TASK II DELIVERABLE
PRE-INVESTIGATION EVALUATION OF GROUNDWATER CORRECTIVE MEASURES

RCRA Facility Investigation
Building Nos. 322 and 330
IBM East Fishkill, Facility
Fishkill, New York

SHA
Sanborn, Head & Associates
Consulting Engineers & Scientists

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Prepared for
IBM Corporation
East Fishkill, New York

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1.0 INTRODUCTION

This report presents the results of a preliminary evaluation of technologies that might be used to supplement existing groundwater corrective measures within specific areas of the IBM East Fishkill Facility. Specifically, the focus of this work is on groundwater in the Building 322 and 330 Areas of Concern (AOCs) which are subject to State-led Resource Conservation and Recovery Act Corrective Action (RCRA CA). A separate Pre-Investigation Corrective Measures Evaluation targeted at soil media is being prepared by others.

This work product is intended to serve as the RCRA Facility Investigation, Task II Pre-Investigation Evaluation of Corrective Measures focused on groundwater (Pre-RFI Evaluation) as defined by IBM's New York State, Department of Environmental Conservation (NYSDEC), Part 373 Permit Module III[1] (Module III). It was prepared by Sanborn, Head & Associates, Inc. under a contract for services authorized through issuance of a Purchase Order by IBM on August 11, 1995. Our work and this report are subject to the limitations outlined in Appendix A.

The original regulatory intent of the Pre-RFI Evaluation is to identify "potentially applicable" remedial technologies in advance of the RFI so that investigation work plans could be tailored to collect the requisite data to screen and perhaps select a remedial technology, and/or complete remedial design. For the IBM East Fishkill Facility, a large body of site characterization data and interpretations already exist and significant groundwater corrective measures have already been put in place. Although additional explorations and testing are not ruled out, we believe that the site specific conditions and issues that would drive additional remediation are adequately framed to narrow the range of technologies considered, and to allow a higher level of screening at this "Pre-RFI" stage.

Clearly, the most significant condition that could drive the need for additional corrective measures for soil and groundwater is the subsurface presence of halogenated volatile organic compounds. By virtue of their prevalence, environmental persistence, and potential mobility, these compounds typically pose more of a potential threat to human health and the environment via the groundwater pathway than would less mobile or less persistent metallic and organic constituents. Due to the degree of containment apparently afforded by on-site bedrock groundwater withdrawals for process use and groundwater corrective action, no "immediate threat to human health or biota" is readily apparent. As a further consideration, it should be noted that the intractable nature of dense nonaqueous phase liquid (DNAPL) in soil and deep fractured bedrock combined with the containment afforded by on-site groundwater supply withdrawals tend to narrow the focus of discussion regarding additional groundwater corrective actions.

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[1] New York State, Department of Conservation, September 29, 1995, Final IBM RCRA Permit, <u>Module III - Corrective Action Requirements for Solid Waste Management Units and Areas of Concern</u>, Section E- Corrective Action Requirement, Subsection 5 (e).

Given the considerations outlined above, IBM's objectives for the Pre-RFI Corrective Measures Evaluation were to:

- further compile existing hydrogeologic and environmental quality data to aid in refining an understanding of site conditions that could drive the need for additional groundwater corrective action within the Building 322 and 330 areas;
- identify data gaps/or conditions requiring further investigation to facilitate evaluation, selection, or design of "final corrective measures;"
- develop a preliminary outline of possible risk management objectives that would influence technology selection;
- identify, discuss, and preliminarily screen technologies that may be applicable to the site conditions; and
- outline possible design concepts as considerations to implementation of further groundwater corrective measures.

The scope of work completed to aid in meeting the objectives outlined above, included:

1. Limited review and compilation of existing hydrogeologic interpretations and environmental quality data to develop and present a "conceptual model" of specific site conditions which are believed to be particularly relevant to groundwater corrective action. This work included the preparation of plan and profile view figures depicting a simplified conceptual geologic and hydrologic model of site conditions, and the compilation and assessment of a recent portion of the water quality monitoring database.

   In general, the assessment of water quality data was limited to compilation and review of those data collected from routine groundwater quality monitoring[2] in the fourth quarter of calendar year of 1994, supplemented by data from a June 1994 "Appendix 33" round of nine monitoring wells located adjacent to Building 322.

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[2] *Our assessment was generally limited to Corrective Action Monitoring (CAM) locations, and more specifically, Interim Monitoring Program (IMP) wells designated by NYDEC as locations for investigative studies associated with Buildings 322 and 330. (See Section 1.12.2 for more detail)*

2. Preliminary assessment of potential pathways for human and/or environmental exposure, and identification of objectives or goals for corrective measures to aid in mitigating or eliminating the pathways.

3. Identification and limited screening of technologies based on technical, environmental, and institutional criteria established by NYSDEC Corrective Action Requirements. This screening is termed "limited" in that it is based on a conceptual model derived prior to completing the RFI Final Reports outlined as Task IV of the Module III.

4. Preparation of a discussion focused on considerations relevant to implementation of the groundwater corrective action technologies outlined under step 3.

This scope of work and report is not intended as the equivalent to a Corrective Measures Study as defined in Appendix C of Module III. It is intended as a more detailed assessment at the "Pre-RFI" stage, commensurate with the existing level of site characterization information. As appropriate, a more detailed and focused screening of remedial technologies and alternatives will be performed after completing the RFI Final Reports. The RFI Final Reports will consist of a more detailed compilation and assessment of existing hydrogeologic and environmental quality data, supplemented if necessary, by additional explorations and testing.

The following subsections provide a capsule summary of "background" information intended to serve as a general backdrop for the Pre-RFI evaluation of groundwater corrective measures. A more detailed summary of background information is being provided in the Work Plan documents under preparation by W.F. Cosulich Associates[3] (Cosulich).

1.1 Background

The IBM East Fishkill facility is comprised of about 4 million square feet of building space located on about 600 acres which are divided into the East and West Complexes. The East Complex-- which is the subject of RCRA Corrective action -- has been used since April 1963 for manufacturing of semiconductor and electronic computing equipment. The West Complex houses semiconductor research and development. The entire Facility is owned by the International Business Machines Corporation which is headquartered in Armonk, New York. Since 1993 portions of the East

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[3] W.F. Cosulich Associates, P.C., RCRA Facility Investigation Work Plan for Solid Waste Management Units at B/330, B/322, B308/310 and B/309/310, and RCRA Facility Assessment Sampling Visit Work Plan for The Southeast Quadrant Area of Concern, to be submitted to NYSDEC in February 1996.

Complex have been leased to a number of independent entities for research, and operations including manufacture of silicon wafers, flat panel displays, and semiconductors.

As stated earlier, the focus of this report is on groundwater media and the Building 322 and 330 AOCs which are two of the seven AOCs subject of Corrective Action being conducted under the New York State Part 373 Hazardous Waste Management Permit. The locations of Buildings 322 and 330 are shown on the Locus Plan provided as Figure 1. These buildings and other relevant site features are depicted in more detail on the Location Plan provided as Figure 2.

IBM's original RCRA Part B Permit with the USEPA, dated December 31, 1983, expired in December 31, 1993. The State of New York was authorized to administer hazardous waste management since issuance of IBM's original permit. In late October 1995, the NYSDEC issued the final Part 373 Permit with an effective date of September 29, 1995. Corrective Action requirements are outlined in Module III of the Permit, with Modules I and II outlining Standard and General Facility conditions, respectively. Buildings 322 and 330 are included as AOCs C and E. Other AOCs include:

- AOC A which covers the region around buildings 303, 308, 309, 310, 316, 384, 385, and 386;
- AOC B -- a former fire training area and leachfield;
- AOC D -- a second fire training area;
- The Southeast Quadrant which formerly was occupied by a contractor staging area; and
- the deep bedrock aquifer.

These areas are subject to corrective action elements beyond the scope of this report and as such for the sake of brevity and clarity, they are not depicted on the figures herein. The vicinity of Buildings 308/310 and 309/310 along with Building 322 and 330 are subject of RFI soil investigations which are at the Work Plan stage. The Southeast Quadrant is subject of an RCRA Facility Assessment (RFA) sampling visit.

1.2 Facility Setting

The Facility is located in south-central Dutchess County within the Town of East Fishkill, New York. As shown on Figure 1, the property is located adjacent and north of Interstate Route 84 and south of Route 52. Lime Kiln Road is located at the eastern border of the East Complex. The East and West Complexes are separated by the Gildersleeve Brook and an electric transmission line that runs along a narrow strip of land owned by Consolidated Edison Company of New York. The IBM Facility is generally zoned for light industrial use (I-1) with smaller areas of General Business (B-1) and Planned Commercial Park (PCP) abutting or contiguous. Zoning of surrounding land allows for residential development with 1 and 2-acre properties.

Residential properties are located east of the facility off of Shenandoah Road and north to northwest off of Route 52. Commercial properties are also located on Route 52 northwest of the facility. John Jay public high school is located between the East and West Complexes, fronting on Route 52. This surrounding area is not served by municipal water or sewer and is generally served by bedrock water supply wells. In 1981 and 1982, about 60 domestic water supplies near the facility were sampled by IBM and the State.

The Facility and surrounding area are drained by the Gildersleeve Brook which along with the Wiccopee Creek, joins the Fishkill Creek about 4,000 feet to the northwest of the East Complex. The Fishkill Creek is tributary to the Lower Hudson River. The IBM East Fishkill facility exists entirely within the watershed of the Gildersleeve. According to Speed (1993), the facility represents about 0.7 square miles of the total 2.6 square mile drainage basin. An unnamed tributary of the Gildersleeve (central drainage) is located between Buildings 322 and 330, draining in a southwest direction to its confluence with the brook at West Drive. At about its midpoint, the central drainage passes through culverts beneath Building 334. Cosulich and others report 2.1 square miles of contributory area to the Route 52 crossing of the Gildersleeve just downstream of the East Complex.

United States Geological Survey (USGS) hydrologic studies of Fishkill Creek suggest basin yields of about 60 percent of the total 40 inches of annual incident precipitation, including direct runoff and baseflow. Assuming a drainage basin area of 2.1 square miles for the Gildersleeve Brook would suggest an average natural streamflow of about 3.7 cubic feet per second (cfs) which is equivalent to just less than 2.4 million gallons per day.[4] This is compared to limited (5 events) historical low flow measurements of 0.3 to just over 1 cfs reported by the USGS between 1962 and 1964[5].

According to mapping by the USGS and others, the valleys of Wiccopee Creek and the Gildersleeve Brook northwest of the subject site are underlain by a glacial sand and gravel aquifer referred to as the Sprout Creek-Fishkill Creek aquifer. According to Cosulich, a wellfield operated by the Brinkerhoff Water Company is located in the aquifer about 1.7 miles to the northwest in a position

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[4] *Contributory to the Route 52 crossing adjacent to the site.*

[5] *Measurements in late summer and early fall conditions at the Route 52 crossing.*

expected to be hydrologically isolated from the facility under natural groundwater flow conditions. The IBM Wiccopee Well field is also located in this aquifer.

1.3 Overview of Facility Waste Generation and Handling

A variety of wastes are generated as a result of site semiconductor and electronic computing equipment manufacturing and support operations including hazardous wastes and wastewaters. Records for 1994 indicate the generation of about 3,620 tons of hazardous wastes, with about 44 percent being waste solvents or solids containing solvent residues. Other hazardous wastes include: cyanide-containing solids and liquids; solids or sludges containing metals including but not limited to arsenic, copper, gold, lead, and molybdenum; and laboratory wastes. Containerized hazardous wastes are stored in Chemical Storage Building 309 which is located north of Building 308 just off of Figure 2.

Industrial (waste hydrofluoric and dilute acid) and sanitary wastewaters generated on site are treated and discharged to the Gildersleeve Brook via a permitted outfall. Perchloroethene (PCE) - also known as tetrachloroethene - is recycled on-site in a closed loop system constituting a totally enclosed treatment system.

The Industrial Wastewater Treatment Plant (IWT) located in building 312 (308/310 area) is used to treat effluent from semiconductor/packaging operations, cooling tower blowdown, backwash from potable water filters, and deionized water system regeneration chemicals. Treatment operations include neutralization of pH, clarification, sludge thickening, dewatering, and blending.

The Fluoride/Heavy Metals Treatment operations (F/HM) housed inside Building 386 is used to treat heavy metal and fluoride wastes generated throughout the facility and transferred to F/HM via pump and lift stations. In a continuous treatment process, fluoride and metals are precipitated as calcium fluoride and metal hydroxides, respectively. The sludges are dewatered and kept segregated from IWT wastes.

The Solvent Recovery operation is housed in Building 335 which is located between Buildings 330C and 330D. A distillation process is used to remove impurities commingled with PCE during the manufacturing operations.

1.3.1 Building 322

Building 322 was constructed in the late 1960s to early 1970s, and has been used to the present day for manufacturing of semiconductors. Virgin and waste solvents are handled in this building including isopropyl alcohol (IPA) , n-butyl acetate (NBA), n-methyl-pyrrolidine (NMP), PCE, and other mixed solvents. Based on documented releases or environmental sampling evidence, potential sources of groundwater contamination identified to date include the vicinity of the "linkway" between Building 322 and Building 320B, and the west face of the Building 322. Documented releases in the linkway area include solvent leakage from Tanks 53B and 157B, and "numerous events" of wastewater leakage from Tank 165.

1.3.2 Building 330

Buildings 330 C and 330D were constructed in the late 1960s, with manufacturing beginning in the mid-1970s. These buildings house the MLC Packaging Substrate Business Unit. The eastern portion of Building 330C contains the Organic Manufacturing Facility (OMF). Wastes generated and handled with this building include mixed waste solvents and fluoride/heavy metal wastewaters. Until the mid-1980s these wastes were transmitted in direct-buried underground piping. Present operations utilize double-walled above ground piping.

Based on documented releases or environmental sampling evidence, SWMUs located in potential source areas associated with Building 330 include a number of below-ground storage tanks and the former below ground transmission piping.

1.4 Regulatory Background

The corrective action process at the IBM Fishkill Facility is regulated by the NYSDEC under Article 27, Title 9[6] and 6 NYCRR 373-2.6(1)[7]. The State of New York has regulatory primacy to implement RCRA Corrective Action where it is "deemed necessary to protect human health and the environment, for all releases of hazardous wastes including hazardous constituents from any solid waste management unit (SWMU) at a storage, treatment or disposal facility needing a 6 NYCRR Part 373 Permit." Part 373 Permit conditions may be imposed by the NYSDEC as the Agency determines necessary to protect human health or the environment. Under NYSDEC rules, "hazardous

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[6] Article 27, Title 9, Section 27-0913.

[7] New York State Department of Environmental Conservation, Division of Hazardous Substances Regulation, January 14, 1995 6 NYCRR Subpart 373-2, Final Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities. Section 373-2.6 Releases from Solid Waste Management Units. Albany, NY.

constituents" are those constituents listed in Appendix 33 of 6 NYCRR Subpart 373-2[8] which is the State equivalent of the Federal 40 CFR Part 261, Appendix VIII.

1.4.1 Overview of RCRA Corrective Action

Under the NYSDEC process, if the results of an RFA indicate the likelihood of a release of hazardous waste or constituents[9], an RCRA Facility Investigation (RFI) is required as a second phase in the corrective action process. The purpose of the RFI is to "determine the nature, extent, direction, and rate of migration" in the various media. The RFI is to include "sufficient data to allow proper assessment of corrective measures alternatives." A third phase of RCRA CA is triggered if "concentrations of hazardous constituents in the media exceed action levels."

1.4.2 Building 322 and 330 Areas of Concern and SWMUs

For the IBM East Fishkill Facility, the NYSDEC required permit conditions regarding RCRA Corrective Action are outlined in the Module III. Table III-1 lists a former landfill area and adjacent Building 330 as Area of Concern-C (AOC-C) . Building 322 is listed in the Module III as AOC- E. The deep bedrock aquifer is also considered by NYSDEC as an AOC. Section E. (5) a, of Module III indicates that the NYSDEC has "determined that there has been a release of hazardous waste and/or constituents from the Building 322 and 330 Areas of Concern."

