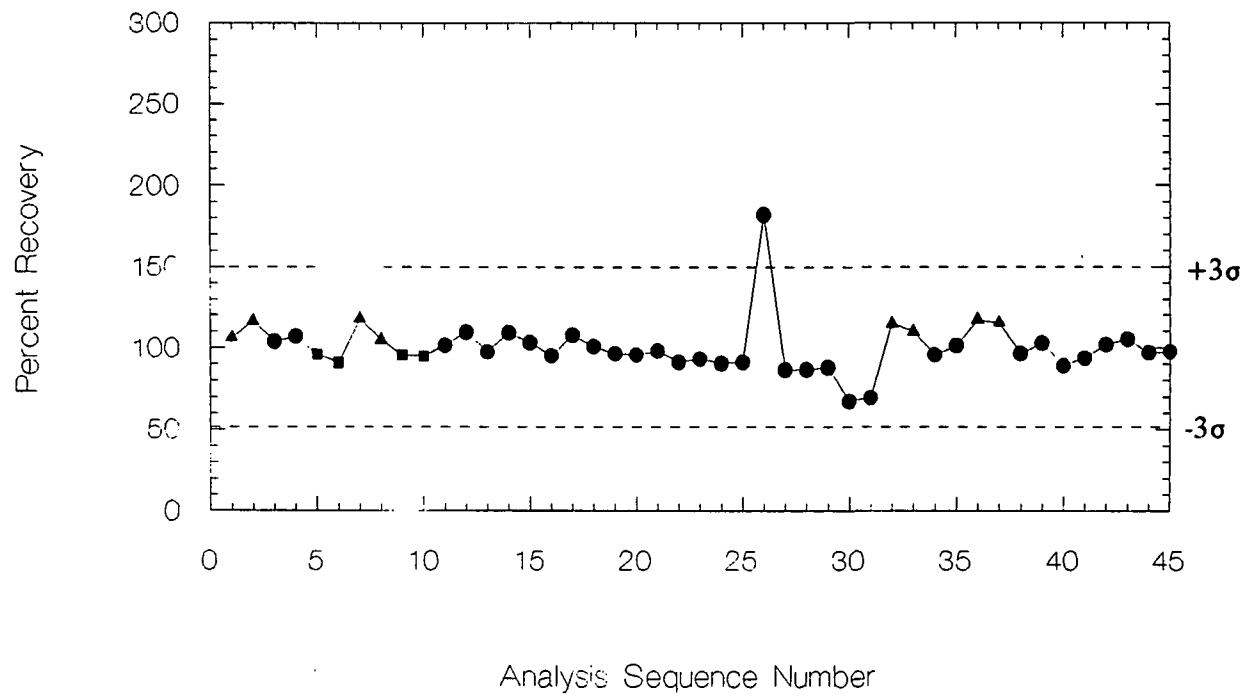


Figure A14. Ethylbenzene Control Chart

1,3-Dichlorobenzene---ISWS

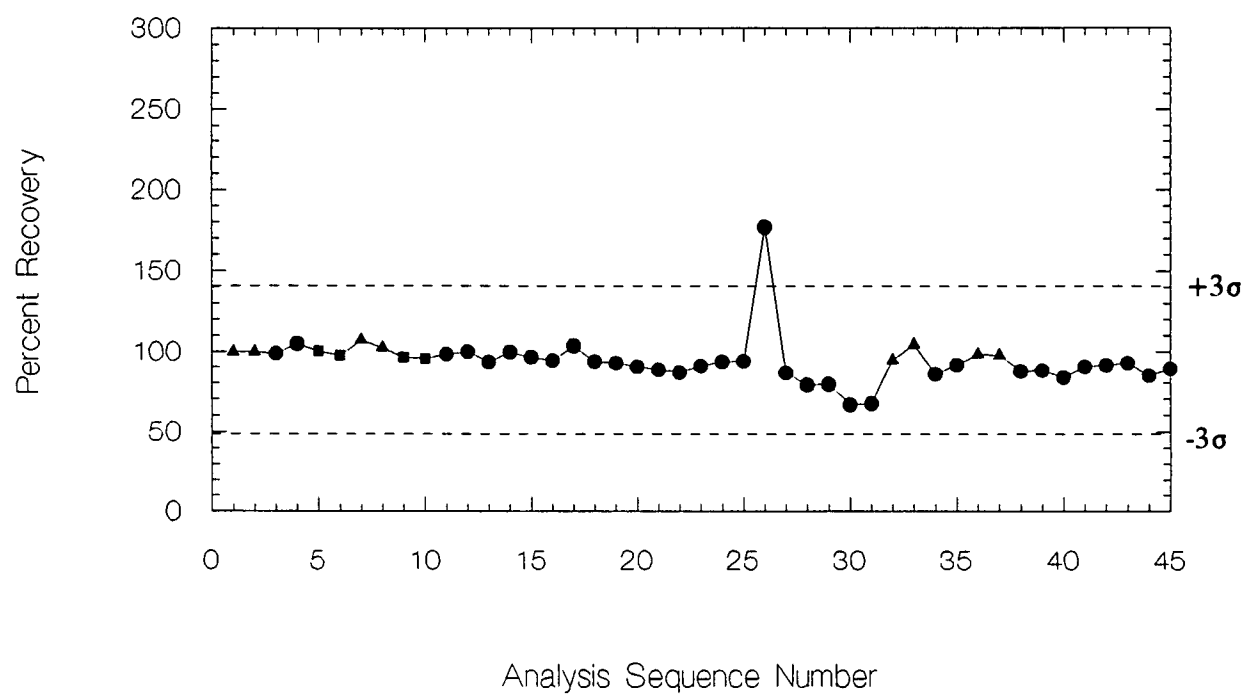


Figure A15. 1,3-Dichlorobenzene Control Chart

1,4-Dichlorobenzene---ISWS

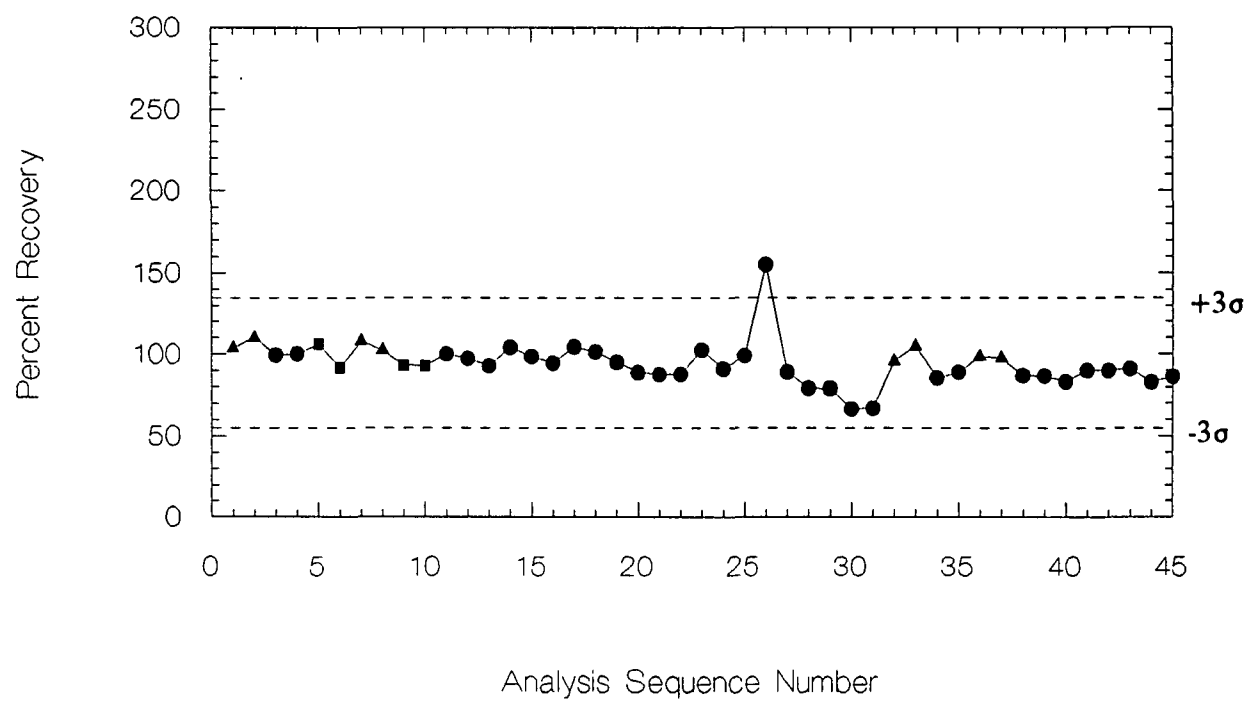


Figure A16. 1,4-Dichlorobenzene Control Chart

