GROUND-WATER STATUS REPORT

International Business Machines Corporation
East Fishkill Facility
Dutchess County, New York

January 1981

IBM-EF-88

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

IBM-EF- 88

I. INTRODUCTION

The purpose of the report is to present a brief, but thorough, summary of the ground-water situation at the IBM Corporation's East Fishkill Facility as of January 1, 1981.

For background purposes the report first describes the geologic and hydrologic conditions pertinent to the ground-water system underlying the facility. The next section contains a summary of investigations conducted through the end of 1980. Later sections describe progress to date and plans for future work.

II. GENERAL REGIONAL HYDROGEOLOGY

The principal geologic formations pertinent to the ground-water system underlying the IBM East Fishkill Facility are unconsolidated surficial glacial deposits of Pleistocene Age and the underlying carbonate bedrock (limestone and dolomite) of Ordovician age.

The glacial deposits vary greatly in both thickness and texture. Where sufficient saturated thickness and permeability exist, the glacial deposits provide water to wells in the vicinity. These are generally small-capacity domestic and livestock wells, although yields of several hundred gallons per minute from sand and gravel deposits may be obtained in valley areas.

The bedrock, geologically known as the Stockbridge limestone, is the principal aquifer supplying water to large-capacity wells--including the IBM production wells at the East Fishkill Facility. The unit of this formation underlying the facility extends under the Fishkill Creek valley from Beacon northeastward to the headwaters of the creek.

IBM-EF- 88

Joints, fractures and bedding planes in the bedrock provide the principal means for storage and movement of water. In fact, the yield of wells can vary from essentially zero to several hundred gallons per minute depending upon the amount and sizes of such openings encountered. The major fractures in the Stockbridge limestone are probably associated with faults. Several northeasterly trending faults have been mapped in the East Fishill area.

The source of ground water found in both the glacial and bedrock formations is derived from that portion of precipitation which falls on the overlying land that percolates downward to the ground-water system. Obviously, the portion of the precipitation that recharges the ground water is dependent upon many factors such as soil texture, soil moisture, type of cover, land slope and rainfall intensity. A general estimate of the average annual recharge is 13 inches--or about one-third of the average annual precipitation of 42 inches. The other two-thirds leaves the area as surface runoff in streams and evapotranspiration to the atmosphere.

Ground-water levels in the area normally are highest in the spring and lowest in the fall in response to the relative intensity of precipitation and evapotranspiration. Also, long-term records of ground-water levels not influenced by pumping show a strong correspondence with rainfall patterns, indicating essentially immediate recharge response to precipitation events.

III. SUMMARY OF GROUND-WATER QUALITY INVESTIGATIONS

A. Chronology of investigations

Test drilling has been conducted, and monitor wells installed, for the purposes of obtaining site-specific information on the physical properties of the glacial deposits and bedrock as well as to provide means for monitoring water levels and water quality. The following sections summarize results obtained from the drilling and monitoring as of December 1980.

The ground-water monitoring program began in February 1978 as the result of a request by the Real Estate and Construction Division of IBM for each IBM site to investigate the quality of their ground water. In addition to beginning a ground-water survey, the IBM East Fishkill site also examined the quality of the water being drawn from the bedrock production wells. These wells are a source of water for industrial and domestic purposes. A series of samples were collected and analyzed from the production well system in

IBM-EF-88

July of 1978. The results of these samples were received in September 1978 and indicated a satisfactory quality for the production wells (1, 2, 4 and 5) on the site.

In the fall of 1978 the ground-water situation was assessed on the site through the installation of a series of shallow and deep monitoring wells. During the planning and installation phase of the ground-water well network a further series of complete analyses were carried out on the production wells in December 1978. In addition to this set of analyses, the U. S. Environmental Protection Agency in early January 1979, carried out a complete analysis on the mixed raw-water supply of the East Fishkill site as part of an effluent guidelines survey. The results of the EPA and the IBM analyses became available in early February 1979. Both sets of analyses indicated the presence of trace organic compounds (chlorinated hydrocarbons) in the ground-water system. During this time frame the installation of a ground-water monitor-well network was finalized primarily in regions where chemicals were stored and/or handled. Sampling of water from these monitor wells began in March 1979.