IBM's SWMU Listing Report[10] indicates the presence of 12 SWMUs for Building 322 and 67 SWMU's for Building 330. These include:

- tank and container loading and unloading areas ;
- storage and treatment tanks associated with industrial wastewaters, corrosives, mixed and unmixed solvents;
- solvent and industrial wastewater lift and pump stations; and

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[8] NYSDEC, January 14, 1995, 6 NYCRR Subpart 373-2, Appendix 33 Groundwater Monitoring List, pgs 168 through 176.

[9] *Release to media including soil, groundwater, surface water/sediments, air, and subsurface gas.*

[10] IBM East Fishkill, May 1995 Update, <u>IBM East Fishkill Solidwaste Management Units</u>, an 11 page spreadsheet.

- inactive subsurface piping that historically transmitted solvents and wastewaters.

Table III-2 in Section E of Module III indicates NYSDEC determination of No Further Action for 10 of the SWMUs associated with Building 322, and 46 of the SWMU's associated with Building 330. These SWMU's include tank and container loading/unloading areas, former treatment and storage tanks that have been removed, an inactive Freon TF reprocessor unit, and several active storage tanks containing PCE and mixed solvent wastes.

Conversely, on the basis of an RFA Preliminary Review, dated October 1, 1992[11], the NYSDEC "determined that there has been a release" from six inaccessible SWMU's associated with Building 330 including, inactive below ground pipelines which formerly transmitted solvent wastes, and wastewaters containing fluorides and metals. These inaccessible SWMUs are subject to future RCRA Investigation once they become accessible due to demolition or abandonment of the buildings as to allow access for investigation. The Module III requires notification of accessibility followed by preparation of Task I, II, and RFI Work Plans. For the Building 330 area, this report and the RFI Final Reports to follow will summarize data and indirect evidence relevant to assessing these inaccessible SWMUs as sources of groundwater contamination, but will be limited by the lack of specific explorations and testing targeted at same.

Similarly, Module III Section E (2) a, indicates NYSDEC determination of potential for releases from three accessible SWMU's associated with Building 322, and two SWMU's associated with Building 330. These include external, below ground pipelines transmitting wastewaters that may include fluoride and metals.

1.4.3 Site-Specific RFI and Corrective Measures Studies

Acknowledging the large amount of existing site characterization data, the compliance schedule for the Building 322 and 330 AOCs indicates that the semiannual progress reports on groundwater monitoring activities collectively can constitute the Final RFI Report for characterizing groundwater contamination. Since the late 1970s, a number of hydrogeologic investigations have been completed at the Fishkill Facility. The majority of the studies have been focused on specific issues and areas peripheral to the Building 322 and 330 AOCs. Additional explorations and testing have been completed across the site as a part of establishing the current groundwater monitoring network, and the groundwater monitoring program.

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[11] NYSDEC, September 29, 1995, Part 373 Permit Module III, Section E(2) b.

A groundwater monitoring program outlined in Section E 17 (c) and associated subsections of the June 16, 1995 Draft Module III, specified locations, frequency, and analytes for monitoring. The Corrective Action Monitoring (CAM) wells were a subset of the total site monitoring well network and were further subdivided into process control and treatment (PCT) wells, contaminant reduction monitoring (CRM) wells, point of compliance (POC) wells , background monitoring (BGM) wells, Appendix 33 wells, detection monitoring wells (DM), and interim monitoring program wells (IMP) wells. Figure 2 depicts the location of the various well categories within the Building 322 and 330 Areas of Concern. The listing of wells was eliminated from the Final Module III, as IBM is presently preparing a Groundwater Monitoring Plan for the IBM East Fishkill facility. This plan will be submitted to the NYSDEC under separate cover.

The subsets of most relevance to the subject areas include the IMP wells and POC wells. The IMP wells are specifically targeted as locations for investigative studies associated with Buildings 322 and 330. Consistent with 6 NYCRR Part 373-2.6 (e)(3)(f)[12], the POC wells are specified points at which the groundwater protection standard is applied. The "point of compliance is defined in the Rules as a vertical surface located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated units." Possible POC wells in the relevant vicinity of the Building 322 and 330 AOCs include MW-66 and MW-67 which are shallow overburden wells located adjacent to the Gildersleeve Brook in areas that under natural non-withdrawal conditions could be downgradient of Building 322.

Table III-8 of the Module III lists Key Compounds, and Table III-9 lists a larger set of Chemical Constituents/Routine Parameters for monitoring associated with the subject areas. For both areas, the Key Compounds include PCE and its breakdown products, and one or more freon compounds. The Module III defines the "approximate limit of each plume" as the "median concentration equal to 5 μg/l of one, or the sum of key compounds." The routine monitoring parameters are inferred to represent the NYSDEC's list of site-specific parameters of concern and include a greater set of VOCs along with fluoride. Arsenic and zinc, are routine monitoring parameters for Buildings 322 and 330, respectively. Table III-9 also lists "Concentration Limits" for all of the monitoring parameters which are referred to in the discussion on termination criterion as "Groundwater Cleanup Standards" under Section E (17)(d)(2). Eighteen other locations are designated Appendix 33 locations subject to annual testing for the complete hazardous constituent list.

At this time, IBM anticipates that the Final RFI Reports focused on groundwater will constitute a compilation and focused refinement of geologic and hydrologic information pertinent to the

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[12] NYSDEC, January 14, 1995, 6 NYCRR Subpart 373-2, Appendix 33 Groundwater Monitoring List, pgs 168 through 176.

respective AOCs, and an updated snapshot of water quality conditions as required to assess the need for further groundwater corrective action, possibly moving the RCRA CA process to the Corrective Measures Study (CMS) phase.

As outlined in the Module III, the need for a CMS is triggered if :

i. The concentrations of hazardous constituents exceed their media-specific action levels; or

ii. The additive exposure risk due to multiple constituents is not protective of human health; or

iii. The concentrations in media pose a threat to human health or the environment given site-specific exposure conditions.

Consistent with Federal RCRA CA, conditions triggering a CMS do not necessarily require remediation, but trigger the need to more rigorously assess the need for remediation, consistent with a proactive risk management approach.

For the Building 322 and 330 areas, it is clear that condition i. would trigger the need for a CMS due to the presence of dissolved volatile organics in overburden and bedrock groundwater. However, we do not believe that the data suggest that site-specific exposure conditions for humans or biota would trigger such a need, nor is it clear at this time that further groundwater remediation would result in greater protection of human health. IBM believes that further groundwater corrective measures should be pursued commensurate with a proactive risk management strategy developed with due consideration of site-specific conditions and technical impracticability limitations.

1.4.4 Implications of Technical Impracticability

In recognition of technical limitations to remediation of sites involving DNAPL, the U.S. EPA has developed guidance for establishing a protective cleanup strategy where complete aquifer restoration is technically impracticable. The "Technical Impracticability" (TI) guidance issued in October 1994[13] is intended for use in making risk management decisions at both CERCLA and RCRA sites. It was developed based on a decade of experience that has shown that achievement of required final cleanup standards may not be practicable due to limitations of technology.

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[13] U.S. EPA, September 1993, Directive 9234.2-25, Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration, Interim Final, Office of Solid Waste and Emergency Response, Washington, DC.

In general, the TI approach advocates "location and removal of subsurface DNAPL source areas" where possible, and where "significant reduction of current or future risk will result." DNAPL source areas that cannot be removed should be "contained to limit further contamination of groundwater." The guidance lists factors to be weighed in assessing TI determination for a site including: the nature and duration of the release, the depth of current contamination, the stratigraphic complexity and heterogeneity, and factors involving the complexity of groundwater hydraulics. Based on our understanding of site conditions, we believe that the IBM East Fishkill Facility meets the primary factors for TI determination considering:

- the nature of historical releases from multiple locations over a range of temporal conditions;
- the apparent depth of DNAPL penetration;
- the presence of complex geologic conditions such as interbedded and discontinuous strata;
- the high heterogeneous nature of interbedded overburden, and fractured bedrock; and
- the presence of significant downward vertical components of flow in both overburden and bedrock.

The TI approach is consistent with proposed national RCRA corrective action strategy in that the Subpart S rules allow three conditions under which attainment of media cleanup standards may not be required, one of which is where "remediation to cleanup standards is technically impracticable." In further applicability to the IBM facility, the EPA indicates a preference for deferring TI decisions until after "full-scale aquifer remediation systems are implemented" in recognition of the difficulty in predicting the effectiveness of remediation based on site characterization data.

We believe that "full scale aquifer remediation" has been in operation, embodied by the bedrock extraction and treatment system. Operational information as described in Section 2.4 to follow indicates the presence of a large amount of VOC mass removal from bedrock and a high degree of hydraulic containment. However, under present extraction system operation, VOC mass entering the bedrock or residing within rock beneath a source area is removed after being transported to the production wells that are often remote from the source location, and diluted by commingling of clean water. Although the amount of VOC mass in the subsurface is unknown and will be difficult to quantify, the site information suggests little abatement in VOC concentrations in spite of this large mass removal.

With this regulatory background in mind, and the present understanding of site conditions as outlined in the text to follow, this Pre-RFI Evaluation was undertaken.

2.0 SITE CONCEPTUAL MODEL

This section presents a summary of the present understanding of existing site conditions as they relate to RCRA Corrective Action and groundwater media. This information is presented as a basis, or framework for the later discussion of possible goals/objectives for further groundwater corrective action. The section begins with an overview of geologic and hydrogeologic information. A discussion follows outlining a preliminary assessment of groundwater quality conditions focused on an enumeration of Appendix 33 constituents detected in past groundwater quality monitoring. Finally, a summary of the existing groundwater corrective measures program is presented as related to the Building 322 and 330 AOCs, and potential objectives of future corrective action.

2.1 Geologic/Subsurface Conditions

The East Fishkill facility is underlain by a complex assemblage of post-glacial and glacial unconsolidated deposits which in turn overlie bedrock. In general, the sequence of unconsolidated deposits beneath the site reflects a complex history of deposition by ice-dominated and water-dominated processes during glaciation and deglaciation, followed by reworking of glacial deposits by post-glacial streams and post-glacial erosion. A generalized stratigraphic profile for the site, with descriptions of different stratigraphic units and their inferred depositional setting is provided as Figure 3.

As shown on Figure 3, the stratigraphy beneath the site has been subdivided for the purposes of this investigation into five major geologic units consisting of the following:

- Post-glacial colluvium, alluvium, swamp deposits, and soil fill - This unit consists of a variable sequence of silty sands, sand and gravel, and/or sand and silt interlayered with peat and organic silt deposits which in turn is overlain by soil fill. Soil fill is observed throughout the developed portions of the facility. Colluvial/alluvial deposits have been identified beneath soil fill over large portions of the site. Swamp deposits consisting of peat and/or organic silt are restricted to low-lying wet areas along Gildersleeve Brook and wet areas along the east margins of the facility.

- Glaciolacustrine silt and clay deposits - This unit overlies lodgement till or outwash and ice-contact deposits, and is located over a large portion of the northern and central portions of the site. Portions of this unit may have a gradational contact with outwash sand and gravel and with post-glacial silty sands.

- Glacial outwash and ice-contact (ablation till) deposits - This unit consists of a mixture of poorly sorted and well-sorted sand and gravel with lesser amounts of silt, clay, cobbles, and boulders. These deposits typically have been identified within depressions in lodgement till and/or bedrock. This unit occurs intermittently across the site.

- Glacial lodgement till - This unit was deposited directly onto bedrock and is located beneath the majority of the site. The thickness of this unit ranges beneath the site from a few feet thick, to over 100 feet thick in the area north of Building 321. This unit generally has a greater density, as well as less sorting and a greater silt, clay, and boulder content than ice-contact/ablation till deposits.

- Bedrock - Bedrock beneath the site is reported to consist of dolomite (Lower Paleozoic Wappinger Group) interbedded with minor amounts of shale, siltstone, and sandstone. Localized brecciated zones and possibly faults are reported to occur beneath the site.

2.2 Hydrology and Groundwater Flow

The relatively complex groundwater flow conditions within the facility reflect the combined influences of infiltration of incident precipitation, the large on-site groundwater withdrawals, geologic controls, and leakage from the Gildersleeve and its tributaries.

In 1993, combined groundwater withdrawals from bedrock production wells totaled about 1.5 to 2 million gallons per day (MGD) which is equivalent to about 1,000 to 1,400 gallons per minute. This water is utilized for facility potable and process water needs. In 1995, on-site groundwater withdrawals were as high as 1.7 MGD.

Between about 2 to 2.5 MGD is returned through outfall 001 which is regulated by a State Pollutant Discharge Elimination System (SPDES) discharge permit with a maximum daily flow of 3 MGD. Forty-seven other outfalls are regulated under the SPDES program. Among others, these include twenty-five and twenty outfalls discharging stormwater runoff to the central drainage and Gildersleeve Brook, respectively. A number of these outfalls are shown on Figure 2. SPDES outfall 004 discharges treated groundwater and runoff to the central drainage, and is permitted to include up to 2.2 milligrams per liter (mg/l) iron and up to 50 micrograms per liter (μg/l) each of seven halogenated VOCs.

The man-made transfers of water, combined with natural geologic strata and processes interact to produce the groundwater flow conditions observed today. In general, the hydrologic units of most interest -- in that they may represent avenues for horizontal contaminant transport in zones of saturation -- include a relatively shallow unit in overburden, and a deeper flow regime in bedrock.

2.2.1 Shallow Overburden

In large areas of the site, the first zone of saturation encountered exists in recent deposits, glaciolacustrine soils, and/or glacial till. Within the area shown on Figure 4A, this "shallow water table" condition is found where low permeability glaciolacustrine soils exist in the area from the north sides of buildings 323, 300, and 334, northerly to the limit of the map. In the central portion of the site, where the glaciolacustrine silt/clays do not exist -- and perhaps where bedrock morphology allows for more vertical leakage -- the overburden is believed to be unsaturated over a large area. On Figure 4A, this area is encircled by the 230 foot groundwater elevation contour which encompasses much of the Building 330. East and southeast of Building 330, the water table exists in glacial till deposits.

At Building 322, the shallow overburden groundwater exists in a true perched condition with a strong vertical downward gradient through the glaciolacustrine silt/clay, recharging bedrock. The predominant component of horizontal flow is southerly towards Building 300 and Building 323 where the glaciolacustrine soils are absent, enhancing downward leakage to bedrock. Based on chemical evidence, a westerly component of transport toward the Gildersleeve Brook also exists. We believe that the westerly component of flow may be influenced by a sloping surface of the underlying lacustrine deposits, and perhaps the presence of utilities including water, sewer, and electric that generally run in a westerly direction from the vicinity of Building 322. This possibility will be further assessed during completion of the groundwater RFIs and hydraulic structures assessment work that is presently under formulation.

At Building 330, groundwater flow in the overburden includes a vertical downward component through glacial till, and perhaps less fractured rock; and a horizontal north to westerly component in the glacial till toward the center of the site where it recharges bedrock.

Along areas of Gildersleeve Brook, shallow groundwater flow is indicated to be away from the brook to the northeast. This flow direction is contrary to what would be expected under non-withdrawal conditions and is believed to exist along the stream reach from where it enters the southern property boundary to about SPDES outfall 009.

2.2.2 Deep Bedrock

As shown on Figure 4B, groundwater levels in the bedrock aquifer are depressed as much as 100 feet by groundwater withdrawals. The inferred centriod of the potentiometric low created by pumping is located north of Building 322, with the low point associated with production well PW-2. As such, groundwater flow in bedrock in this area of the facility would tend to be in a direction slightly west of north. As shown on Figure 4B, groundwater flow in the Building 330 area is indicated to be in a more westerly direction, away from the bedrock ridge to the east, and toward the central potentiometric depression.