1,2-Dichlorobenzene---ISWS

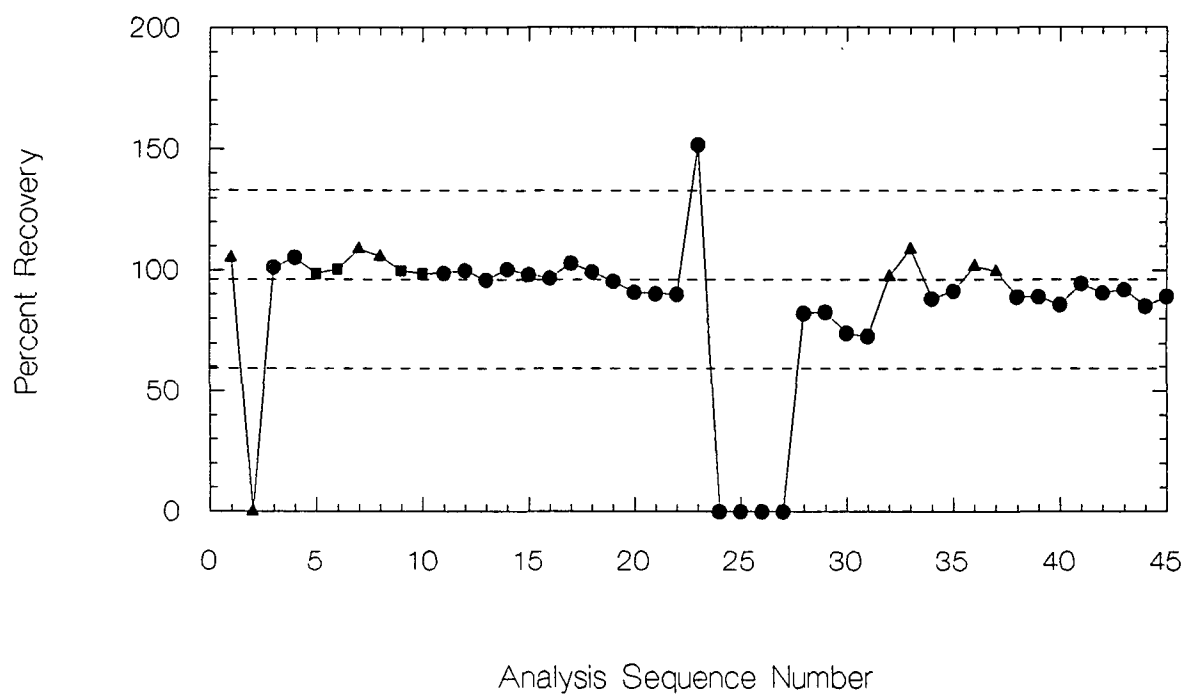


Figure A17. 1,2-Dichlorobenzene Control Chart

Figures A18 to A29. \bar{X} -Control Charts of Percentage Recovery Data of Laboratory Standards, IDPH/Springfield (December, 1989). Dashed lines indicate mean and mean $\pm 3\sigma$.