Based on the results of the IBM survey and the EPA survey, it was decided to carry out a confirmatory analysis on the production wells. The use of production wells #2 and #4 (in which organic solvents were found) was minimized to prevent these materials from entering the potable water supply of the site. The results of this particular survey were received during the first week of March 1979 confirming the presence of organics in the production well system. Based on these results it was decided to minimize the use of the two particular wells involved until such a time that a granular activated carbon system could be installed. In the second week of April 1979 a Calgon granular activated carbon system was installed on production well #2. The design parameters for this system and other details were forwarded to the New York State Department of Health. A representative of the State Health Department visited the IBM site in May 1979 to discuss the potable water situation and made suggestions with respect to operating the granular activated carbon system. During the remainder of 1979 and the early part of 1980, IBM reported the results for organics in the production wells to the State Department of Health on a monthly basis to demonstrate the effectiveness of the carbon adsorbers.

IBM-EF- 88

Table 1. Water-Quality Monitoring Parameters

Organic solvents

Tetrachloroethylene
Trichloroethylene
cis-1, 2-dichloroethylene
Methylene chloride
Trichloroethane
Freon TF
Toluene
Benzene
Isopropanol
Dichloroethane
Carbon tetrachloride
Chloroform

Metals

Antimony	Mercury
Chromium	Selenium
Cobalt	Iron
Copper	Manganese
Nickel	Calcium
Silver	Aluminum
Zinc	Magnesium
Arsenic	Sodium
Cadmium	Potassium
Lead	Hardness

Non-metals

Fluoride
Nitrate
Sulfate
Chloride
Alkalinity
Ammonia
Cyanide

Physical parameters

pH
Conductance

Special organics

Tetrahydorfuran
Phenols
Total Organic Carbon (TOC)

Table 2. Levels of Organics[1/] in Ground Water

Area	Geometric mean (ppb)	Maximum concentration (ppb)
A	760	297,000[2/]
B	600	29,700
C	140	2,000
D	70	700

[1/] Includes those organic solvents listed in Table 1.
[2/] One well has had a separate solvent phase at various times.

IBM-EF-88

Recent data on the quality of water in the bedrock production wells is summarized in Table 3.

Figure 1: Monitor Well and Production Well Locations
missing from original document