2.3 Groundwater Quality

This section is intended to serve as an overview of our Pre-RFI understanding of relevant groundwater quality conditions as related to possible remedial goals under RCRA Corrective Action. Our present assessment of data regarding Appendix 33 constituents historically found in groundwater beneath the Building 322 and 330 AOCs is included as Tables 1A and 1B. This information was compiled to support, or "frame" the later discussion of possible remedial technologies and will be addressed in more detail in the later Groundwater RFI Reports.

2.3.1 Volatile Organic Compounds

As acknowledged in the Permit Module III, the predominant issue related to groundwater as a media is the relatively widespread presence of halogenated volatile organics. Approximately 45 volatile organic compounds (VOCs) have been detected in samples from the CAM wells surrounding Buildings 322 and 330.

This data is generally consistent with historical soil vapor survey results[14] which indicate the presence of ten VOCs in soil gas samples in the same area. At Building 322, the highest soil gas concentrations were recorded east of the walkway connecting Building 322 with Building 320B to the north, and adjacent to the southwest building wall nearby well MW-766. In the Building 330 area, soil gas samples were collected generally south and east of Building 330. The highest concentration of PCE in soil gas (220 μg/l) was detected east of Building 330D in the vicinity of monitoring wells MW-928 and MW-929 and SWMUs 88 and 89.

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[14] Report prepared by Tracer Research Corp. entitled "Shallow Soil Gas Investigations - IBM East Fishkill Facility - Hopewell Junction, New York" dated November 1989.

As noted above, Tables 1A and 1B provide a list of VOCs detected in groundwater samples from the Building 322 and Building 330 areas, respectively, during the four quarters of 1994. Figure 5 illustrates the inferred extent of VOCs based generally on 4th quarter 1994 data for overburden and bedrock locations, and using the 5 μg/l contour of the sum of Module III Key compounds[15]. Where data gaps existed, data for the next sequential monitoring event was utilized.

As depicted on Figure 5, VOCs have been detected in groundwater samples from monitoring wells surrounding both Buildings 322 and 330. The highest total Key compound concentrations in the Building 322 and Building 330 areas were reported for samples collected from monitoring wells 735 (593 μg/l) and 572 where the presence of DNAPL has been noted. Based on data for IMP monitoring wells, the apparent extent of VOCs in overburden groundwater[16] is about 800 to 900 feet west of Building 322 in the direction of the Gildersleeve Brook. At Building 330, the data suggest an overlapping of plumes from the former landfill area and potential sources adjacent to Building 330. This configuration is generally consistent with the inferred groundwater flow direction in the overburden as presented on Figure 4A.

In general, it appears that the distribution of VOCs in bedrock groundwater is consistent with inferred groundwater flow conditions in bedrock (Figure 4B) and primarily coincides with areas where the lacustrine deposits are absent (i.e., generally south of Building 322). The highest VOC concentration detected in bedrock for the data reviewed was about 160,000 μg/l for a sample collected from well 574 which is located inside the east end of Building 330C. In contrast, data for bedrock wells proximate to Building 322 do not suggest the presence of DNAPL in bedrock. The limited detections of VOCs of generally less than 5 μg/l may be attributable to dissolved phase transport through the silt/clay confining layer and/or inflow of VOC-containing groundwater from other sources.

The predominant VOCs detected in groundwater include PCE and its degradation products trichloroethene (TCE), and cis-1,2-dichloroethene (CDCE). PCE was detected in over 50 soil gas samples collected in the vicinity of Building 322 and Building 330. Maximum concentrations ranged from 28 μg/l north-northeast of Building 322 to 220 μg/l near monitoring wells 928 and 929 adjacent to the south side of Building 330. PCE was detected in groundwater samples collected from approximately 56 monitoring wells with maximum historical concentrations of 579 μg/l for a sample from monitoring well 768 located west of Building 322, and concentrations consistent with the

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[15] *Key compounds for Building 322 include PCE, trichloroethene, cis-1,2-dichloroethene, and Freons TF and 123. Key compounds for Building 330 include the above plus vinyl chloride, minus Freon 123.*

[16] *As defined by the 5 μg/l isopleth shown on Figure 5.*

presence of separate phase product PCE in well 572, which is located inside Building 330D. In two days in September 1995 during a routine sampling visit, IBM removed approximately 138 gallons of PCE product from this well via conventional peristaltic and bladder pumping.

TCE has been detected in soil gas from approximately 54 sampling points with elevated concentrations (i.e., > 30 μg/l) observed adjacent to the north-northeast wall of Building 322. TCE was also detected in groundwater samples collected from approximately 37 monitoring wells; with approximately 83 of the samples exceeding the NYSDEC Part 703 water quality standard of 5 μg/l. Particularly elevated concentrations (i.e., > 50 μg/l) of TCE were detected west of Building 322 (MW-768) north and south of Building 330 (MW-941 and 181, respectively) and north of Building 300 (MW- 959 and 960).

CDCE was detected in groundwater samples from 38 monitoring wells; primarily coincident with the presence of PCE and/or TCE. The highest concentrations detected were about 3,700 μg/l for MW- 768 west of Building 322, and 108,297,900 μg/l for MW-572 where separate phase DNAPL is present for 1994 data. For 1994 data, approximately 129 groundwater samples exceeded the NYSDEC Part 703 water quality standard for CDCE of 5 μg/l.

The detection of vinyl chloride was limited to an area bounded by the west wall of Building 322 and the north wall of Buildings 323 and 300, and to an area east-northeast of Building 330. The exception was one detection in monitoring well 931 south of Building 330. Groundwater samples exceeding the NYSDEC Part 703 water quality standard for vinyl chloride (2 μg/l) were collected from 6 monitoring wells located west of Building 322 and adjacent to the north wall of Building 323.

2.3.2 Metals and Other Inorganics

Inorganics specified as required monitoring parameters under Module III, include fluoride for both Building 322 and 330, and the metals arsenic and zinc for each of 322 and 330, respectively. Fluoride historically has been associated with industrial wastewater transmission and storage units, and at least sixteen of the SWMUs located in these AOCs.

Fluoride was detected in past groundwater sampling at concentrations ranging from 30 μg/l to 153,000 μg/l. Samples from six wells exhibit concentrations exceeding the NYSDEC Part 703 water quality standard of 1,500 μg/l. Five of the wells (MW-735, MW-740, MW-766, MW-767, and MW-793) are located adjacent to the west wall and northeast corner of Building 322. Only one location in the Building 330 area (MW-181) exhibited fluoride concentrations over NYSDEC Part 703 water quality standard.

Arsenic was detected in groundwater samples at concentrations ranging from 1 μg/l to 110 μg/l. Samples from five monitoring wells[17] exceeded the NYSDEC Part 703 water quality standard of 25 μg/l. With the exception of well MW-960 -- which is a bedrock well located adjacent to the northwest side of Building 300 -- the arsenic exceedances are located adjacent to the north end of Building 322.

Zinc was detected in groundwater with maximum concentrations for the Building 322 and 330 areas of 617 μg/l (MW-740) and 362,000 μg/l (MW-572), respectively. Samples collected from five wells[18] exhibited zinc concentrations exceeding the NYSDEC Part 703 water quality standard of 300 μg/l.

As outlined on Table 1A, ten other metals were detected in past Appendix 33 monitoring of a limited number of wells located immediately adjacent to and downgradient of Building 322. In aggregate, based on the present level of review, we do not believe that these data alone are indicative of conditions warranting corrective action. Barium, copper, chromium, nickel, and zinc were detected in most or all of the samples, but at concentrations well below drinking water standards or guidance values, and thus may represent natural background conditions. Antimony, beryllium, cadmium, selenium, and thallium were detected in single unfiltered or filtered samples at concentrations generally at or near method detection or practical quantification limits, and generally below regulatory standards. In two cases, lead was detected in two unfiltered samples (14 and 16 μg/l), but not the corresponding filtered sample. Cobalt was detected in samples from three locations at concentrations ranging from 50 to 260 μg/l.

The available laboratory data suggests that in some areas, the presence of VOCs in groundwater is accompanied by the presence of iron, manganese, and hardness at concentrations above what would be considered background. Although these conditions do not constitute a condition to drive further corrective action, precipitation and fouling of wells, pumps, and VOC treatment units will be a consideration in design of groundwater corrective measures for VOCs. The presence of iron above 2.5 mg/l would likely rule out direct surface discharge through a SPDES outfall. In the immediate vicinity of Building 322, iron and manganese have been detected in samples at up to 130 and nearly 20 mg/l, respectively; with hardness values exceeding 1,500 mg/l as compared to what appears to be a background of 200 to 500 mg/l. Further downgradient, the median concentrations are about 10, 1, and 700 mg/l, respectively for iron, manganese, and hardness. In the vicinity of Building 330, the

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[17] *Wells including (MW-960, MW-793, MW-767, MW-766, and MW-735)*

[18] *Wells including MW-572, MW-181, MW-957, MW-930, and MW-740)*

data reviewed to date suggest more modest levels of about 1 to 2 mg/l, generally less than 1 mg/l, and 500 to 600 mg/l respectively.

2.3.3 Semi-Volatile Organics

The June 1994 Appendix 33 monitoring information for the vicinity of Building 322 does not suggest a significant presence of Semi-Volatile Organic Compounds (SVOCs) in terms of areal distribution or concentration. Pesticides, herbicides, and PCBs were not detected. SVOCs were only detected in samples from monitoring wells immediately adjacent to Building 322 (MW-735, 766, and 767. These included several phenolics, benzyl alcohol, a dichlorobenzene, and a substituted toluene isomer. In general, the concentrations were at or near the method detection limits and substantially below regulatory standards. In aggregate, we do not believe that the presence of semi-volatiles alone in groundwater constitutes a condition warranting either corrective action, or would constitute a significant consideration in designing a remedial approach for VOCs.

2.4 Existing Groundwater Corrective Measures

IBM has been implementing groundwater corrective measures including collection, treatment and monitoring of VOC-containing groundwater. Active collection and treatment remediation is on-going in AOCs A, B, and D, and from the deep bedrock. The active extraction and treatment from deep bedrock is most relevant to the Building 322 and 330 AOCs in that the resultant cone of depression is acknowledged to contain contamination in bedrock from these and other areas of the facility.

As shown on Figure 2, and Figure 4A, groundwater is withdrawn from the deep bedrock via eight production wells. The water is treated via a central activated carbon system known as "Central Carbon" and used for on-site process and potable water supply needs. Central Carbon consists of an influent tank and four trains of activated carbon, each consisting of two 20,000 pound downflow contactors operated in series. Water is withdrawn continuously from production wells (PW) 2, 4, and 7, while wells 1, 5/5A, and 6 are pumped only as water demands require. PW-9 is an emergency backup.

As outlined in the Table[19] below and shown on Figure 4B, the operation of these production wells results in considerable removal of mass from the subsurface, and hydrodynamic containment.

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[19] Based on information provided by IBM Corporation as Appendix III-H of Module III.

Production Well No.	Average Withdrawal (gpm)	Median Concentrations (μg/l) **PCE/*TCE/dce/*freon tf**	Estimated Potential Mass Removal[20] (pounds per day,(gallons per year))
PW-1	250	**4**/*3*/0.6/0.2	$2.3\text{x}10^{-2}$,(0.7)
PW-2	190	**8,339**/*1,113*/*145*/*101*	22,(640)
PW-4	190	**117**/*2*/2/0.2	$6.9\text{x}10^{-3}$,(0.2)
PW-5	350	**3**/*<0.2*/<0.2/<0.2	$1.3\text{x}10^{-2}$,(0.4)
PW-6	60	**<0.2**/*<0.2*/<0.2/<0.2	NA
PW-7	70	**1,245**/*14*/11/0.6	1.1, (32)
PW-9	0	**0.2**/<0.2/<0.2/<0.2	NA

It is readily apparent that of the continuously pumped wells, PW-2 and PW-7 are the most productive in terms of mass removal. PW-2 is located approximately 750 feet northeast of Building 322, and adjacent to AOC-A. PW-7 is located about 500 feet south of Building 330C and about 700 feet west of the former landfill area.

The remaining groundwater treatment facilities are located remote from the Building 322 and 330 AOCs and would not be expected to influence groundwater quality conditions in these areas. Based on information included as Appendix III-H of the Module, a summary of basic information regarding these other areas is as follows:

Designation	Location and Description	Historical Operations	Estimated Mass Removal (pounds per day, (gallons per year))
Area A	Between Buildings 310 and 308. Groundwater is collected from the top of the silt/clay via perforated horizontal drains, and treated by air stripping prior to blending with industrial wastewaters and discharge to the sanitary sewer .	1 gpm of groundwater with about 14,300 μg/l VOCs, primarily PCE	0.2,(6)
Area B	Adjacent to IBM Gate 4. Extraction of groundwater from shallow bedrock using well 863, and treatment with GAC unit prior to discharge to a leachfield.	Average 1.6 gpm with about 5 μg/l PCE	$1\text{x}10^{-4}$,($1\text{x}10^{-3}$)

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[20] *Computed arbitrarily assuming an average chlorinated VOC specific gravity of 1.5.*

Designation	Location and Description	Historical Operations	Estimated Mass Removal (pounds per day, (gallons per year))
Area D	Adjacent to the sanitary wastewater treatment facility. Extraction of shallow groundwater from the shallow overburden via well GW-32 blending with sanitary and treated industrial waste.	Average flow of 5 gpm with 20 μg/l VOCs including DCE, PCE, and TCE	$1x10^{-3}$,($3x10^{-2}$)

The amount of mass removal from the shallow overburden and bedrock systems at Area B and D is negligible as compared to the removals at Area A and bedrock production wells PW-2 and PW-7. In general, the mass removals outlined above can be used as a "benchmark" of comparison in assessing the efficacy of future groundwater corrective measures.

3.0 PRE-RFI ASSESSMENT OF CORRECTIVE MEASURES TECHNOLOGIES

This section provides a summary of the pre-RFI assessment of corrective measures which has been conducted on the basis of our present assessment of relevant site conditions as previously outlined in Sections 1.0 through 2.0. Section 3.1 begins with a summary of our present opinions and conclusions regarding the "current situation" as related to the need for, and possible objectives of, further corrective measures. A discussion of potential corrective action goals/objectives is presented in Section 3.2. A summary of technologies that may be applicable to meet potential remedial objectives is outlined in Section 3.3. A preliminary screening of these technologies is included as Section 3.4.

As a preamble to this discussion it should be noted that, consistent with our charge -- to assess possible corrective measures technologies for groundwater media -- we have limited our focus to conditions existing within zones of saturation (i.e. VOCs as a solute and separate phase both in residual and free forms). A separate assessment focused on soil media is being prepared by others. It is acknowledged that some degree of overlap between these assessments may occur.

3.1 Pre-RFI Situation Assessment

On the basis of information obtained and reviewed as outlined above, our opinion remains that the only significant condition that would drive the need for additional groundwater corrective action is the subsurface presence of chlorinated VOCs (CVOCs) -- predominantly PCE and its breakdown products -- in both overburden and bedrock. In aggregate, the site-wide water quality data indicate the presence of DNAPL in overburden and bedrock that would remain a continued source of groundwater contamination for an interminable period.

Although other areas of the greater facility have already been shown to be release sources for CVOCS to the bedrock aquifer, the data suggest that the vicinities of Buildings 322 and 330 are possible or confirmed DNAPL entry locations. The presence of recoverable separate phase PCE in one well beneath Building 330 has been documented since 1994. Engineered separate phase recovery is being initiated at this location. Otherwise, specific DNAPL source zones in overburden and rock -- either in the form of free separate phase or residual separate phase -- have not been identified and mapped. Direct or indirect evidence of the presence of DNAPL such as dissolved phase concentrations approaching saturation, or the physical presence of separate phase product in wells has not be observed in the Building 322 area. Overburden DNAPL source zones may be identified via the RFI Soil Investigation planned for the Building 322 and 330 AOCs. The presence of structural features such as buildings and other components of existing operations will limit this work.