Symbol code:

- ▼ 0.4 $\mu\text{g/L}$ Standard
- 2 $\mu\text{g/L}$ Standard
- ▲ 4 $\mu\text{g/L}$ Standard
- 8 $\mu\text{g/L}$ Standard
- ◆ 20 $\mu\text{g/L}$ Standard

Carbon Tetrachloride---IDPH/Springfield

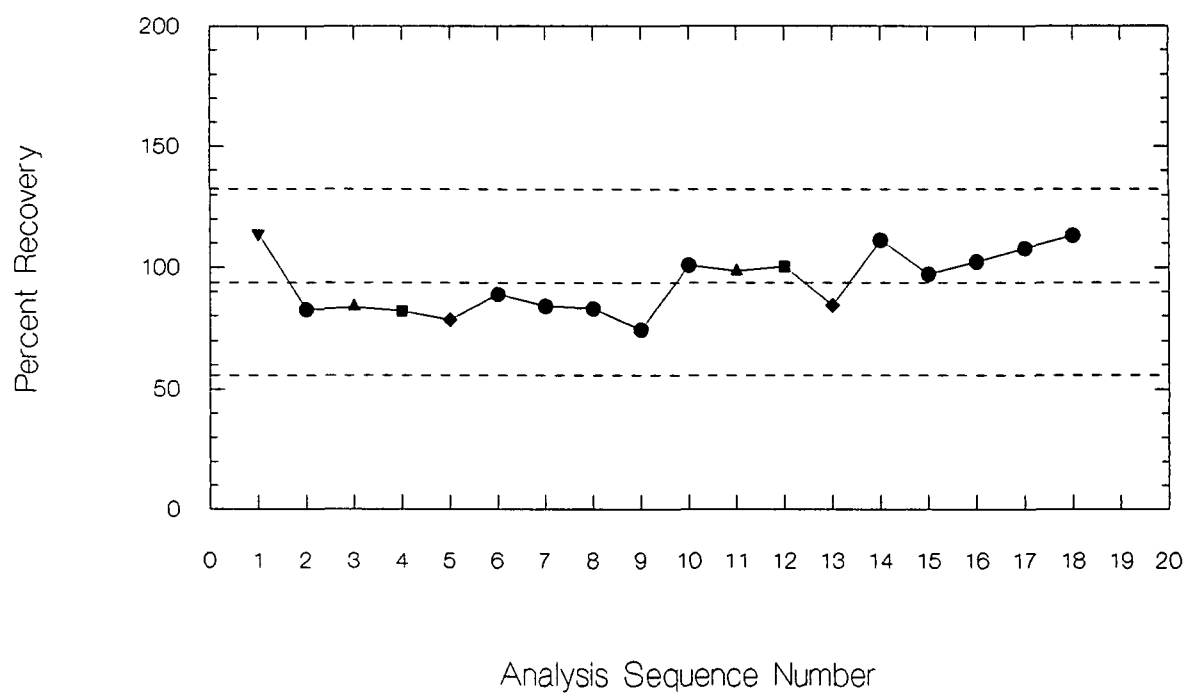