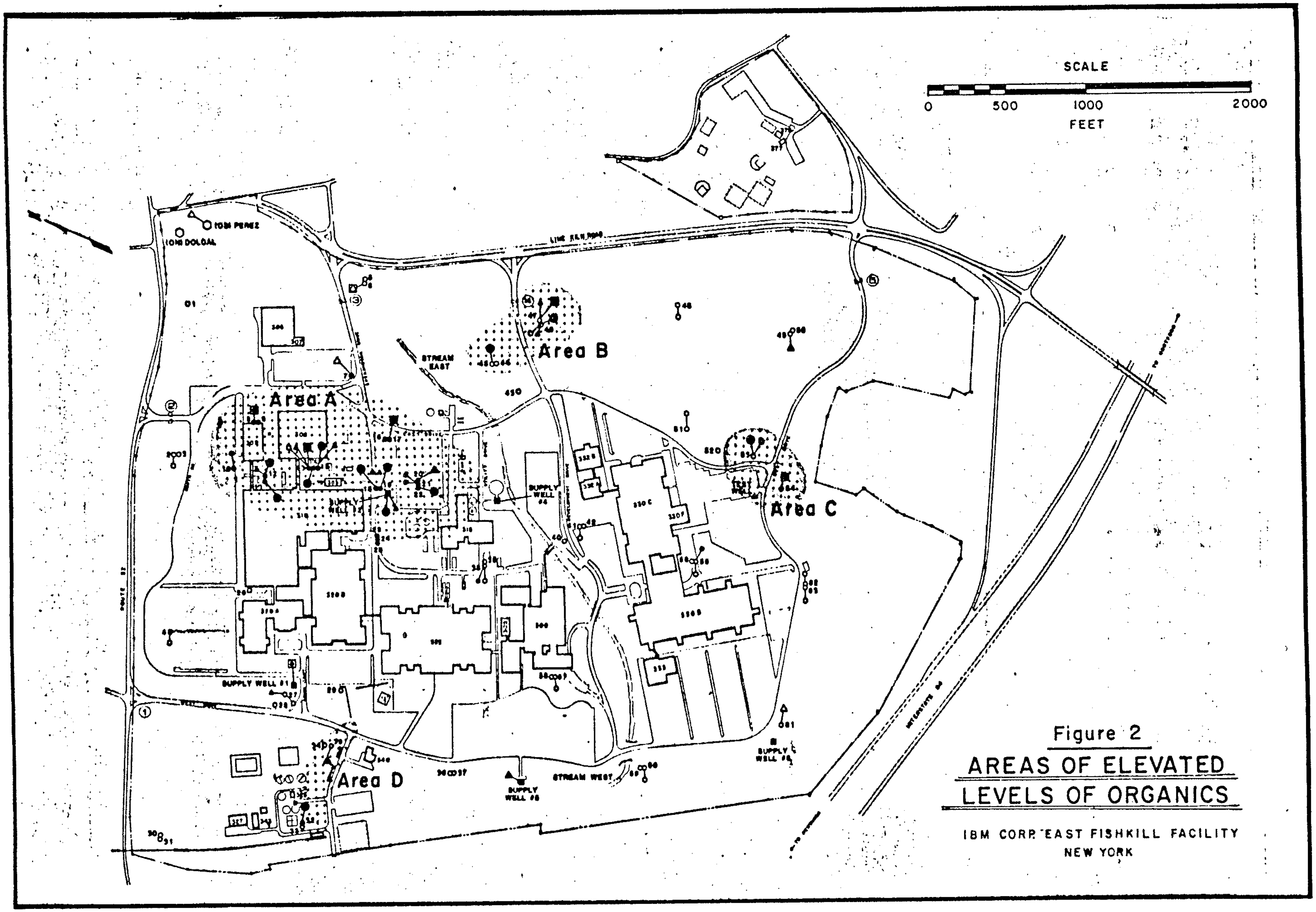

Figure 2
AREAS OF ELEVATED LEVELS OF ORGANICS

IBM CORP. EAST FISHKILL FACILITY
NEW YORK

IBM-EF- 88

Table 3. Production Well Water Quality[1/]

Well No.	Average concentrations (ppb)[2/]
1	< 2
2	10,400
4	12
5	< 2
6	< 2
7	9
Recreation Center (Lime Kiln Road and Shenandoah Road)	< 2

The quality of water (after G.A.C. treatment of wells 2 and 4) entering the domestic system is less than 2 parts per billion of the organic compounds listed in Table 1.

[1/] Prior to treatment with Activated Carbon, October 1980.

[2/] For compounds listed in Table 1, Organic Solvents.

The ground-water quality at the site perimeters has been monitored, and the findings are summarized in Table 4.

Table 4. Ground-Water Quality[1/]

Site perimeter	Geometric mean (ppb)	Maximum concentration (ppb)
North	7	300
East	14	1,400
South	16	4,000
West	11	900

[1/] Includes organic solvents listed in Table 1.

IBM-EF- 88

A number of monitoring wells installed in the second well construction program were found to contain levels of tetrahydrofuran. This compound was traced to the solvent cement used to join the PVC well casings. This material had been used in the past without difficulty and its presence in these wells was attributed to lack of curing time prior to installation of the casings. The level of this compound is declining rapidly as a result of well purging and possible biological degradation during the time period of the sampling program (9 months).

C. Ground-water quality summary--inorganics

All site production wells are analyzed for the parameters listed in Table 1 twice a year. In addition, a series of key inorganic species are analyzed twice a month. The results of these analyses have demonstrated that all production wells meet U. S. EPA primary and secondary drinking water standards.

A series of analyses for inorganics were carried out on ground-water samples for a period of 6 months as part of the routine sampling program. Based on an evaluation of the results, these analyses will be carried out on a quarterly basis in the future. The results of analyses of ground-water samples were quite good with only two areas of concern. Some monitor wells (shallow) have high levels of salts, such as chlorides and sulfates. These materials are attributed to the use of de-icing chemicals and general surface runoff. There does not appear to be a pattern of migration of those compounds into the bedrock aquifer at the present time. A second area of concern is the presence of elevated fluoride levels (2 to 10 ppm) in the area of Buildings 308 and 310. It is presumed that these levels are the result of processing fluoride wastes in the vicinity of the wells. There is no evidence that the fluorides have moved into the bedrock aquifer since production wells on site show non-detectable fluoride levels.