Although some form of soil remediation or near-source groundwater recovery for mass removal may be possible at identified DNAPL entry points, and removal of identified free separate phase DNAPL may be possible, substantially complete removal of DNAPL residual from the soil and rock is likely to be technically impracticable. Although we have not performed a rigorous assessment, we believe that the site clearly meets the intent of the TI Guidance in that restoration of groundwater to the standards outlined in Table III-9 of Module III will not be practicable due to the nature of fractured bedrock, and the limitations imposed by low permeability soils.

Historical groundwater monitoring has indicated the presence of several Appendix 33 metals and fluoride in more limited areas of the Building 322 and 330 AOCs, and overlapping areas of VOC contamination. In general, based on the relatively limited assessment completed to date, we believe that natural redox conditions likely limit the mobility of these metals at this site. In aggregate, we do not believe that the presence of metals or fluoride alone would constitute a condition that will drive further groundwater corrective action. This assertion is made in consideration of the overlapping distribution of metals and VOCs, and the apparent lack of sensitive human or environmental receptors. However, it should be recognized that the presence of these and other metals (e.g., calcium, iron, and manganese) is a technical consideration in the selection of groundwater treatment technologies, and that any extraction-based groundwater containment measure would intercept and remove these metallic constituents from the subsurface.

A perched overburden zone of saturation constitutes the "first water bearing zone" of saturation beneath Building 322 and a smaller portion of the Building 330 AOC. In general, horizontal groundwater flow in overburden within the area of investigation is inward towards the center of the site where groundwater levels are depressed due to on-site withdrawals. The possible exception is shallow groundwater flow at Building 322. Although the predominant horizontal groundwater flow direction is southerly towards the center of the site, the distribution of VOCs suggests a westerly component of transport toward the Gildersleeve Brook, possibly due to influences of subsurface utilities. Our present assessment does not suggest that VOCs have reached the brook via bulk groundwater flow other than perhaps at trace (<1 μg/l) concentrations. The future advance of the "plume" may be limited by vertical downward leakage and will be further assessed as a part of the groundwater RFIs.

In aggregate, we believe that under present site use conditions, there is little opportunity for human and biotic exposure to VOCs in groundwater. Nor do we see great potential for such exposure to occur under future conditions assuming that the groundwater withdrawals continue. In making these assertions, we assume that:

- Human exposure via drinking water at the facility is controlled by the activated carbon treatment presently in operation;
- The degree of containment afforded by existing groundwater withdrawals/corrective actions mitigates potential for off-site migration and potential human exposure via private or public drinking water supplies;
- The presence of VOCs, metals, and possibly other hazardous constituents in the soil and groundwater is a necessary consideration for future subsurface construction or maintenance work at the facility. Proper worker health and safety procedures and practices should mitigate potential short term exposures during such activities; and
- If the VOC plume west of Building 322 reaches the Gildersleeve Brook, human and biotic exposure via direct contact and incidental ingestion might be possible. However, loss of VOC mass would be expected due to the combined effects of volatilization, and adsorption onto natural organic matter.

A more rigorous assessment of possible pathways for human exposure will be performed during preparation of the groundwater RFI reports.

3.2 Potential Corrective Action Goals/Objectives

In consideration of the findings and conclusions of the Pre-RFI situation assessment as outlined above, we believe that goals for additional groundwater corrective action may be focused on:

- Containment -- should the results of additional hydrogeologic assessment indicate the need to protect potential human or biotic receptors at the Gildersleeve Brook or other exposure points; and

- Enhanced mass removal -- where site characterization information suggests the presence of source areas for groundwater contamination in the form of free or residual separate phase product.

In specific application to the site, corrective action goals could include containment of the apparent dissolved phase VOC plume extending westerly from Building 322 to the Gildersleeve Brook, and/or enhanced mass removal from the immediate vicinities of the Buildings where soil gas and groundwater quality data suggest the likely presence of DNAPL. Aggressive near source mass removal would likely reduce the amount of mass cycling through the hydrologic system, and the amount of groundwater to be pumped and treated under the present day containment groundwater corrective action. In a pragmatic sense, whether or not enhanced mass removal would materially decrease the amount of time that containment and treatment of groundwater from bedrock is necessary should be a design criterion/consideration.

3.3 Potential Corrective Action Technologies

A listing of technologies identified as potentially applicable to groundwater corrective measures at the IBM East Fishkill Facility is included on Table 2. These technologies were identified based on past experience on projects, supplemented by relevant technical literature by the EPA and others as referenced below.[21,22]

In general, the technologies were selected with site conditions and limitations in mind, consistent with the goals outlined above, and include:

- five technologies focused on containment of dissolved phase VOC plumes, including two extraction-based technologies that utilize hydrodynamic containment, two that involve insitu treatment, and one employing a low permeability barrier;

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[21] U.S. EPA, 1993, Proceedings of Seminar on Characterizing and Remediating Dense Nonaqueous Phase Liquids at Hazardous Sites, Presentation Outlines and Slide Copy, EPA Office of Research and Development, Cincinnati, OH 45268.

[22] U.S. EPA, 1991, Dense Nonaqueous Phase Liquids--A Workshop Summary, Dallas, Texas,, Kerr Environmental Research Laboratory, Ada OK.

- two technologies for treatment of VOC-containing aqueous streams through engineered unit operations; and

- four technologies selected with the goal of enhancing removal of VOC mass from the subsurface through addressing a VOC source area.

It is acknowledged that additional technologies beyond those listed above may have "potential" application for this site. In some cases additional technologies were not listed as they offered no additional advantage over those included on Table 2, with greater cost or implementability barriers.

The technologies for treatment of aqueous streams were limited to VOC technologies with the assumption that metallic species removed with the extracted water (i.e., iron, manganese and possibly lower concentrations of Appendix 33 metals) can be accommodated via the facility wastewater treatment unit, with or without pretreatment at the fluoride/heavy metals facility located in the Building 308/310 area and/or the industrial wastewater treatment facility located between Buildings 300 and 322. We believe that direct surface discharge of the VOC treated water may not be possible due to the presence of iron, and in some cases other metals. Containment/treatment alternatives that utilize trenches will not likely be applicable to bedrock.

3.4 Preliminary Screening of Corrective Action Technologies

As outlined on Table 2, we have completed a preliminary screening of corrective action technologies believed to have potential application to the Building 322 and 330 AOCs. The screening consisted of a comparison of the respective technologies with the primary remedy selection factors outlined by the NYSDEC in the Module III, Appendix III-C Guidance for a Corrective Measures Study. The factors assessed include:

- long and short term reliability in terms of risk reduction;

- reduction of mobility, toxicity, and volume (MTV); and

- implementability of construction, operations, and maintenance.

In general, for the site conditions identified to date, the most promising technology for either containment or mass removal is believed to be extraction using production wells. The presence of buildings and subsurface utilities, and the depth of contamination in rock likely would limit the use of recovery drains or low permeability barriers, and the presence of dissolved metals and hardness in groundwater would limit application of insitu treatment technologies.

Of the technologies considered for treatment of VOC-containing aqueous streams, we believe that activated carbon adsorption may be favorable considering the site history of success with this technology. However, if near source extraction is implemented near Building 322, the presence of iron and manganese at over 100 and 10 milligrams per liter, and hardness at about 1,500 mg/l may make air stripping via a diffused aeration unit a more suitable choice even if air controls are required to meet permitting requirements.

Of the mass removal techniques, recovery of DNAPL and high concentration dissolved phase in groundwater via extraction is believed to offer the most promise in that the target zone of extraction might include both rock and overburden, and the presence of site utilities may limit other extraction methodologies. The addition of steam flooding or chemically enhanced dissolution is worthy of additional consideration in that:

- the potential incremental risk of inducing vertical migration of DNAPL through further explorations and remediation is believed to be limited in that site data suggests that DNAPL has already penetrated into deep bedrock; and

- capture of VOC plumes in bedrock is demonstrated.

Perhaps enhancement of dissolution could be considered after conventional extraction is initiated and hydraulic capture is demonstrated to mitigate concerns about release of chemical agents (alcohols) to the subsurface and possible effects on the facility process and potable water supply from incomplete capture of the agents.

It is our opinion that given the nature of the contaminants of concern and site-specific conditions, that future assessment of additional groundwater corrective measures should be completed in consideration of:

- incremental reduction in potential for exposure of humans or biota via existing pathways; and/or

- incremental reduction in cleanup time through mass removal from the subsurface as compared to the present rate of removal via facility production wells.

For example, the 138 gallons of DNAPL removed from MW-572 in two days, represents a mass removal rate about three orders of magnitude greater than that via operation of recovery well PW-7 at 70 gpm. As such, the mass removal is equivalent to over four and one quarter years of PW-7 operation, at much lower cost. In contrast, the mass removal afforded by operation of the AOC-B treatment system is deminimis in terms of its effect on overall site remediation, and at much greater incremental cost.

Lacking some potential exposure to humans or biota, it should be recognized that continued monitoring without active remediation should be considered for situations that offer only deminimis mass removal. As such, the option for no further action with groundwater monitoring will be a consideration at the RFI and CMS phase.

4.0 CONCLUSIONS AND RECOMMENDATIONS

We have completed a Pre-RFI evaluation of groundwater corrective measure technologies, having performed technology screening at a degree of detail that we believe is commensurate with the large amount of site characterization data, and exceeding the Module III requirements for the Task II report. The scope of work included the development of a conceptual model of site conditions, preliminary assessment of pathways of human and/or environmental exposure, and a limited identification and screening of potentially applicable remedial technologies.

On the basis of the information reviewed and analyses completed as outlined in this report, it is concluded that goals for additional groundwater corrective action work at this site may be focused on:

- containment, if necessary, to block a possible exposure pathway at the Gildersleeve Brook west of Building 322; or
- enhancing mass removal at potential DNAPL source zones.

A number of technologies may be applied to meet the goals outlined above. Of the eleven groundwater corrective measures technologies identified by SHA, nine are believed to merit additional consideration at the corrective measures study phase. These include:

Containment Technologies:

- Extraction Wells
- Recovery Trench
- Low Permeability Barrier Wall

Aqueous Stream Treatment Technologies:

- Air Stripping
- Activated Carbon Adsorption

Mass Removal Technologies:

- Near Source Groundwater Extraction and Treatment
- DNAPL Product Extraction
- Chemically-Enhanced Dissolution
- Steam Flooding

It should be recognized that these technologies may be applicable alone or in combination.

The entire list, and additional technologies should be reassessed after completion of the groundwater RFIs and in consideration of the results of soil RFIs to be performed concurrently, and on-going technological advances.

The following subsections provide an overview of issues identified -- based on the level of assessment conducted to date -- as particularly pertinent to the RFIs for Buildings 322 and 330. Similarly, a summary of specific data/information required to select and/or design a remedial measure is provided as Table 3. It should be recognized that in the case of relatively experimental technologies such as chemically-enhanced dissolution, it is likely that much of the information would more appropriately be collected during feasibility studies conducted as a part of corrective measures evaluation work, or field-scale pilot studies conducted as design-support testing.

4.1 Building 322 Area of Concern

Issues of particular focus for the Building 322 RFI include:

- Assessing the rate of transport of VOCs toward the Gildersleeve Brook. Data reviewed as a part of this evaluation suggests that the plume has not reached the brook via bulk groundwater flow. Further advance may be limited by vertically downward leakage to bedrock and other removal mechanisms. If the plume has reached a pseudo steady state before reaching the brook, or the potential mass discharge to the brook is deminimis, we believe that near-source mass removal, or monitoring without active remediation would be warranted.

- Verifying the presence, concentration, and migration dynamics of Appendix 33 metals including arsenic, cadmium, chromium, cobalt, thallium, and zinc which were detected in a June 1994 sampling of wells immediately adjacent to Building 322, but not farther downgradient. We recommend completing at least one more round of sampling and analysis for these metals before completing the RFI.

Analysis of selected samples from the next monitoring round for total organic carbon (TOC), and chemical oxygen demand (COD) would provide additional information to base an assessment of alternatives for treatment of aqueous streams from this area via activated carbon or air stripping.

4.2 Building 330 Area of Concern

It is our opinion that issues of primary importance for the Building 330 RFI include:

- Assessing the relative contribution of the landfill area and Building 330 to the water quality conditions observed in this area. At this time, we anticipate utilizing groundwater levels and flow information along with organic and inorganic geochemistry to aid in fingerprinting the relative contribution of these apparently overlapping plumes.

- Further defining the apparent presence of free separate phase DNAPL in overburden and bedrock within the vicinity of Building 330.

IBM is intending to complete analysis for Appendix 33 constituents for a number of sampling locations proximate to Building 330. Concurrent analysis for TOC and COD will be performed to provide additional data to assess potential organic loading on carbon or other aqueous phase treatment units.

TABLES

TABLE 1.A
Summary of Organic Compounds and Metals Detected By Media/Sampling Location - Building 322

(Note: Key compounds are shown capitalized and embolded; routine monitoring parameters are shown as embolded.)

Compound/ Element	Soil Gas	Ground-water	Comments
Metals[1]			
Antimony			Not detected in past sampling except for a single unfiltered sample from MW-735 at the method detection limit of 4 μg/l.
ARSENIC		X	Detected in samples from three of eight wells tested for Appendix 33 Metals. The detections corresponded to wells immediately adjacent to Building 322. Arsenic was not detected in samples collected from five wells located between 100 and 200 feet further downgradient. Where detected, it was reported at concentrations ranging from about 25 μg/l for well 735, about 31 μg/l for well 766, and up to 41 μg/l for well 767. These values compare with the NYSDEC Part 703 Standard of 25 μg/l.
Barium		X	Detected in all eight samples at concentrations ranging from 30 μg/l to 140 μg/l as compared to the Federal MCL of 2,000 μg/l. Believed to be naturally occurring.
Beryllium			Apparently only detected in a single unfiltered sample from MW-735 at a concentration of 5 μg/l as compared to the method detection limit of 3 μg/l and the NYSDEC Part 703 Standard of 3 μg/l.
Cadmium		X	Detected in a single unfiltered sample and filtered sample of groundwater collected from MW-740 at 15 and 10 μg/l, respectively, as compared to the NYSDEC Part 703 Standard of 10 μg/l and method detection limit of 2 μg/l.
Chromium		X	Detected in unfiltered and filtered samples collected from five of eight wells at concentrations below the NYSDEC Part 703 Standard of 50 μg/l
Cobalt		X	Detected in filtered and unfiltered samples from wells 735, 766, and 767 at concentrations between 50 μg/l and 260 μg/l. No NYSDEC or Federal MCL for Cobalt.
Copper		X	Detected in groundwater samples from all eight wells at concentrations ranging from 14 to 101 μg/l for filtered and unfiltered samples as compared to a Federal MCL Goal of 1,300 μg/l at a tap and the NYSDEC Part 703 Standard of 200 μg/l.
Lead		X	Detected in three of eight samples (735, 767, and 793) at concentrations of 14 and 16 μg/l for filtered samples and 1, <1, and 2 μg/l for filtered samples.
Mercury			Not detected in past monitoring.
Nickel		X	Detected in all samples subjected to Appendix 33 analyses at concentrations ranging from 20 μg/l to 460 μg/l as compared to a RCRA Subpart S Action Level of 700 μg/l.
Selenium			Reported as detected in one unfiltered sample from MW-768 at the method detection limit of 2 μg/l, but not in the filtered sample.
Silver			Not detected in past monitoring.
Thallium		X	Detected in one filtered and unfiltered sample from MW-735 at 6 and 4 μg/l, respectively as compared to a Federal MCL of 2 μg/l and the NYSDEC Part 703 Standard of 4μg/l.
Vanadium		X	Detected only in one unfiltered and filtered sample from MW-735 at 22 and 7 μg/l, respectively, as compared to method detection limit of 3 μg/l.
Zinc		X	Detected in filtered and unfiltered samples at concentrations ranging from 8 to 127 μg/l.