Figure A18. Carbon Tetrachloride Control Chart

Vinyl Chloride---IDPH/Springfield

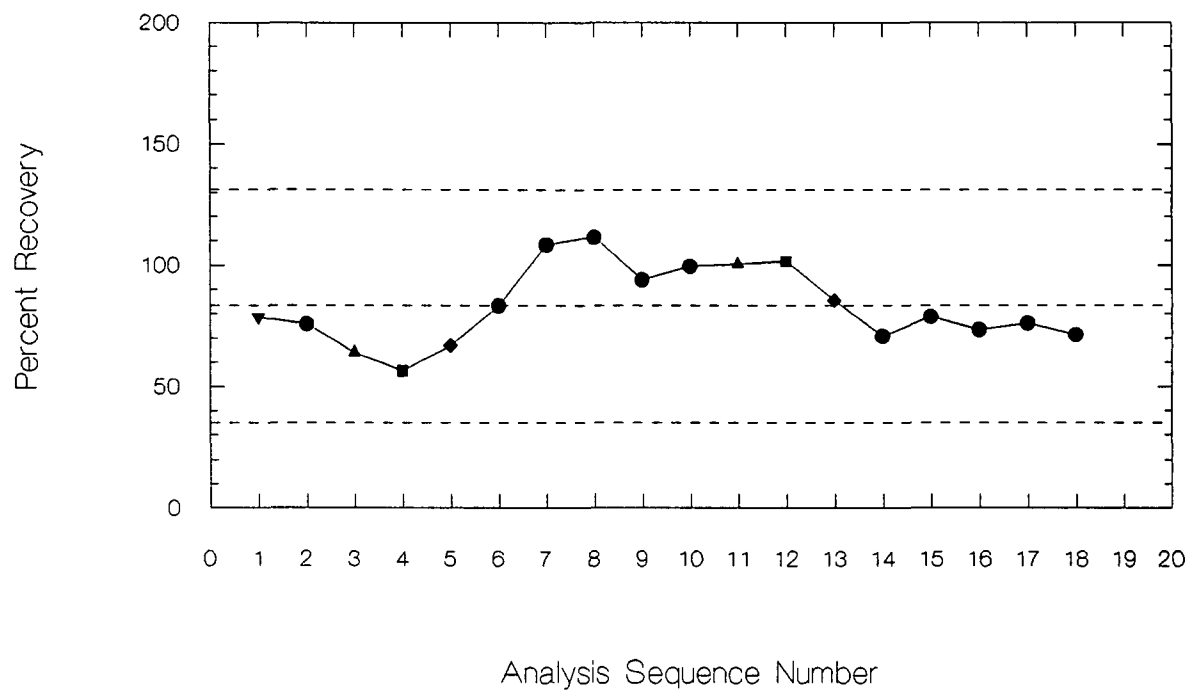


Figure A19. Vinyl Chloride Control Chart

Bromoform---IDPH/Springfield

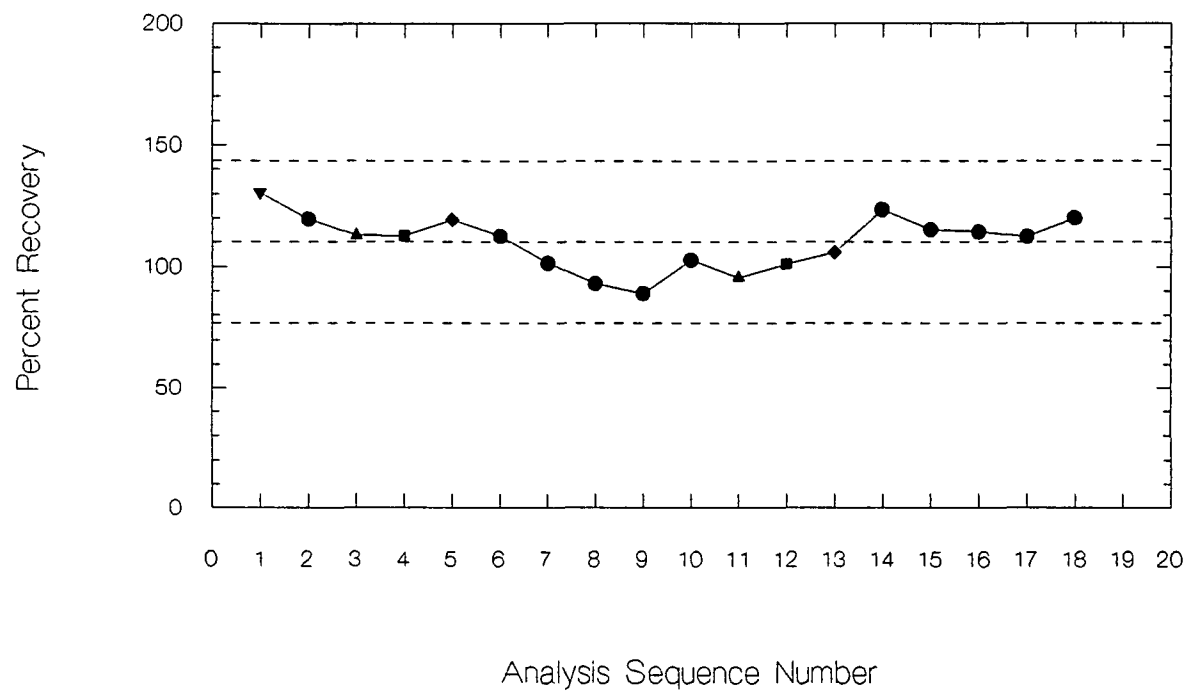


Figure A20. Bromoform Control Chart