D. Potential sources of chemicals in ground water

Information from previous studies highlights areas of concern on the East Fishkill site which indicated ground water containing various levels of organic compounds. These areas are shown in Fig. 2. The primary source of organics appears to be the chemical and waste solvent tank farm. Secondary sources such as spills, pipeline leaks and incidental discharges probably existed area wide because elevated levels occur in several areas of the plant that are hydraulically unexplainable if we assume only one source.

Unlike the findings obtained for the organic compounds, there is a less distinct pattern of degraded ground water by inorganic chemicals which appear to be much more widespread. These may be the accumulated results of incidental discharges, sporadic spills, leaks and de-icing compounds over the years.

E. Site-specific ground-water hydraulic characteristics

As of the end of 1980, over 100 holes have been drilled with monitor wells and piezometers installed on the IBM East Fishkill site. Fig. 3 (in pocket) is a geologic fence diagram which helps visualize the three-dimensional geometry and heterogeniety of the site. A summary of the physical information obtained to date follows:

1. Fill and glacial overburden deposits range in thickness from less than 1 foot to over 80 feet.

2. The bedrock surface is uneven with well defined depressions and high areas. Bedrock surface elevations under the site range from less than 50 feet to over 250 feet above mean sea level.

3. The exposed bedrock dips 30 to 40 degrees eastward. Folding and faulting in the area is evident.

4. The glacial deposits are heterogeneous, both horizontally and vertically. Permeabilities range from a few feet per day to 200 feet per day.

5. The degree of fracturing in the bedrock varies significantly. The permeability is essentially zero in those areas with no fracturing to 120 feet per day (or more) in localized areas where fracturing is extensive.

6. The natural water-table configuration in the glacial deposits probably conformed to the general topography of the area prior to construction on the facility. Thus, ground-water flow was to the low areas, such as streams and swamps, that served as outlets. Measurements of water levels in the monitor wells, however, show that a strong vertical gradient now exists because of pumping from the bedrock.

7. The flow of ground water in the bedrock is controlled by the fracture patterns as well as relative potentiometric heads in the formation. The general flow direction across the site was probably southwesterly before the IBM wells were put into production. Recent measurements show pronounced influence of the production wells causing the direction of bedrock ground-water flow under much of the site to be towards the pumped wells.

8. Although the vertical permeability of the glacial deposits is very low, chlorinated hydrocarbons have been found at the base of the deposits indicating vertical percolation of the organics.

IV. PRESENT ABATEMENT AND PROTECTION PROGRAMS

A. Spill prevention, control and countermeasures (SPCC)

A ground-water protection program has been in effect since January 1978. The primary purpose of the program is to prevent future spills, control and abate existing situations, and establish a series of countermeasures in the event of an accidental spill episode. The main features of the program are as follows:

1. A formal SPCC Plan for petroleum and for hazardous materials.
2. Diking of all above-ground storage tanks or hazardous materials.
3. Truck loading/unloading spill control facilities at all hazardous waste transfer areas.
4. Site-wide ground-water monitoring program.
5. New specifications covering all new hazardous waste pipe and tank installations.
6. Training of key personnel in spill prevention and cleanup procedures.
7. Onsite specialized emergency equipment for use on hazardous waste spills.
8. Long-term replacement program of storage tanks and pipes conveying hazardous materials.

IBM-EF-88

9. Pilot plant for ground-water extraction and treatment of organics and inorganics.

10. Site-wide leak testing program of hazardous material storage tanks and piping systems.

B. Granular activated carbon systems

When the presence of organic compounds was confirmed in production wells #2 and #4, a number of potential treatment systems for organics removal were considered. Granular activated carbon (GAC) was chosen because the technology had been successfully applied to the removal of materials similar to those which existed in the ground water on the East Fishkill site. In addition to being capable of removing the particular organics, a system (CALGON, INC.) was available for delivery and installation on short notice. Two weeks after confirmation of the presence of organics, the GAC system was installed on well #2 and was fully operational by April 1979. The unit consists of two tanks, each containing 10,000 pounds of Calgon GAC, operated in series at a flow rate of 250 gpm. Water-quality into the system between the two tanks, and the output of the system is monitored on a weekly basis. Adsorption isotherm data from Calgon, Inc., indicated the material in the water which would break through (exhaust) the carbon most rapidly was cis-1, 2-dichloroethylene. When the level of this compound exceeds 10 ppb at the between sample point, the first GAC bed is replaced with virgin carbon and the flow pattern of the system is reversed which assures that the freshest carbon is on the output of the system at all times. The spent carbon is reactivated by Calgon for industrial use.