TABLE 1.A
Summary of Organic Compounds and Metals Detected By Media/Sampling Location - Building 322

Compound/ Element	Soil Gas	Ground-water	Comments
Miscellaneous Inorganic Ions --cyanide and fluoride[2]			
FLUORIDE		x	A routine monitoring parameter for Building 322 under Module III. Detected in unfiltered samples at concentrations ranging from 153 mg/l to 0.03 mg/l in past sampling of wells adjacent to Building 322. These values compare with the NYSDEC Part 703 Standard of 1,500 μg/l.
Total Cyanide		x	Detected in five of eight samples at concentrations of 3 to 9 μg/l as compared to the NYSDEC Part 703 Standard of 100μg/l.
Volatile Organic Compounds[3]			
Bromochloromethane		x	
Bromomethane		x	
Carbon Tetrachloride			
Chloroethane		x	
Chloromethane		x	
Dibromomethane		x	
Dichlorodifluoromethane		x	Detected in past monitoring of well no. 68 at concentrations above the NYSDEC Part 703 Standard.
1,1-Dichloroethane		x	Detected in one sample from well 68 at a concentration of 0.21 μg/l compared with the NYSDEC Part 703 Standard of 5 μg/l. 1,1-DCA is also a degradation product of TCA and/or 1,2-DCA.
1,2-Dichloroethane		x	Detected in one sample from well 767 at a concentration of 0.28 μg/l. This concentration compares to a Federal MCL of 5 μg/l. 1,2-DCA is also a degradation product of 1,1,2-TCA.
1,1-Dichloroethene		x	A routine monitoring parameter for Building 322 under Module III. Detected in two samples from wells (747 and 68) at concentrations of 0.1 and 0.01 μg/l respectively. These values compare with the NYSDEC Part 703 Standard of 5 μg/l. 1,1-DCE is used in adhesives and is a degradation product of TCE and 1,1,1,2-TECA.
CIS-1,2-DICHLOROETHENE	x	x	Elevated soil gas concentrations detected adjacent to the west wall of Building 322 with the maximum concentration (85 μg/l) detected near well 766 and SWMUs 3093 and 208. Detected in groundwater samples collected from 20 wells and ranging in concentration from 3,700 μg/l for well 768 to 0.02 μg/l in well 755. These values compare with the NYSDEC Part 703 Standard of 5 μg/l and a Federal MCL of 70 μg/l. This compound is used as an industrial solvent, in dye extraction, and is a degradation product of TCE and/or 1,1,1,2-TECA.
trans-1,2-Dichloroethene		x	Detected in groundwater samples from 15 wells ranging in concentration from 17 μg/l for well 768 to 0.01 μg/l for well 789. These values compare with the NYSDEC Part 703 Standard of 5 μg/l and a Federal MCL of 100 μg/l. This compound is used as an industrial solvent, in dye extraction, and is a degradation product of TCE.
1,2-Dichloropropane			

TABLE 1.A
Summary of Organic Compounds and Metals Detected By Media/Sampling Location - Building 322

Compound/ Element	Soil Gas	Ground-water	Comments
1,3-Dichloropropane			
2,2-Dichloropropane			
1,1-Dichloropropene			
cis-1,3-Dichloropropene			
trans-1,3-Dichloropropene			
Methylene Chloride		x	
1,1,1,2-Tetrachloroethane		x	Detected in well 767, west of Building 322 at a concentration of 56 μg/l and for well 947 at a concentration of 5 μg/l. These values compare with the NYSDEC Part 703 Standard of 5 μg/l and a Federal Lifetime Health Advisory of 70 μg/l. This compound is used an industrial solvent, degreaser and is a degradation product of Pentachloroethane.
1,1,2,2-TETRACHLOROETHENE(PCE)	x	x	Detected at 0.01 to 3 μg/l in soil gas collected adjacent to the west and northeast walls of Building 322 and along the north wall of Building 300 near SWMUs 60 and 3246. Detected in soil gas at elevated concentrations (up to 28 μg/l) in samples collected to the north-northeast of Building 322. Detected in groundwater samples from 27 wells at concentrations ranging from 579 μg/l in well 768, west of Building 322, to 0.01 μg/l in well 772. These values compare with the NYSDEC Part 703 Standard and Federal MCL of 5 μg/l, and a solubility in water of 200 mg/l.
1,1,1-Trichloroethane		x	Detected in samples from 10 wells at concentrations ranging from 5 to 0.01 μg/l. These values compare with the NYSDEC Part 703 Standard of 5μg/l and a Federal MCL of 200 μg/l. 1,1,1-TCA is a common degreaser, solvent and a degradation product of 1,1,1,2-TECA.
1,1,2-Trichloroethane			Not detected in any samples.
TRICHLOROETHENE	x	x	Detected at low concentrations (0.01 to 1 μg/l) in soil gas collected adjacent to the west and east of Building 322 and along the north wall of Building 300 near wells 959 and 960. Detected in soil gas concentrations (up to 38 μg/l) in samples collected to the north-northeast of Building 322. Detected in 20 wells at concentrations ranging from 1,251 to 0.01 μg/l. These values compare with the Module III and Federal MCL concentration limit of 5 μg/l and a solubility in water of 1,100 mg/l. Highest concentrations (> 5 μg/l) detected north and west of Building 322 and adjacent to the north wall of Building 300.
Trichlorofluoromethane		x	
1,2,3-Trichloropropane			
VINYL CHLORIDE		x	Detected in samples from 9 wells ranging in concentration from 248 to 0.07 μg/l. These values compare with the NYSDEC Part 703 Standard of 5 μg/l and a Federal MCL of 2 μg/l. Highest concentrations (> 5 μg/l) were detected west of Building 322 and north of Buildings 323 and 300. Vinyl Chloride is a degradation product of 1,1,2-TCA; cis-1,2-DCE; trans-1,2-DCE; and 1,1-DCE.
Benzene		x	
Bromobenzene		x	
n-Butylbenzene		x	

TABLE 1.A
Summary of Organic Compounds and Metals Detected
By Media/Sampling Location - Building 322

Compound/ Element	Soil Gas	Ground-water	Comments
sec-Butylbenzene		x	
tert-Butylbenzene			
chlorobenzene		x	
2-Chlorotoluene		x	
4-Chlorotoluene			
1,2-Dichlorobenzene		x	
1,3-Dichlorobenzene		x	
1,4-Dichlorobenzene		x	
Ethylbenzene		x	
Hexachlorobutadiene		x	
Isopropylbenzene		x	
p-Isopropyltoluene			
n-Propylbenzene		x	
Naphthalene			
Styrene			
Toluene		x	
1,2,3-Trichlorobenzene		x	
1,2,4-Trimethylbenzene		x	
1,3,5-Trimethylbenzene		x	
m&p-Xylene		x	

TABLE 1.A
Summary of Organic Compounds and Metals Detected By Media/Sampling Location - Building 322

Compound/ Element	Soil Gas	Ground- water	Comments
o-Xylene		x	
Bromodichloromethane			
Bromoform		x	
Chloroform			
Dibromochloromethane		x	
FREON TF		x	Detected in samples from 29 wells ranging in concentration from 848 to 0.02 μg/l. These values compare to the NYSDEC Part 703 Standard of 5 μg/l. Freon TF (trichlorotrifluoroethane) is used as a refrigerant and a drying agent.
Tetrahydrofuran		x	
Acetone		x	
2-Chloroethylvinyl Ether			
1,2-Dibromomethane			
1,2-Dibromo-3-Chloropro			
Freon 123A		x	Detected in samples from 15 wells at concentrations ranging from 187 to 0.06 μg/l.
Methyl-tert-Butyl Ether		x	
C_1-C_3 (Methane through butane)	x		Elevated soil gas concentrations detected on the west and north sides of Building 322 with the maximum (86 mg/l) detected near monitoring well 766.
THC (Total Hydrocarbons)	x		Maximum soil gas concentrations (15 to 60 μg/l) were detected near the Building 322 - 320B walkway. Trace levels were detected adjacent to the west wall of Building 322.
Semi-Volatile Organic Compounds[4]			
2,4- dimethylphenol		x	Acid extractable, commonly associated with soluble oils. Trace detection in groundwater sample from MW-767 at 3 μg/l.
acetophenone		x	Trace detection in one sample from well 767 (3 μg/l J).
benzyl alcohol		x	Trace detection in one sample from monitoring well 735 at (2 μg/l J).
4,6,-dinitro-2-methyl phenol		x	Trace detection (0.1 μg/l) reported for one sample from well 767.

TABLE 1.A
Summary of Organic Compounds and Metals Detected By Media/Sampling Location - Building 322

Compound/ Element	Soil Gas	Ground-water	Comments
bis(2-Ethylhexyl)phthalate		x	Trace detection in three of nine samples at concentrations of 1, 1, and 2 μg/l. For samples from wells 766 was detected in a duplicate but not the original sample. A plasticizer and common laboratory contaminant.
1,2-dichlorobenzene		x	Common component of degreasing solvents. Detected in groundwater samples from wells 735 located adjacent to the northeast corner of building 322 and from downgradient wells 766 and 767 at concentrations ranging from 2 μg/l to 65 μg/l.
2,6-dinitrotoluene		x	Detected in one sample from monitoring well 766 at 6 μg/l.
Pesticides and Polychlorinated Biphenyls (EPA 8080) and Herbicides (EPA 8150)[5]			
HSL Pesticides, Herbicides and PCB Isomers			None detected. Pesticides are not and have not been used in manufacturing processes at this facility.

Notes:

1. For building 322, the Module III requires monitoring for Arsenic only as a routine parameter. SHA's assessment of other metals is based on results of a June 1994 Appendix 33 sampling of eight monitoring wells located immediately adjacent to and downgradient of the building. The results discussed in the table are as reported by the IBM Environmental Service Laboratory.

2. For Building 322, the Module III requires monitoring for Fluoride only. The discussion centered on this parameter is based on SHA's limited review of quarterly monitoring data collected for 1994 and 1995. The discussion for Cyanide is based on a review of results for a June 1994 Appendix 33 sampling of eight monitoring wells located immediately adjacent to and downgradient of the building. The results discussed in the table are as reported by the IBM Environmental Service Laboratory.

3. Volatile Organic data reviewed by SHA includes quarterly groundwater sampling results for 1994. Data was provided by IBM in a database format (GWORG.EXE) which includes the monitoring wells listed in Module III. Soil gas data was obtained from a report prepared by Tracer Research Corp. entitled " Shallow Soil Gas Investigation - IBM East Fishkill Facility, Hopewell Junction, New York" dated November 1989.

4. Semi-Volatile data reviewed by SHA includes data from a June 1994 "Appendix 33" sampling of eight monitoring wells located immediately adjacent to and downgradient of Building 322. Specifically the sampling round included monitoring wells 735, 740, 766, 767, 768, 769, 772, and 793. The samples were analyzed by Envirotest Labs, Inc. of Newburgh, New York. The results were reported in accordance with NYSDEC ASP Category B reporting requirements. In general, these wells are located where the volatile organic concentrations are the highest. Because many of the semi-volatiles are believed to be associated with the presence of solvents, results for samples from these wells are believed to represent " worst-case" locations where concentrations would be the highest.

5. Pesticide and PCB data reviewed by SHA includes data from a June 1994 "Appendix 33" sampling of eight monitoring wells located immediately adjacent to and downgradient of Building 322. Specifically the sampling round included monitoring wells 735, 740, 742, 766, 767, 768, 769, 772, and 793. The samples were analyzed by Envirotest Labs, Inc. of Newburgh, New York. The results were reported in accordance with NYSDEC ASP Category B reporting requirements.

TABLE 1.B
Summary of Organic Compounds and Metals Detected By Media/Sampling Location - Building 330

Note: Key compounds shown as capitalized and embolded; routine monitoring parameters shown as embolded.

Compound/ Element	Soil Gas	Ground-water	Comments
Metals[1]			
Arsenic		x	Trace levels (3 to 8 μg/l) detected in samples from 12 wells located northeast, south and east of Building 330. The detected concentrations compare with the NYSDEC Part 703 Standard of 25 μg/l.
Chromium		x	Not detected in any filtered samples. Detected in unfiltered samples collected from wells located east, southeast and northwest of Building 330 at concentrations of 2 to 23 μg/l. These concentrations compare to a Federal MCL of 100 μg/l and the NYSDEC Part 703 Standard of 50 μg/l.
ZINC		x	Detected in samples from four monitoring wells (572, 181, 957 and 930) at concentrations exceeding the Module III concentration limit for zinc (300 μg/l). Detected concentrations ranged from 362,000 to 2 μg/l compared to a Federal SMCL of 5 mg/l and the NYSDEC Part 703 Standard of 300 μg/l.
Miscellaneous Inorganic Ions --cyanide and fluoride[2]			
FLUORIDE		x	Detected at concentrations ranging from 2,990 μg/l to 30 μg/l in samples collected from wells surrounding Building 330. A maximum concentration (2,990 μg/l) was detected in well 181. These values compare with the NYSDEC Part 703 Standard of 1,500 μg/l.
Total Cyanide		x	Detected in one sample from MW-966 at a trace concentration of 3 μg/l compared to the NYSDEC Part 703 Standard of 100 μg/l and a Federal MCL of 200 μg/l.
Volatile Organic Compounds[3]			
Bromochloromethane		x	
Bromomethane		x	
Carbon Tetrachloride			
Chloroethane		x	
Chloromethane		x	
Dibromomethane		x	
Dichlorodifluoromethane		x	
1,1-Dichloroethane		x	Detected in samples from nine wells located south and west of Building 330 at concentrations ranging from 0.01 μg/l (931) to 0.70 μg/l (923). These values compare to the NYSDEC Part 703 Standard of 5 μg/l. 1,1-DCA is also a degradation product of TCA and/or 1,2-DCA.