Bromodichloromethane---IDPH/Springfield

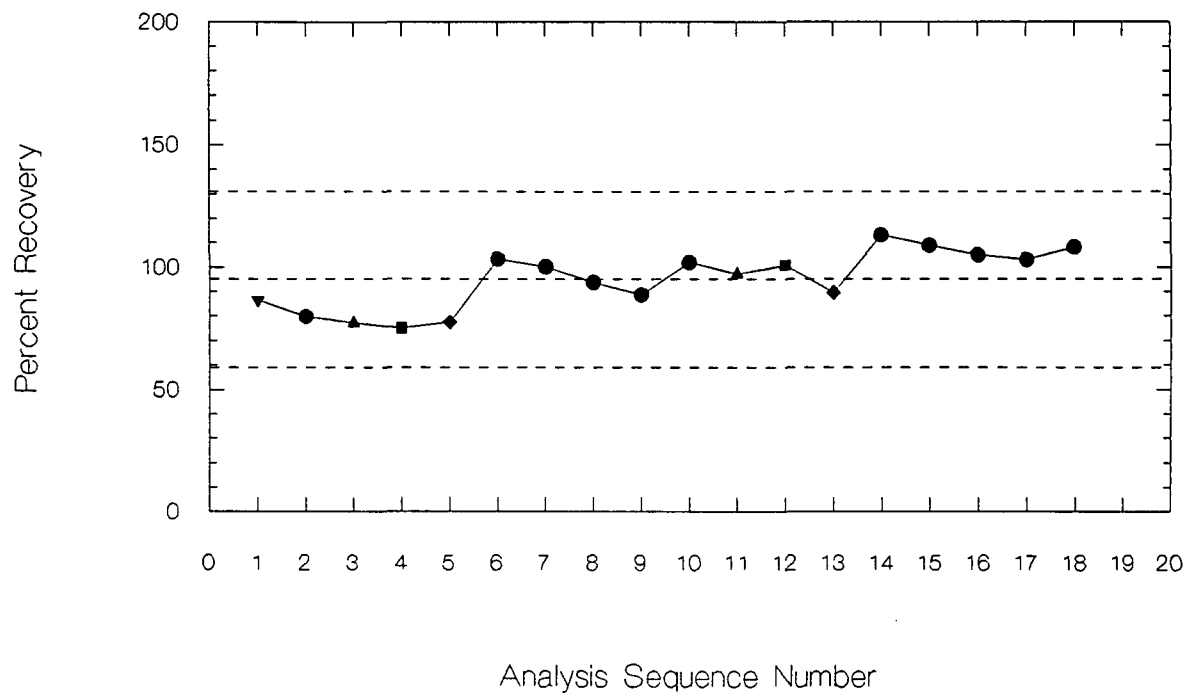


Figure A21. Bromodichloromethane Control Chart

Chloroform---IDPH/Springfield

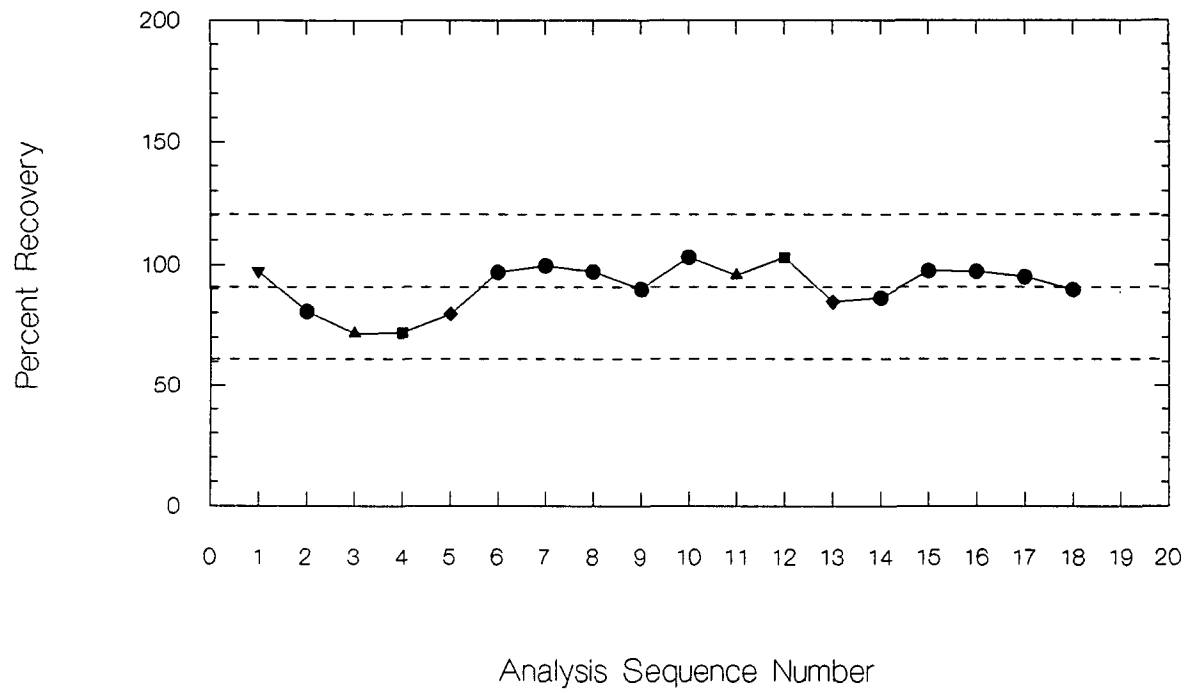


Figure A22. Chloroform Control Chart

Chlorodibromomethane---IDPH/Springfield