The design, the operating and maintenance procedures, and the analysis and reporting schedules were discussed with and approved by the New York State Department of Health in Albany and the Dutchess County Department of Health.

IBM-EF-88

The pumping of production well #2 (with the GAC in place) resulted in a significant drop in the levels of organics in production well #4 which is hydraulically downgradient of #2.

A similar GAC system has been installed on production well #4 (August 1980) in order to further improve the quality of water from this source and the overall quality of the mixed raw-water supply for the site.

The GAC system on production well #2, in addition to removing organics from the site raw-water supply, is acting as an extraction and treatment facility for organics in the ground water in the vicinity of Buildings 308 and 310. During the course of operation from April 1979 through December 1980, this system has processed in excess of 130 million gallons of ground water.

C. Treatment of areas containing elevated levels of organic/solvents

There are four areas on the East Fishkill site which have been identified as regions in which the ground water contains elevated levels of organics (Fig. 2). These findings are based on the results of the various hydrogeologic studies and the site-wide ground-water monitoring program.

A number of procedures have been implemented to extract, treat, and contain the ground water in these areas. A detailed program has been established to detect and correct any spills or leaks from the site chemical handling systems. The abatement procedures discussed below were implemented on a priority basis to contain the areas of interest, remove organics where possible, and study long-term concepts for the extraction and treatment of organics from ground water on a site-wide basis.

Area A. Pilot plant studies were conducted between June and November 1980 to investigate the feasibility and advisability of implementing a suitable process for ground-water extraction and treatment under the chemical and waste solvent storage area near Buildings 308, 309, and 310. Alternative treatment technologies for removal of organics, inorganics, and heavy metals at the levels occuring in ground water pumped from the shallow unconsolidated sediments and the underlying upper bedrock aquifer in this area, were investigated to develop detailed design parameters.

IBM-EF-88

The purpose of the study was threefold--to determine a suitable and effective treatment procedure to permit sizing and costing of a full-sized system; to initiate early treatment of shallow ground water from a group of selected small-diameter monitoring wells; and to study the feasibility of recharging ground water. The project was grouped into five work categories:

1. Initial laboratory study and design of pilot plant (Bench Scale).
2. Furnishing and installation of the pilot plant.
3. Operation of the pilot plant.
4. Performance of a recharge feasibility test.
5. Study and report

The pilot plant design was based on five unit operations: separation, equalization and storage, air stripping, coagulation and filtration, and adsorption. A continuous and fairly constant low volume stream of ground water was provided to the individual unit treatment processes making up the pilot plant by the conversion of several selected monitoring wells of varying depths into a connected and pumping extraction well network. Approximately 110,000 gallons per month was recovered, tested, and processed through the well network. Results indicated that special consideration must be given to design and selection of compatible materials and construction practices in the event very high concentrations, or separate phase organics, are encountered.

Results from operating the recovery well network confirm previously collected data and indicate complex hydrogeologic conditions. Over a 4-month period, approximately 6-7 gpm of ground water was successfully pumped on a semi-continuous basis and processed through the system.

Results from the pilot plant operations served to confirm basic assumptions regarding the appropriate methodology that should be considered for extracting of ground water pumped from the chemical and waste solvent storage area. The information that was evaluated on extracted ground water (analysis and treatment parameters) resulted in the design of an abatement program. The major conclusions from the pilot treatment plant investigation area as follows:

1. Variable well production and analysis requires equalization/storage prior to treatment.
2. Presence of iron and managanese in the water as well as possible suspended solids requires clarification with chemical treatment followed by filtration, prior to further treatment.