TABLE 1.B
Summary of Organic Compounds and Metals Detected
By Media/Sampling Location - Building 330

Compound/ Element	Soil Gas	Ground-water	Comments
1,2-Dichloroethane		x	Detected in samples from two wells, 923 and 921, at concentrations of 0.04 μg/l and 0.01 μg/l, respectively. These concentrations compare to the NYSDEC Part 703 Standard of 5 μg/l. Used as an industrial solvent and degreaser, 1,2-DCA is also a degradation product of 1,1,2-TCA.
1,1-Dichloroethene		x	Detected in samples from six wells at concentrations ranging from 0.92 to 0.01 μg/l. These values compare to a Federal MCL of 7 μg/l. 1,1-DCE is used in adhesives and is a natural degradation product of TCE and 1,1,1,2-TECA.
CIS-1,2-DICHLOROETHENE	x	x	Trace levels (0.1 to 1 μg/l) detected in soil gas collected near monitoring wells 928 and 929 (in the vicinity of SWMUs 88 and 89) and near SWMUs 3109, and 3102. Detected in groundwater samples from 17 wells ranging in concentration from non aqueous phase liquid (>800,000 μg/l) in well 572 to 0.02 μg/l in well 576. These values compare with the NYSDEC Part 703 Standard of 5 μg/l and a Federal MCL of 70 μg/l. This compound is a degradation product of TCE and 1,1,1,2-TECA.
trans-1,2-Dichloroethene		x	Detected in groundwater samples from 21 wells ranging in concentration from 98.70 μg/l in well 574 to 0.01 μg/l in well 931. These values compare with the NYSDEC Part 703 Standard of 5μg/l. This compound is used as an industrial solvent, in dye extraction, and is a natural degradation product of TCE.
1,2-Dichloropropane			
1,3-Dichloropropane			
2,2-Dichloropropane			
1,1-Dichloropropene			
cis-1,3-Dichloropropene		x	
trans-1,3-Dichloropropene			
Methylene Chloride		x	
1,1,1,2-Tetrachloroethane			
1,1,2,2-TETRACHLOROETHENE (PCE)	x	x	Elevated concentrations (up to 220 μg/l) were detected in soil gas collected near monitoring wells 928 and 929 (in the vicinity of SWMUs 88 and 89). Trace levels (0.01 to 1 μg/l) were detected in soil gas collected in the general vicinity of Building 338. Detected in groundwater samples from 24 wells at concentrations ranging from non-aqueous phase liquid (< 200 mg/l) in well 572, inside Building 330D, to 0.02 μg/l in well 59, west of Building 330D. These values compare with the NYSDEC Part 703 Standard and Federal MCL of 5 μg/l, and an aqueous solubility of 200 mg/l.
1,1,1-Trichloroethane		x	Detected in samples from 9 wells at concentrations ranging from 5 to 0.02 μg/l. These values compare with the NYSDEC Part 703 Standard of 5 μg/l and a Federal MCL of 200 μg/l. 1,1,1-TCA is a common degreaser, solvent and a natural degradation product of 1,1,1,2-TECA.
1,1,2-Trichloroethane			

TABLE 1.B
Summary of Organic Compounds and Metals Detected
By Media/Sampling Location - Building 330

Compound/ Element	Soil Gas	Ground-water	Comments
TRICHLOROETHENE	x	x	Trace concentrations (0.1 to 1 μg/l) were detected in soil gas collected near monitoring wells 928 and 929 (in the vicinity of SWMUs 88 and 89). Detected in 17 wells at concentrations ranging from non-aqueous phase liquid (> 1,100 mg/l) to 0.02 μg/l. These values compare with the NYSDEC Part 703 Standard and Federal MCL concentration limit of 5 μg/l.
Trichlorofluoromethane		x	
1,2,3-Trichloropropane		x	
VINYL CHLORIDE		x	Detected in samples from 8 wells ranging in concentration from 0.90 to 0.03 μg/l. These values compare with the NYSDEC Part 703 Standard of 2 μg/l. Vinyl Chloride is a natural degradation product of 1,1,2-TCA; cis-1,2-DCE; tans-1,2-DCE; and 1,1-DCE.
Benzene		x	
Bromobenzene			
n-Butylbenzene		x	
sec-Butylbenzene		x	
tert-Butylbenzene		x	
chlorobenzene		x	
2-Chlorotoluene		x	
4-Chlorotoluene			
1,2-Dichlorobenzene		x	
1,3-Dichlorobenzene		x	
1,4-Dichlorobenzene		x	
Ethylbenzene		x	
Hexachlorobutadiene		x	

TABLE 1.B
Summary of Organic Compounds and Metals Detected By Media/Sampling Location - Building 330

Compound/ Element	Soil Gas	Ground-water	Comments
Isopropylbenzene		x	
p-Isopropyltoluene		x	
n-Propylbenzene			
Naphthalene		x	
Styrene		x	
Toluene		x	
1,2,3-Trichlorobenzene		x	
1,2,4-Trimethylbenzene		x	
1,3,5-Trimethylbenzene		x	
m&p-Xylene		x	
o-Xylene		x	
Bromodichloromethane		x	
Bromoform			
Chloroform		x	
Dibromochloromethane			
FREON TF		x	Detected in samples from 18 wells at concentrations ranging from 719 to 0.01 µg/l. These values compare with the NYSDEC Part 703 Standard of 5 µg/l. Freon TF (trichlorotrifluoroethane) is used as a refrigerant and drying agent.
Tetrahydrofuran		x	
Acetone		x	

TABLE 1.B
Summary of Organic Compounds and Metals Detected By Media/Sampling Location - Building 330

Compound/ Element	Soil Gas	Ground-water	Comments
2-Chloroethylvinyl Ether			
1,2-Dibromomethane			
1,2-Dibromo-3-Chloropro		x	
Freon 123A		x	Detected in samples from 14 wells at a concentration range of 12 to 0.05 µg/l. These values compare with the NYSDEC Part 703 Standard of 5 µg/l.
Methyl-tert-Butyl Ether		x	
C_1-C_3 (methane through butane)	x		2 to 7 µg/l detected in soil gas collected from the east and south sides of Building 330.
THC (Total Hydrocarbons)	x		0.1 to 7 µg/l detected in soil gas collected from the east and south sides of Building 330.
Semi-Volatile Organic Compounds[4]			
Pesticides and Polychlorinated Biphenyls and Herbicides[4]			

Notes:

1. SHA reviewed metals data for 1994 and the 1st quarter of 1995. Data was provided by IBM in a database format (NEWINORG.EXE) which includes the monitoring wells listed in Module III.

2. For Building 322, the Module III requires monitoring for Fluoride only the discussion centered on this parameter is based on SHA's limited review of quarterly monitoring data collected for 1994 and 1995. The discussion for Cyanide is based on a review of results for a June 1994 Appendix 33 sampling of nine monitoring wells located immediately adjacent to and downgradient of the building. The results discussed in the table are as reported by the IBM Environmental Service Laboratory.

3. SHA reviewed volatile organic data for 1994 and the 1st quarter of 1995. Data was provided by IBM in a database format (GWORG.EXE) which includes the monitoring wells listed in Module III. Soil gas data obtained from a report prepared by Tracer Research Corp. entitled "Shallow Soil Gas Investigation - IBM East Fishkill Facility, Hopewell Junction, New York" dated November 1989.

4. Data on semi-volatiles, pesticides and PCBs was not available at the time of SHA's review.

TABLE 2
Identification and Preliminary Screening of Groundwater Corrective Action Technologies
Pre-RFI Corrective Measures Evaluation
Building 322 and 330 AOCs

Technology /Method	Process Description	Effectiveness/Advantages/ Limitations	Possible Site Application	Preliminary Screening Factors				Comments/*Additional Information Required?*
				Long-Term Reliability-Effectiveness	Reduction of MTV	Short Term Effectiveness	Implementability	
CONTAINMENT TECHNOLOGIES - goal of containing contaminated groundwater, limiting migration at the front of an existing plume to block a potential exposure pathway								
Extraction Wells	Hydrodynamic containment via pumping from drilled production wells to treatment at an engineered treatment unit.	Conventional technology may be more applicable at this site due to the prevalence of underground utilities which would limit the use of trenches. Can be used for both overburden and bedrock. May require a relatively large number of wells to achieve capture under shallow unconfined flow conditions such as the perched condition near Buildings 322 and 330. Possible vacuum enhancement to increase capture of individual wells.	Containment of VOC plume in the shallow unconfined perched water table downgradient of Building 322 should the need arise to intercept the plume before the Gildersleeve Brook.	Will likely require operation for tens of years and have no effect on the need for bedrock containment.	Yes, reduce mobility.	Properly engineered system could be implemented in less than one year including permitting, quickly blocking pathway.	Uses conventional water well technology.	Retain for further consideration; *Need to assess the rate of plume advance toward, Gildersleeve Brook, the only readily apparent location where additional containment may be necessary under present day site operations.*
Recovery Trench	Use of an engineered underdrain trench to provide hydrodynamic containment of contaminated groundwater.	Conventional technology, can be more passive recovery as compared to wells if geologic conditions allow. Most applicable for shallow water table conditions (<25 feet deep). As a general rule of thumb, should be installed parallel to groundwater contours, in this case could limit applicability due to presence of underground utilities running perpendicular.	Recovery of groundwater from shallow perched system, specific application not identified.	Will likely require operation for tens of years, and will have no effect on need for bedrock containment.	Yes, reduce mobility.	Same as above.	Uses conventional technology.	No specific application identified, not ruled out.
Insitu Treatment Wall	A permeable flow-through wall constructed with granulated zero- valent metals (typically Fe, Zn, Al) shown to abiotically dehalogenate CVOCs.	Passive treatment technology that could represent lower O&M costs, generates no aqueous stream, and without inter-media transfers. Laboratory and field experiments have demonstrated 90% removal of TCE and PCE. May not treat to drinking water standards due in part to incomplete dehalogenation of breakdown products such as C-1,2-DCE.	Insitu treatment of shallow groundwater transport toward Gildersleeve Brook at leading edge of the plume.	Unknown, experimental infant technology with no long term experience. Ineffective for treatment of non-halogenated VOCs.	Potentially reductions in mobility and toxicity through permanent destruction.	Would need extensive laboratory and field pilot testing to demonstrate applicability.	Presence of utility trenches, buildings may limit applicability. Presence of metals, fluoride, alkaline groundwater conditions may limit treatment or reduce permeability of treatment zone over time.	Although an exciting and promising technology for treatment of plumes limited to halogenated VOCs, site constraints such as utilities and other cultural features, non-applicability to bedrock, and the presence of reduced metallic species, pose significant limitations to its application.
Insitu Aeration Wall	A permeable flow-through wall equipped with injection and extraction points/lines to inject air below the water table, and recover vapor from unsaturated zone.	Properly applied for an ideal site should be as effective as air stripping for VOC removal, can be hydraulically complex to maintain flow-through condition. Precipitation of metals from solution would likely clog the trench with time.	No specific application identified.	Relatively experimental technology in similar application. Not as reliable as extraction based technologies.	May reduce mobility does not reduce toxicity or volume.	NA	Presence of iron, manganese, hardness in groundwater and underground utilities/buildings is a limitation to application in the vicinity of Building 322.	Eliminate from further consideration unless area of VOCS is found coincident w/ low iron, manganese, and hardness.

TABLE 2
Identification and Preliminary Screening of Groundwater Corrective Action Technologies
Pre-RFI Corrective Measures Evaluation
Building 322 and 330 AOCs

Technology /Method	Process Description	Effectiveness/Advantages/ Limitations	Possible Site Application	Preliminary Screening Factors				Comments/*Additional Information Required?*
				Long-Term Reliability-Effectiveness	Reduction of MTV	Short Term Effectiveness	Implementability	
Low Permeability Barrier Wall	Use of a low permeability wall (i.e. slurry wall, grout curtain, sheet piling etc.) to impede lateral migration.	Could be used in conjunction with wells or trenches to reduce the amount of water withdrawn, or to enhance dewatering exposing DNAPL-containing soils to Soil Vapor Extraction. Can be used to divert groundwater around source zone. No advantage over wells for containment. Where practicable should be keyed into low permeability soils. Presence of site utility trenches and buildings would limit applicability. Not applicable for bedrock.	None specifically identified for containment goal; Possible use in near-source containment if soil source is identified near Bld 322 where silt clay soils exist. Less applicable to vicinity of Building 330 where contiguous silt/clay soil confining layer is absent.	Long-term integrity of soil-based barriers to chlorinated solvents unknown. May reduce long term O&M costs of extraction-based containment.	Reduce mobility.	NA	Relatively conventional technology. Would require excavations with depths of 15 to 25 feet. Subsurface utilities would limit applicability.	Further consideration for possible near-source application. Complete encapsulation of source zone likely not possible due to structural features and downward vertical gradients.
GROUNDWATER TREATMENT TECHNOLOGIES - Potentially applicable for treatment of VOC containing aqueous streams generated by pumping for containment or mass removal purposes								
Air Stripping	Removal of VOCs from aqueous stream via contact with air, facilitating partitioning into gas phase. Three most common designs include packed tower, tray aeration, and diffused aeration.	Considering capital and long term operations and maintenance, represents the least expensive means of removing VOCs from aqueous streams, assuming no air controls are required. Presence of high concentrations of iron and other reduced metals, high alkalinity likely would favor the use of diffused aeration unit which is less susceptible to fouling. Past application of air stripping at this site has shown operational difficulties associated with calcium carbonate precipitation in treatment unit packing material.	Treatment of aqueous streams generated from groundwater withdrawals conducted for containment or mass recovery objectives. At this time the most likely application would be treatment of groundwater extracted to contain the perched water table plume downgradient of Building 322.	Proven technology; reliable if supported by a maintenance program.	Reduce VOC mass in subsurface. VOCs transferred to the air stream unless air controls are applied.	NA	Presence of Appendix 33 metal and /or high concentrations of iron and manganese may necessitate further treatment before discharge. Options for further treatment may include discharge directly to the Facility Wastewater Treatment unit, or to metals pretreatment via the facility Industrial Wastewater Treatment Facility.	Further consideration for application if mass discharges do not necessitate air controls. *Need to assess potential mass loadings for specific application against air discharge requirements, and assess the need for further treatment for metals which may include iron, manganese, arsenic, zinc, and others depending on point of extraction.*

TABLE 2
Identification and Preliminary Screening of Groundwater Corrective Action Technologies
Pre-RFI Corrective Measures Evaluation
Building 322 and 330 AOCs

Technology /Method	**Process Description**	**Effectiveness/Advantages/ Limitations**	**Possible Site Application**	**Preliminary Screening Factors**				**Comments/*Additional Information Required?***
				Long-Term Reliability-Effectiveness	**Reduction of MTV**	**Short Term Effectiveness**	**Implementability**	
Activated Carbon Adsorption	Removal of VOCs from aqueous stream via adsorption on granular activated carbon.	Typically much higher O&M costs as compared to air stripping. Site experience with carbon treatment is good however, the presence of high metals concentrations is a consideration in the design of a carbon system.	Treatment of aqueous streams generated from additional groundwater withdrawals conducted for containment or mass recovery objectives.	Proven technology, reliable with proper O&M.	Remove mass without inter-media transfer.	Good.	Presence of metals may necessitate further treatment prior to discharge. Discharge options same as air stripping.	May be the most favorable option, given site history of success with carbon treatment. *Need to assess potential volumetric and mass loading and possible implications of metals on carbon life. Possible short or long term field scale treatability test warranted. Data on Total Organic Carbon in groundwater would be useful in assessing carbon life.*
MASS REMOVAL TECHNOLOGIES - applications to more aggressively promote removal of VOC mass from the subsurface via removal of DNAPL or near source groundwater extraction and treatment								
Near Source GW Extraction and Treatment	Groundwater extraction from at or near identified source areas where the plume is narrow and concentrations are high , resulting in greater mass removal per gallon treated than groundwater containment conducted primarily to contain the leading edge of a plume. Can be used in conjunction with water flooding, chemically- or thermally-enhanced dissolution, and/or with SVE to expose more soil to air flow.	Can reduce quantity of groundwater pumped and treated and achieve containment. Removal of DNAPL product may occur at same time if present. Could be combined with a low permeability barrier to limit mixing of clean water. Presence of elevated metals concentrations near the source may increase maintenance needs, and increase likelihood of metals treatment and residuals disposal. In many cases like Building 322, the near source extraction would not contain the leading edge of the plume which would be expected to dissipate with time.	Extraction from overburden in the vicinity of MW-735 and the south limit of Building 322. Extraction from overburden and/or bedrock near Building 330.	More mass removal over time and assuming containment, allow water bearing unit downgradient to cleanup through natural flushing. Enhanced mass removal may shorten, albeit by a small amount, the duration of bedrock containment pumping.	Reduces mobility and volume of groundwater requiring treatment.	In the case of Building 322, near- source extraction would not alone halt or contain the leading edge of the plume in perched unit.	Conventional technology using wells, likely to require metals treatment/treatment for fluoride.	Retain for further consideration. *Need to assess potential volumetric and mass loading for VOC treatment units, assess capacity of existing sanitary and/or Industrial Wastewater System to accept metals discharge. Verify presence and concentration of metals including As, Cd, Cr, Co, Pb, Vn in Building 322 vicinity.*

TABLE 2
Identification and Preliminary Screening of Groundwater Corrective Action Technologies
Pre-RFI Corrective Measures Evaluation
Building 322 and 330 AOCs