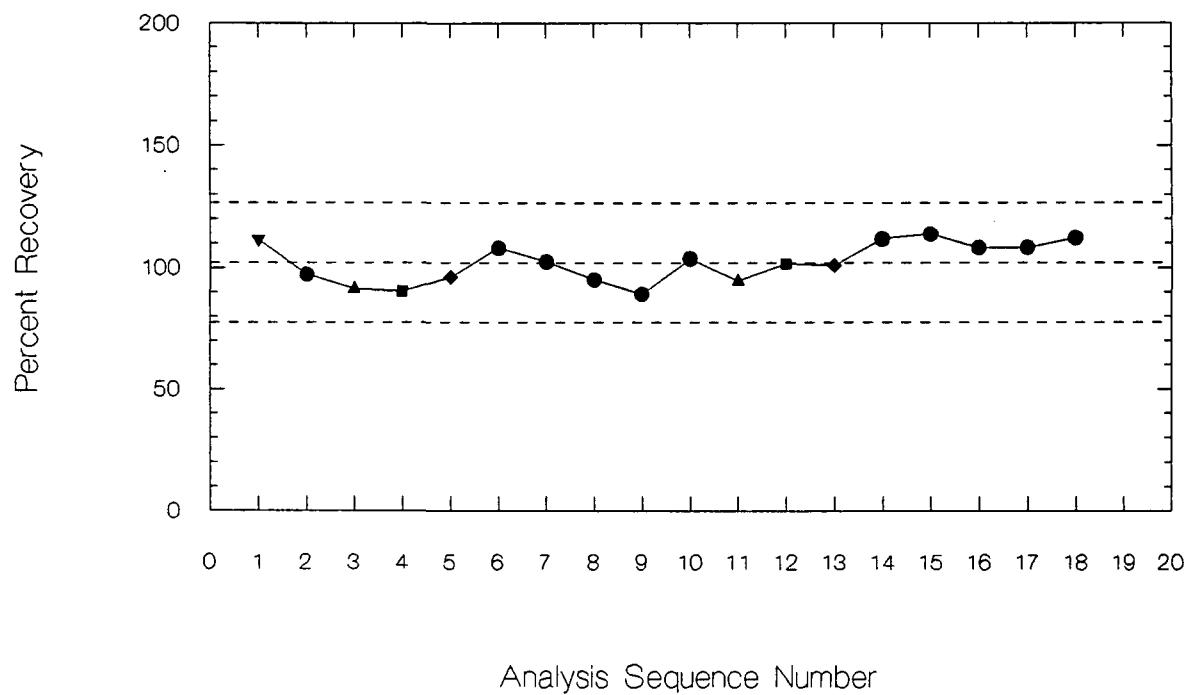


Figure A23. Chlorodibromomethane Control Chart

1,2-Dichloroethane---IDPH/Springfield

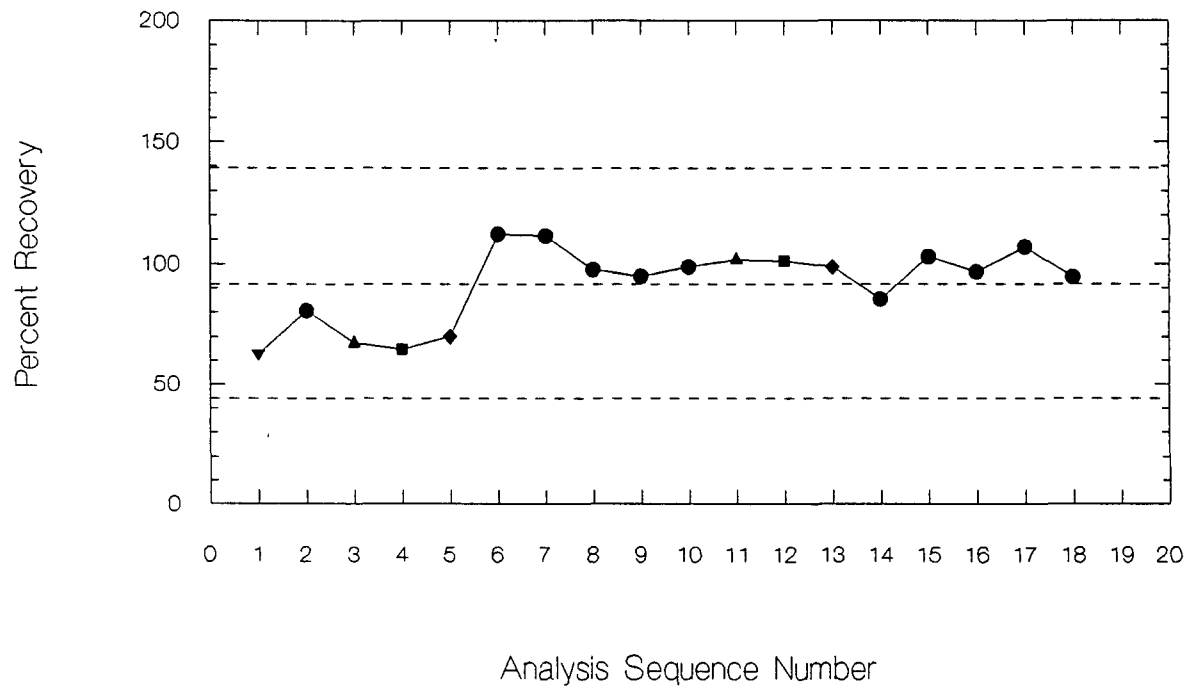


Figure A24. 1,2-Dichloroethane Control Chart

1,1,1-Trichloroethane---IDPH/Springfield

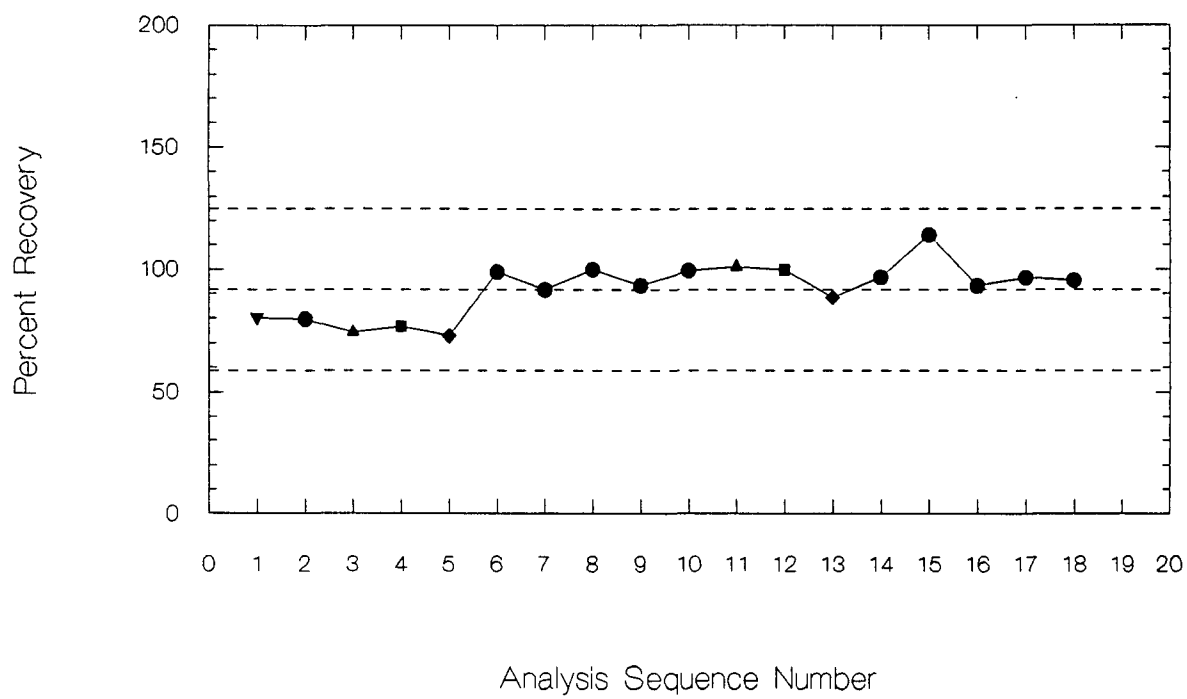