IBM-EF- 88

3. While cooling tower type air stripping is effective in removal of organics, a flooded, packed tower air stripping design is much more efficient.

4. The various activated carbons were more effective than had been calculated,although the synthetic resin type, Ambersorb XE 340, did not perform as predicted by the manufacturer. Steam stripping of the carbon after exhaustion, while extremely effective, did not return it to its original efficiency. This fact, together with capital and operating cost analysis, suggests the use and subsequent discard of virgin carbon for the project operating conditions.

Based on the results of the pilot plant/extraction field study, a number of design options for a full-scale project are in progress.

In addition to the construction and operation of a full-scale system, plans are underway to reinstall a modified pilot plant system for operation during the May 1981-November 1981 time frame. This will allow continued treatment of ground water in this area during the construction phase of the full-scale system.

Area B. The presence of particular species (i.e., methylene chloride) and their relative ratio with respect to other compounds suggests an isolated area of high organic levels shown as Area B on Fig. 2. The treatment of this area of ground water is being addressed in the studies presently underway (site hydraulic modeling). As an interim measure, a temporary system consisting of a submersible pump with level controls is being installed to pump water from this area into a storage trailer which will then be treated at a permitted waste disposal facility.

Areas C & D. As shown on Fig. 2, two additional areas (C & D) with elevated levels of organics have been identified. A study of ground-water flow patterns and data from the water-quality monitoring program suggests that additional monitoring is called for at the present time (see the data summary, Table 4). In addition, the stream which runs along the site western boundary may act as a natural barrier to the organics in the shallow unconsolidated zone.

IBM-EF-88

D. Development of site-specific hydraulic model

The complexity of the ground-water system as influenced by geometry, heterogeneous hydraulic characteristics, pumping, etc., requires that rather sophisticated analysis and prediction techniques be used. The analysis and prediction needed to evaluate proposed abatement plans can best be accomplished using a mathematical model of the system. Development of such a model requires sufficient knowledge of the system to adequately simulate its responses to pumping and recharge.

A program directed at obtaining the necessary information for developing such a model was begun in mid-October 1980. The work has included installation of a network of piezometers for measuring potentiometric head at specific elevations, additional definition of bedrock fracturing and an aquifer pumping test.

The aquifer pumping test, which included periodic measurement of water levels in monitor wells and piezometers, provides a base for calibrating a model so that simulated responses correspond with the field measurements. The aquifer pumping test was performed December 26-29, 1980.

V. FUTURE PLANS AND TIME SCHEDULES

Ongoing and planned future work are scheduled over a 12-month period as shown in Fig. 4. The data and information programs, and the abatement facilities for Area A, have been discussed in earlier sections of this report. The plan of work related to the development and use of an hydraulic model is discussed in more detail below.

A. Phase I, Data collection and preliminary analysis

As shown in Fig. 4, Phase I is estimated to require 4 months and contain 6 major tasks. Because of the field work involved, the progress of the work is particularly vulnerable to adverse weather conditions.

Task IA--Hydraulic investigations. The work to be accomplished under this task is the most time consuming of all the Phase I tasks. It is anticipated that as many as 64 dual piezometers (two piezometers per hole) may

IBM-EF-88

DATA & INFORMATION PROGRAMS

A. Water-quality data (monthly throughout year)
B. Water-level data (monthly throughout year)
C. Leakage information
D. Water-use data (historical)
E. Water need projections

SITE - SPECIFIC HYDRAULIC MODEL TASKS

Phase I, Data Collection and Preliminary Analysis

A. Hydraulic investigations
B. Geologic investigations
C. Initial migration evaluations
D. Initial water-supply evaluations
E. Model selection
F. Development of conceptual abatement plans

Phase II, Model Verification and Analysis

A. Model verification
B. Model analysis of abatement plans
C. Model analysis of water supply
D. Model analysis of migration situation
E. Continued data analysis

Phase III, Design Phase

A. Design site-wide abatement facilities
B. Supervise construction of abatement facilities
C. Continued data analysis
D. Prepare plan of work for monitoring and evaluating the progress of abatement

ABATEMENT FACILITIES

A. Design of abatement facilities for area of highest concentration of organics

B. Construction of abatement facility

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |

MONTHS FROM BEGINNING OF PROJECT

IBM-EF- 88

Fig. 4, PLAN OF WORK

IBM-EF- 88

be required to adequately define ground-water flow conditions in the shallow and bedrock formations. Task IA can be further subdivided into subtasks which need to be performed sequentially as follows:

1. Design piezometer layout and construction details.
2. Determine which of the existing monitor wells can be converted to the piezometer network and how the conversion can be accomplished.
3. Engage a contractor(s) to install piezometers.
4. Supervise construction assuring satisfactory work.
5. Conduct pumping tests on production wells.
6. Analyze data for use in model.