Technology /Method	Process Description	Effectiveness/Advantages/ Limitations	Possible Site Application	Preliminary Screening Factors				Comments/*Additional Information Required?*
				Long-Term Reliability-Effectiveness	Reduction of MTV	Short Term Effectiveness	Implementability	
DNAPL Product Extraction	Removal of mobile DNAPL by pumping from wells or drains placed in areas where product has been identified. Can be combined with near-source groundwater extraction and/or water flooding to "hydraulically manipulate" DNAPL by locally increasing fluid gradients.	Effective mass removal as compared to aqueous phase pumping. Possible vacuum enhancement to increase gradients on DNAPL to improve hydraulic control. Identification of DNAPL zones is often difficult. Can increase extent of contamination by drawing DNAPL over larger geologic surface area. Separate recovery of DNAPL and water is difficult in most cases necessitating total fluids pumping and gravity separation before treatment of the aqueous stream.	Removal of DNAPL from vicinity of overburden monitoring well MW 572; vicinity of bedrock monitoring well MW-574 also highly suspect.	Effective as mass removal compared to present bedrock containment. Will not result in complete removal of VOC mass from subsurface.	Reduces mobility by removing mobile DNAPL, reduces volume of groundwater.	Highly effective mass removal over short term.	Presence of building elements existing operations increases effort, to define DNAPL limits and conduct remedial operations. Explorations may increase downward penetration of DNAPL.	Retain for further consideration where DNAPL is found. *Additional explorations and testing near west end of Building 330 C and adjacent to the building proximate to 572 are warranted to better define the presence of DNAPL.*
Chemically Enhanced Dissolution	Removal of residual and free separate phase DNAPL from source zone through increased mobility as DNAPL and increase solubility through injection of surfactants, or cosolvents (alcohols) and extraction.	Lower number of pore volume exchanges to remove significant quantities of DNAPL. Risk of remobilizing downward movement of DNAPL. Hydraulic delivery of chemicals and recovery of solute made more difficult by low permeability soils and fractured rock. A technology in R&D stage. Treatment needs of extracted fluid needs to be assessed on a case by case basis depending CVOC species.	Removal of DNAPL from a well-defined overburden or bedrock source.	May greatly enhance mass removal as compared to present bedrock containment system.	Reduce volume/ mass of VOCs.	May be most effective in short run; Would require significant, preferably small-scale, field pilot testing.	Presence of building elements may limit delivery of chemical agents to source zone. Possible effects on existing potable and process water system is a major concern.	Retain for further consideration. *Assess possible implications on process and potable water system if introduced to production well location.*
Steam Flooding	Use of high temperature water to increase volatilization and dissolution of DNAPL	Lower number of pore volume exchanges to remove significant quantities of DNAPL; Risk of remobilizing downward movement of DNAPL. Hydraulic delivery made more difficult by low permeability soils and fractured rock. A technology in research and development stage. Less concern about treatability issues as compared to chemical enhancements.	Removal of DNAPL where risk of remobilization, addition of additional chemicals is limited.	May greatly enhance mass removal in short run but would likely not diminish the need for containment in the long run.	Reduce volume/mass of VOCs in subsurface.	May be most effective in sort run.	Presence of building elements may limit delivery of high-temperature fluid to source zone.	Retain for further consideration if well defined low risk source zone is identified.

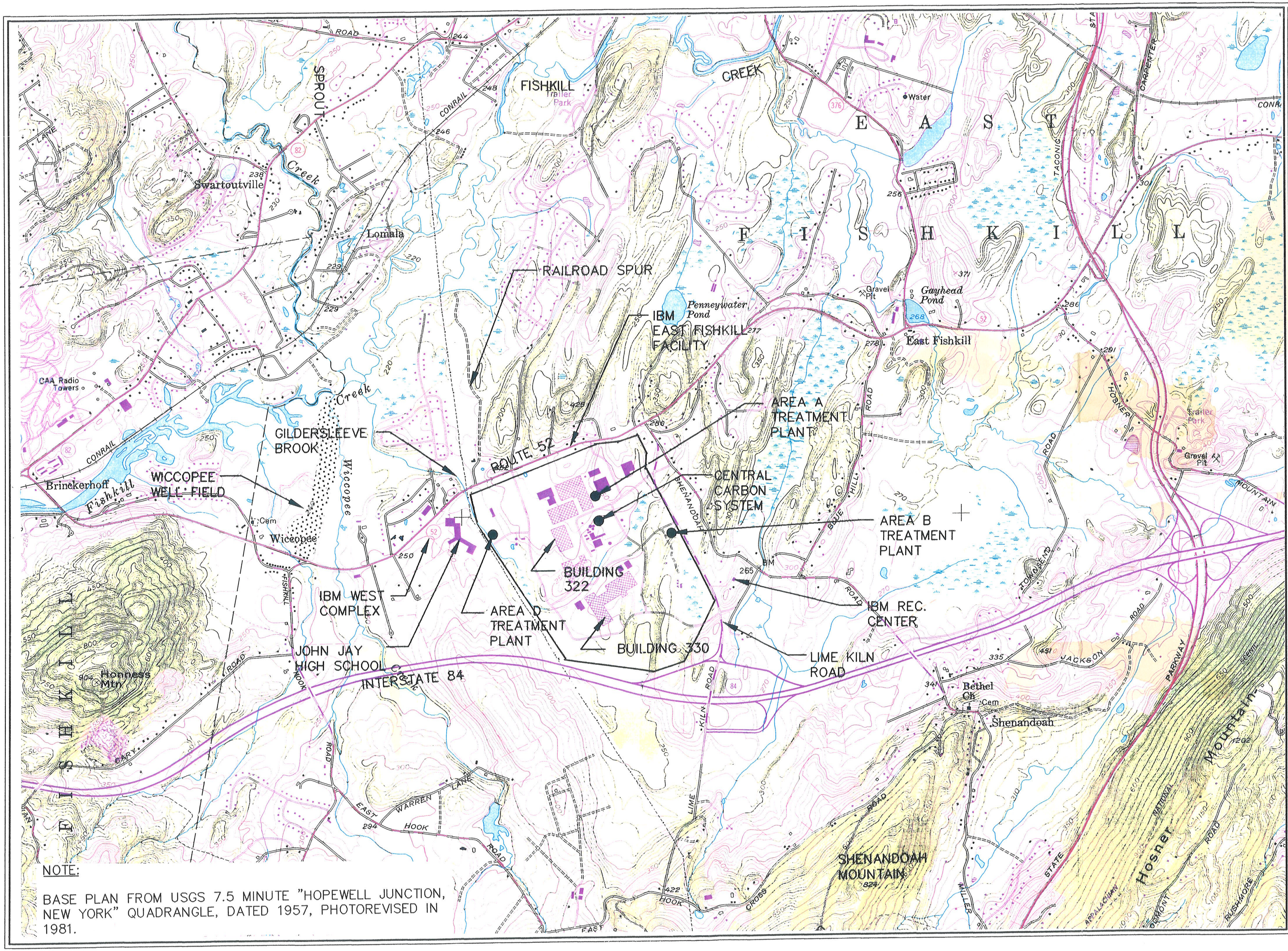
TABLE 3
Technologies for Further Consideration -- Summary of Information Objectives/Data Needs
Pre-RFI Corrective Measures Evaluation
Building 322 and 330 AOCs

Technology Class/ Technology	**Information Objectives/*Data Required***
Containment Technologies	
Extraction Wells and Trenches	Building 322 - Assessment of the rate and flux of VOCs toward Gildersleeve Brook using existing data and mapping of utilities in conjunction with hydraulic structures assessment; Verify presence, concentration, and migration dynamics of certain Appendix 33 metals. Building 330 - Additional definition of groundwater levels and flow interaction/paths between bedrock and overburden ,and vertical and horizontal distribution of VOCs in groundwater particularly on the downgradient side of the building to the north, northwest, and west. >a more detailed investigation of localized bedrock morphology is warranted as related to groundwater flow and transport; >estimates of groundwater flux and mass loading for extraction;
Low Permeability Barrier Wall	No specific possible application identified. Need to identify subsurface conditions conducive to technology, specifically an area relatively free of utilities underlain by a shallow confining layer; *assess subsurface stratigraphy as appropriate and groundwater chemistry to assess compatibility of construction materials with types and concentrations of compounds.*
Aqueous Stream Treatment Technologies	
Air Stripping Activated Carbon Adsorption	Estimates of potential withdrawal rates and mass loading--*Data regarding TOC and COD concentrations to aid in assessing alternatives for treatment of aqueous streams, verify the presence or absence of commonly used alcohols, ketones, or other organics with low aqueous phase volatility (limited air stripping potential)* For given scenarios assess possible volumetric and mass loading for metals against need for metals pretreatment and available capacity of fluoride/heavy metals treatment facility, industrial wastewater treatment facility, wastewater treatment plant. For situations involving high iron and hardness, possibly pilot treatability testing with carbon or diffused aeration unit would be warranted at the CMS phase.

TABLE 3
Technologies for Further Consideration -- Summary of Information Objectives/Data Needs
Pre-RFI Corrective Measures Evaluation
Building 322 and 330 AOCs

Technology Class/ Technology	**Information Objectives/*Data Required***
Mass Removal Technologies	
Near-Source Groundwater Extraction and Treatment	Building 330 - as noted under containment --further definition of "hotspot" areas with particularly elevated (>1 mg/l) VOC concentrations. Assessment of hydraulic interaction of bedrock and overburden. Assessment of localized hydraulic properties of bedrock and overburden; hydraulic response under withdrawal conditions.
DNAPL Product Extraction	Further definition of bedrock morphology as related to possible DNAPL migration. Further definition of the existence of free separate phase DNAPL directly through well installations and sounding, and indirectly through groundwater dissolved phase and soil evidence. Collection and testing to verify physical properties of in-place separate phase DNAPL; Assessment of matrix properties of soil and rock as related to retention and transmission of DNAPL including but not necessarily limited to matrix (primary) porosity, bulk density, fraction of organic carbon.
Chemically-Enhanced Dissolution	Experimental infant technology which would require significant pilot testing as a part of the CMS and implementation phase. As a part of RFI phase further definition (horizontally and vertically) of apparent hot spot areas is believed to be warranted. Further definition of hydraulic parameters as related to chemical delivery would be necessary. Like DNAPL recovery, assessment can be through direct observation of free separate phase DNAPL but also indirect inference based on aqueous phase and soils data. CMS phase would likely include the assessment of ternary phase relationships for site-specific DNAPL and candidate alcohols, as well as assessment of treatability of the resultant solution.
Steam Flooding	Experimental infant technology which would require significant pilot testing as a part of the CMS and implementation phase. As a part of RFI phase further definition (horizontally and vertically) of apparent hot spot areas is believed to be warranted. Further definition of hydraulic parameters as related to fluid delivery would be necessary.

FIGURES



NOTE:

BASE PLAN FROM USGS 7.5 MINUTE "HOPEWELL JUNCTION, NEW YORK" QUADRANGLE, DATED 1957, PHOTOREVISED IN 1981.

SCALE
0 1000 2000 4000
1 INCH = 2000 FEET

Sanborn, Head & Associates
Consulting Engineers & Scientists

DRAWN BY: MRP
DESIGNED BY: RCW
CHECKED BY: RCW
REVIEWED BY: DBC
PROJECT MGR: MFD
PIC: CLH
DATE: JAN 96

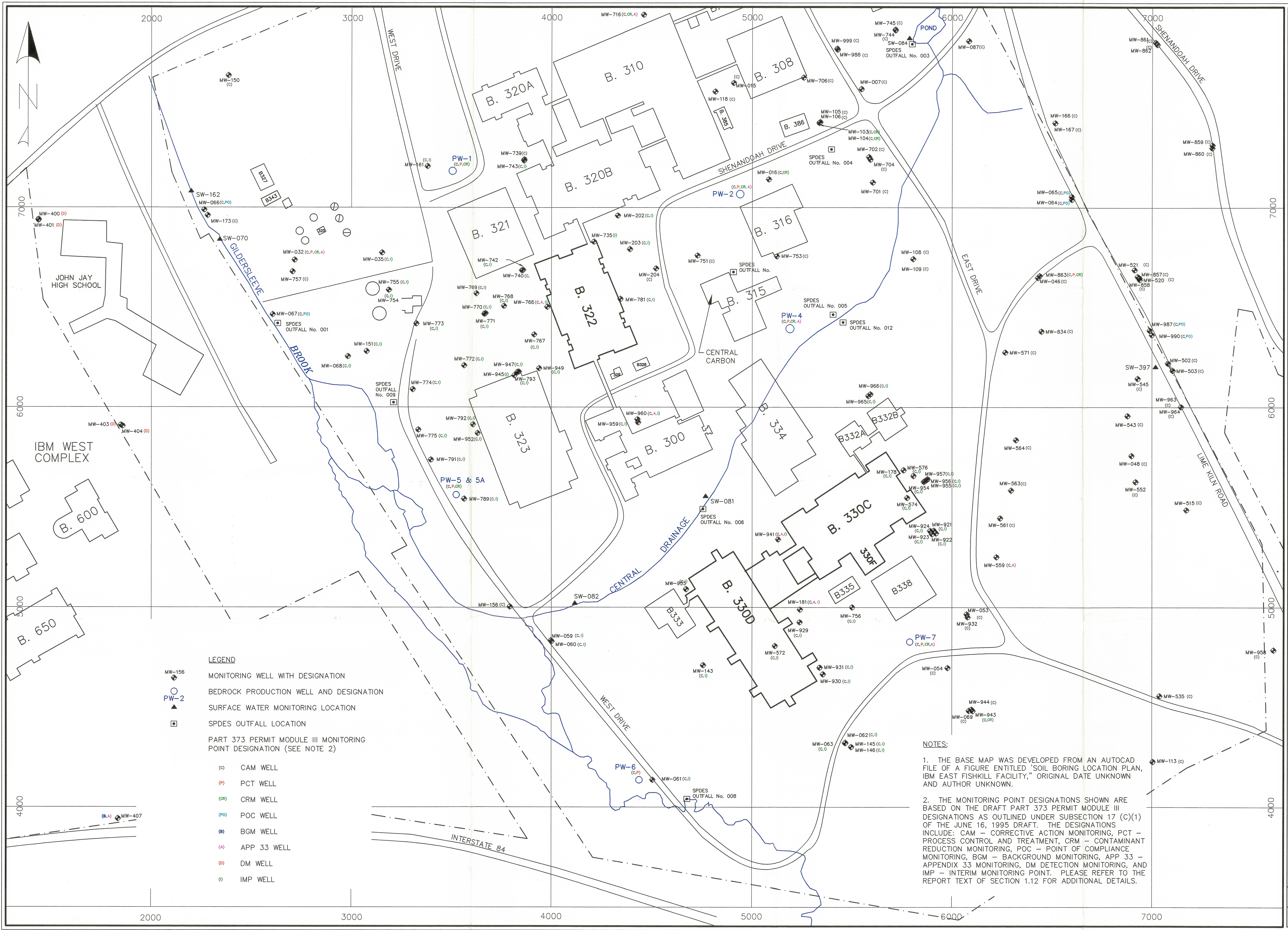
IBM EAST FISHKILL FACILITY
EAST FISHKILL, NEW YORK

PRE-INVESTIGATION EVALUATION OF CORRECTIVE MEASURES
LOCUS PLAN

PROJECT NUMBER:
1176

FIGURE NUMBER:
1

PLOT DATE: 01-04-96



NOTES:

1. THE BASE MAP WAS DEVELOPED FROM AN AUTOCAD FILE OF A FIGURE ENTITLED "SOIL BORING LOCATION PLAN, IBM EAST FISHKILL FACILITY," ORIGINAL DATE UNKNOWN AND AUTHOR UNKNOWN.

2. THE MONITORING POINT DESIGNATIONS SHOWN ARE BASED ON THE DRAFT PART 373 PERMIT MODULE III DESIGNATIONS AS OUTLINED UNDER SUBSECTION 17 (C)(1) OF THE JUNE 16, 1995 DRAFT. THE DESIGNATIONS INCLUDE: CAM – CORRECTIVE ACTION MONITORING, PCT – PROCESS CONTROL AND TREATMENT, CRM – CONTAMINANT REDUCTION MONITORING, POC – POINT OF COMPLIANCE MONITORING, BGM – BACKGROUND MONITORING, APP 33 – APPENDIX 33 MONITORING, DM DETECTION MONITORING, AND IMP – INTERIM MONITORING POINT. PLEASE REFER TO THE REPORT TEXT OF SECTION 1.12 FOR ADDITIONAL DETAILS.