Figure A25. 1,1,1-Trichloroethane Control Chart

Benzene---IDPH/Springfield

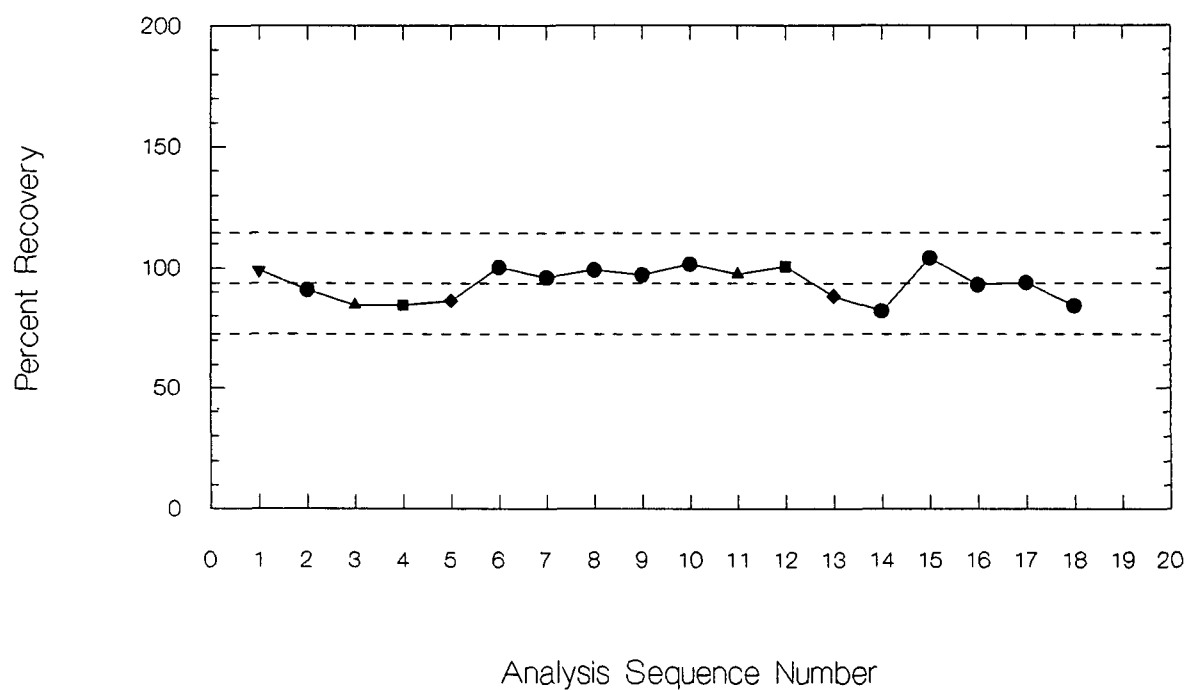


Figure A26. Benzene Control Chart

1,4-Dichlorobenzene---IDPH/Springfield

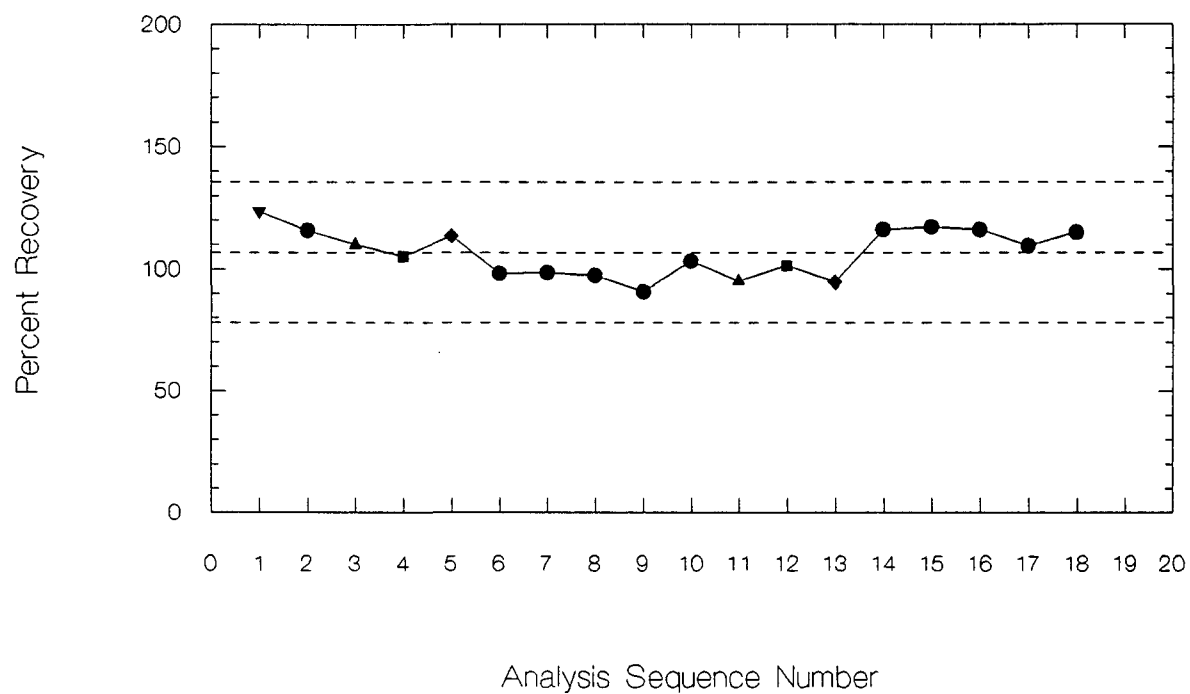