As of January 1, items 1, 2, 3 and 5 have been completed; item 4 is near completion; and item 6 is yet to be done.

<u>Task IB--Geologic investigations</u>. Geologic investigations will be conducted to supplement data and information already available so as to better define the location and orientation of bedrock fractures. Specific subtasks include:

1. Make detailed inspection and measurements of bedrock outcrops.
2. Study aerial photographs, including satellite imagery.
3. Do TV survey in existing wells and new holes prior to installation of piezometers.
4. Acquire and study well logs available in area.
5. Analyze data for use in model.

As of January 1981, items 1 and 2 have been partially completed; item 3 has been accomplished; and items 4 and 5 have yet to be done.

IBM-EF-88

<u>Task IC--Initial migration evaluations</u>. As data on quality analyses of ground-water samples taken from existing monitor wells become available, trend analyses and evaluations of potential migration will be made. The ultimate analyses will be made after the model is verified (Phase II), but preliminary evaluations will be made as soon as sufficient data are available.

Task ID--Initial water-supply evaluations. As additional geologic and hydraulic data are developed during Phase I, preliminary evaluations of the facility water supply will be made--including recommendations for new production wells, if possible. However, ultimate analyses will be made after the model is verified (Phase II).

Task IE--Model selection. Existing ground-water models will be evaluated for applicability to the East Fishkill Facility and one or more will be selected for use.

Task IF--Development of conceptual abatement plans. Using preliminary data on ground-water flow conditions and quality, alternative abatement plans will be developed. It is anticipated that these will be in the form of ground-water pumping and recharge installations at alternate locations, numbers and sizes.

B. Phase II, Model verification and analysis

The modeling phase is expected to require 5 months to complete its five major tasks. The first task, model verification and calibration, must be completed before the next three are started.

Task IIA--Model verification and calibration. An important part of model development is the testing of the model against known field conditions and responses to verify that it truly simulates the system. During the calibration and verification process important decisions often must be made in adjusting model components. Data from piezometer and monitor-well measurements will be used in the verification process. Additional data from the ongoing leak-testing program for use in the modeling endeavor, as well as information on production well pumping, will be provided.

Task IIB--Model analysis of abatement plans. Alternative abatement plans will be tested with the model. The principal objective will be to identify the plan that will provide the most efficient and fail-safe operational abatement program. Plans for an abatement program for the area of highest concentration will be available by this stage of the work and will therefore be incorporated in the model.

IBM-EF- 88

Task IIC--Model analysis of water supply. Using the model, the proposed abatement plan and the projected water needs will be imposed on the system to evaluate the quantity and quality problems expected to impact future water supplies. Programs will be implemented to assure adequacy of supply.

Task IID--Model analysis of migration situation. The model will be used to evaluate the potential migration. Control methods will be tested and implemented, if necessary.

Task IIE--Continued data analysis. Monthly trend analyses on quality and water-level data will continue through Phase II. These will be particularly scrutinized for changes near the facility boundaries.

C. Phase III, Design phase

After the alternate abatement plans have been tested and approved, the following tasks will be pursued.

Task IIIA--Design of abatement facilities. Plans and specifications for construction of the abatement facilities will be prepared, along with cost estimate of same.

Task IIIB--Supervision of construction of abatement facilities. Construction of the facilities in conformance with specifications will be quite closely supervised.

Task IIIC--Continued data analysis. Monthly trend analyses on quality and water-level data will continue through Phase III.

Task IIID--Preparation of plan of work. A plan of work for monitoring and evaluating the progress of abatement will be prepared prior to the completion of Phase III.

IBM-EF-88

Figure 3: Geologic Fence Diagram
missing from original document