NO.	DATE	DESCRIPTION	BY

SCALE 200 100 0 200 400

1 INCH = 200 FEET

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DESIGNED BY: MRP
CHECKED BY: RCW
REVIEWED BY: DBC
PROJECT MGR: MFD
PIC: CLH
DATE: JAN 96

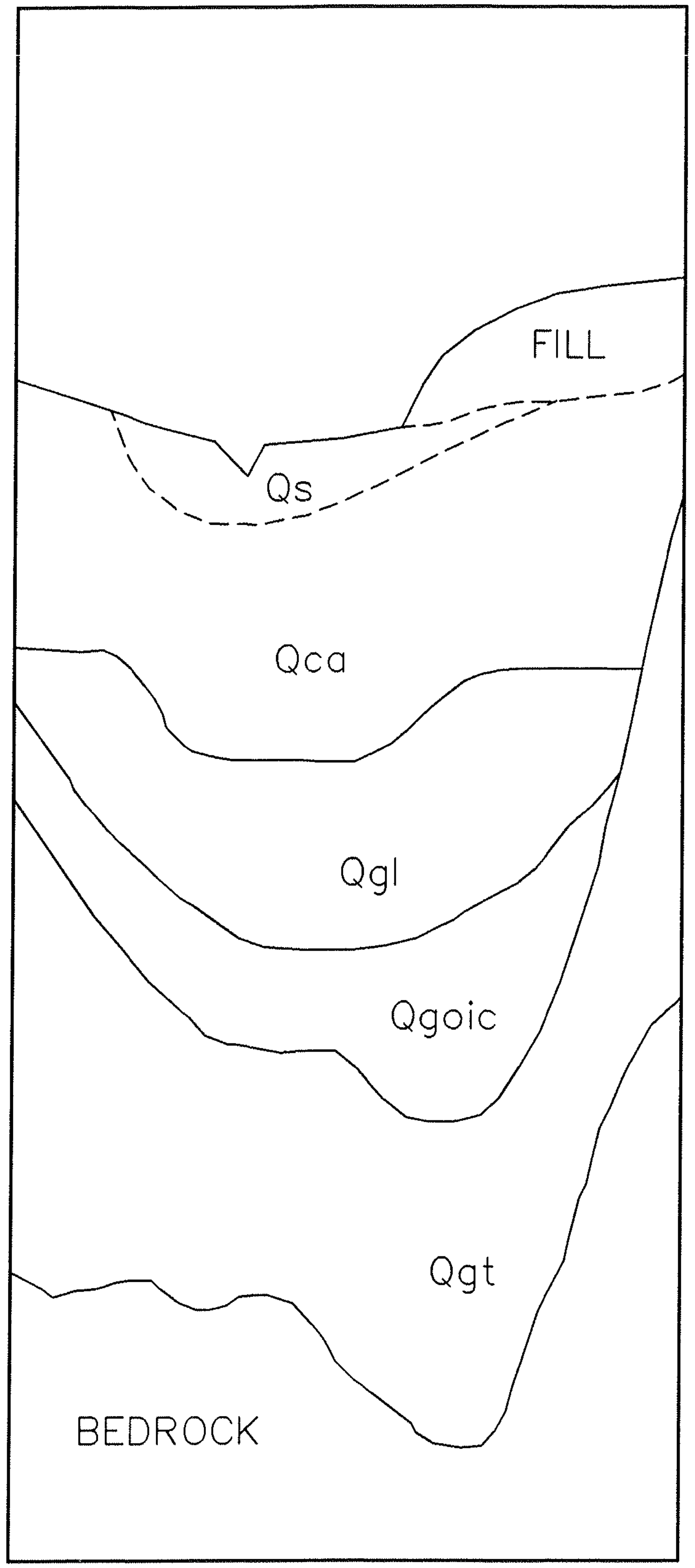
IBM EAST FISHKILL FACILITY
EAST FISHKILL, NEW YORK

PRE-INVESTIGATION EVALUATION OF CORRECTIVE MEASURES LOCATION PLAN

PROJECT NUMBER: 1176

FIGURE NUMBER: 2

GENERALIZED STATIGRAPHIC COLUMN



GEOLOGIC STRATA	DESCRIPTION	INFERRED DEPOSITIONAL SETTING
Post-glacial Deposits **(Fill)** Soil Fill	Mixture of sand and gravel with lesser amounts of silt/clay and/or cobbles/boulders. Organic material and miscellaneous debris also present in a few locations.	Deposits placed during site development.
(Qca) Recent Colluvium	Sand and gravel, sand and silt, or silt with fragments of gravel.	Deposits composed of reworked glacial deposits which developed due to post-glacial erosion and/or slump/debris flow.
(Qca) Recent Alluvium	Silty sand and sandy-silt deposits with lesser amounts of gravel and clay.	Deposited on flood plains and stream beds by post-glacial streams.
(Qs) Swamp Deposits	Peat, organic silt mixed with clay, silt, and fine sand.	Composed of sediments and organic material that accumulated in depressions or poorly-drained areas.
(Qgl) Glaciolacustrine Deposits	Silt, clay, sand, and minor amounts of gravel. Commonly well-stratified, and may be rhythmically bedded.	Composed of sediments that accumulated on the floor of a glacial lake. Coarser-grained deposits typically along glacial lake margins.
(Qgoic) Glacial Outwash and Ice-Contact Deposits (ablation till and related glaciofluvial sediments)	Sand and gravel with lesser amounts of silt and variable amounts of cobbles and boulders. Generally less dense than lodgement till (see below). Poorly- to well-sorted and locally stratified.	Deposited by meltwater streams in front of a receding ice margin and adjacent to stagnant glacial ice.
(Qgt) Basal or Lodgement Till	Generally dense to very dense, heterogeneous mixture of clay, silt, sand, and gravel with cobbles and boulders.	Deposited directly by glacial ice.
Bedrock (mapped as consisting of the Pine Plains Formation of the Lower Paleozoic carbonate rocks of the Wappinger Group).	Dolostone interbedded with lesser (generally <10%) amounts of shale, siltstone, and sandstone. Localized oolitic beds and brecciated dolostone zones identified in some rock cores.	

NOTE:

THIS STRATIGRAPHIC PROFILE IS INTENDED TO PRESENT A GENERALIZED DIVISION OF GEOLOGIC STRATUM AT THE IBM EAST FISHKILL FACILITY, CONSISTENT WITH AVAILABLE INFORMATION. DESCRIPTIONS OF EACH STRATA HAVE BEEN GENERALIZED BASED UPON A REVIEW OF A LIMITED NUMBER OF BORING LOGS AND GEOLOGIC CROSS SECTIONS CONSTRUCTED BY OTHERS. ACTUAL CHARACTERISTICS OF EACH STRATUM TYPE ARE EXPECTED TO BE MORE COMPLEX THAN DESCRIBED ABOVE. TRANSITIONS BETWEEN DIFFERENT STRATA ARE ALSO EXPECTED TO BE MORE GRADUAL AND COMPLEX THAN SHOWN.

SCALE
NOT TO SCALE

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DESIGNED BY: RCW
CHECKED BY: RCW
REVIEWED BY: DBC
PROJECT MGR: MFD
PIC: CLH
DATE: JAN 96

IBM EAST FISHKILL FACILITY
EAST FISHKILL, NEW YORK

PRE-INVESTIGATION EVALUATION OF CORRECTIVE MEASURES
GENERALIZED STRATIGRAPHIC SEQUENCE

PROJECT NUMBER:
1176
FIGURE NUMBER:
3

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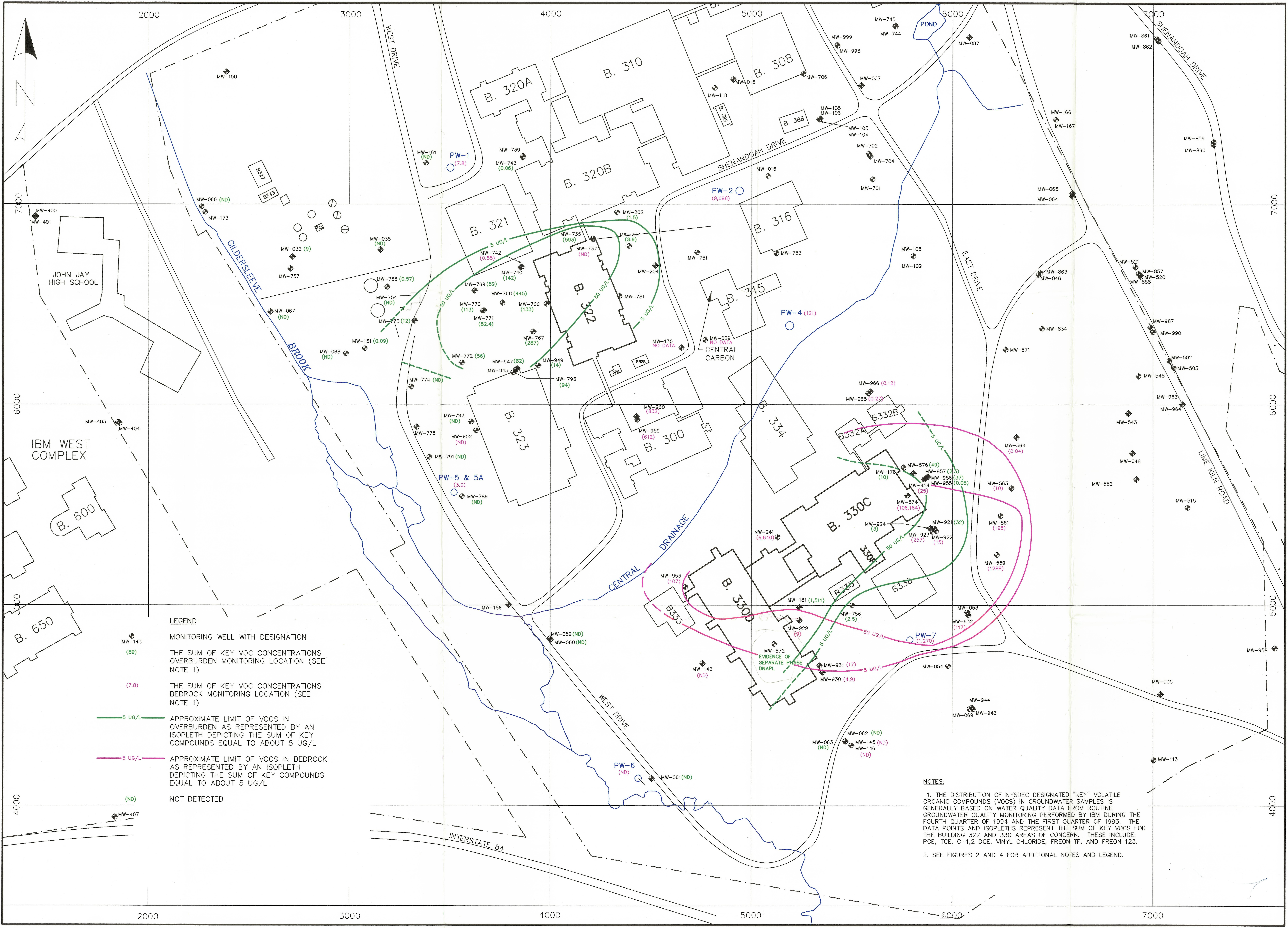
PLOT VIEW: SHEET1-PLOT: PLOT SCALE: 1=1
PLOT DATE: 01-04-96

NOTE: Figure 4 missing from original document



LEGEND

MW-143	MONITORING WELL WITH DESIGNATION
(89)	THE SUM OF KEY VOC CONCENTRATIONS OVERBURDEN MONITORING LOCATION (SEE NOTE 1)
(7.8)	THE SUM OF KEY VOC CONCENTRATIONS BEDROCK MONITORING LOCATION (SEE NOTE 1)
5 UG/L	APPROXIMATE LIMIT OF VOCS IN OVERBURDEN AS REPRESENTED BY AN ISOPLETH DEPICTING THE SUM OF KEY COMPOUNDS EQUAL TO ABOUT 5 UG/L
5 UG/L	APPROXIMATE LIMIT OF VOCS IN BEDROCK AS REPRESENTED BY AN ISOPLETH DEPICTING THE SUM OF KEY COMPOUNDS EQUAL TO ABOUT 5 UG/L
(ND)	NOT DETECTED

NOTES:

1. THE DISTRIBUTION OF NYSDEC DESIGNATED "KEY" VOLATILE ORGANIC COMPOUNDS (VOCS) IN GROUNDWATER SAMPLES IS GENERALLY BASED ON WATER QUALITY DATA FROM ROUTINE GROUNDWATER QUALITY MONITORING PERFORMED BY IBM DURING THE FOURTH QUARTER OF 1994 AND THE FIRST QUARTER OF 1995. THE DATA POINTS AND ISOPLETHS REPRESENT THE SUM OF KEY VOCS FOR THE BUILDING 322 AND 330 AREAS OF CONCERN. THESE INCLUDE: PCE, TCE, C-1,2 DCE, VINYL CHLORIDE, FREON TF, AND FREON 123.

2. SEE FIGURES 2 AND 4 FOR ADDITIONAL NOTES AND LEGEND.

NO.	DATE	DESCRIPTION	BY

SCALE
200 100 0 200 400
1 INCH = 200 FEET

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REVIEWED BY: DBC
PROJECT MGR: MFD
PIC: CLH
DATE: JAN 96

IBM EAST FISHKILL FACILITY
EAST FISHKILL, NEW YORK

PRE-INVESTIGATION EVALUATION OF CORRECTIVE MEASURES SUMMARY OF GROUNDWATER QUALITY

PROJECT NUMBER:
1176

FIGURE NUMBER:
5

APPENDIX A
LIMITATIONS

1. The conclusions and recommendations described in this report are based in part on the data obtained from a limited number of soil samples from widely spaced subsurface explorations observed and logged by others. The nature and extent of variations between these explorations may not become evident until further investigation or remediation. If variations or other latent conditions then appear evident, it will be necessary to re-evaluate the recommendations of this report.

2. The generalized soil profile described in the text is intended to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized and have been developed by interpretations of widely spaced explorations and samples; actual soil transitions are probably more gradual.

3. Water level measurements have been recorded by others in monitoring wells and other observation points at times and under conditions stated within the text of the report and indicated on the exploration logs and in the report. SHA has not conducted an independent review of the reliability of these data. Note that fluctuations in the level of the groundwater may occur due to variations in rainfall and other factors not evident at the time measurements were made.

4. Quantitative laboratory testing was performed by others as part of the investigation as noted within the report. Where such analyses have been conducted by an outside laboratory, SHA has relied upon the data provided, and has not conducted an independent evaluation of the reliability of these data.

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

6. The VOC concentration isopleths shown on Figure 5 were inferred based on the data provided using generally accepted professional practices and are based on limited information obtained from widely spaced data points. They are intended to depict inferred water quality conditions at a given period of time, consistent with available information. The actual conditions will vary from that shown both spatially and temporally. Other interpretations are possible.

7. This report has been prepared for the exclusive use of the IBM Corporation for specific application for the RCRA Facility Investigations of the IBM East Fishkill facility in

accordance with generally accepted hydrogeologic practices. No other warranty, express or implied, is made.

8. The analyses and recommendations contained in this report are based on the data obtained from subsurface explorations coordinated, observed, and logged by others. The explorations indicate subsurface conditions only at the specific locations and times, and only to the depths penetrated. They do not necessarily reflect strata variations that may exist between such locations. The validity of the recommendations is based in part on assumptions SHA has made about conditions at the site. Such assumptions may be confirmed only during remediation. If subsurface conditions different from those described become evident, the recommendations in this report must be re-evaluated.

9. In the event that any changes in the nature, design, or location of the facilities are planned, the conclusions and recommendations contained in this report should not be considered valid unless the changes are reviewed and conclusions of this report modified or verified in writing by SHA. SHA is not responsible for any claims, damages, or liability associated with interpretation of subsurface data or re-use of the subsurface data or engineering analyses without the express written authorization of SHA.