Figure A27. 1,4-Dichlorobenzene Control Chart

1,1-Dichloroethene---IDPH/Springfield

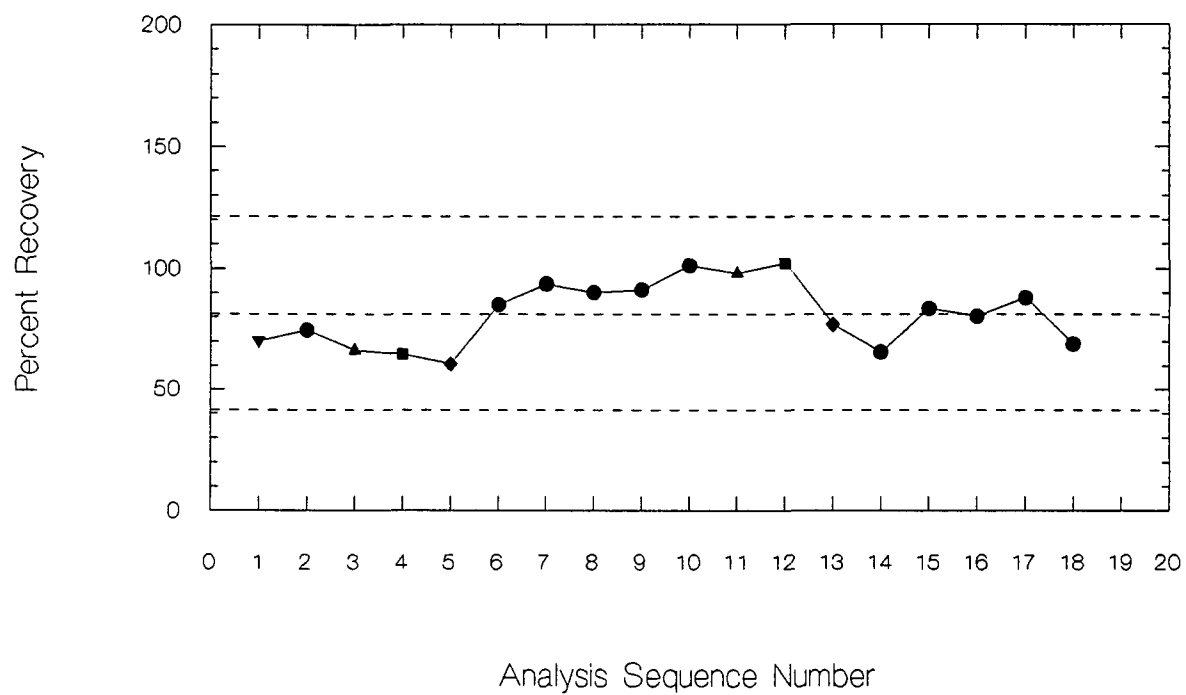


Figure A28. 1,1-Dichloroethene Control Chart

Trichloroethene---IDPH/Springfield

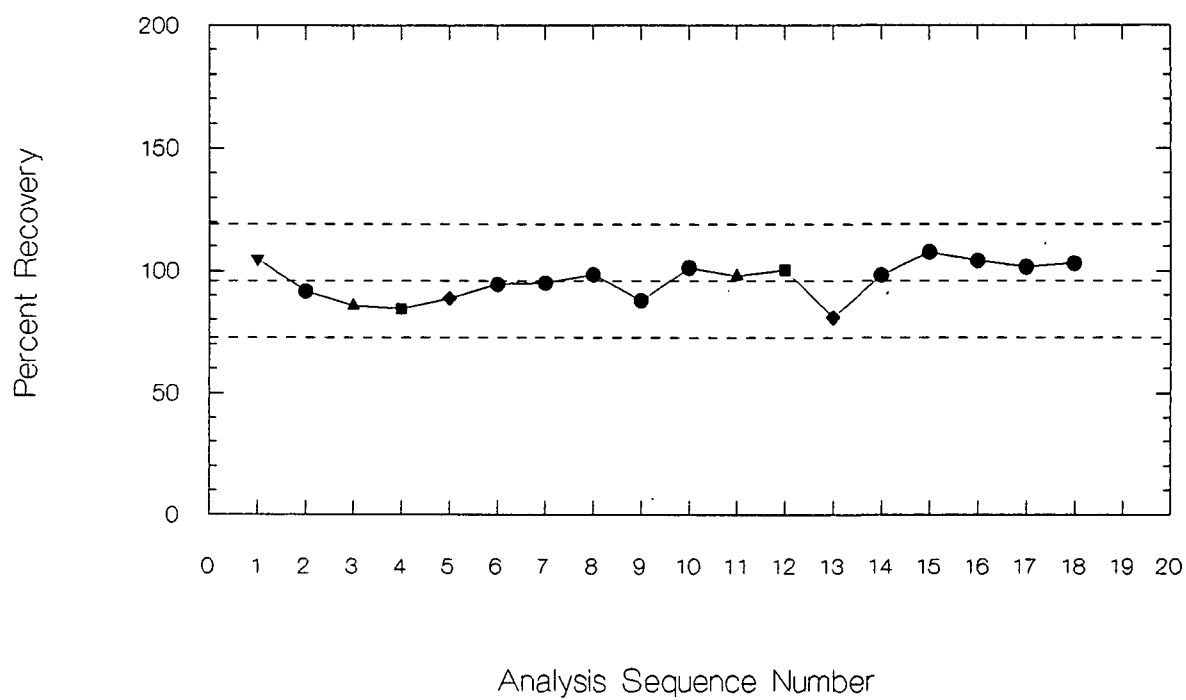


Figure A29. Trichloroethene Control Chart