# SITE INVESTIGATION WORK PLAN
# AUGUST 1997

## TAYLOR INSTRUMENTS SITE
## 95 AMES STREET
## ROCHESTER, NEW YORK

*Prepared for:*

Combustion Engineering, Inc.
Norwalk, Connecticut

*Prepared by:*

ABB Environmental Services, Inc.
Portland, Maine

August 14, 1997
(Revision of April 1997 Work Plan)

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Confidential Settlement Communication

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**ABB Environmental Services, Inc.**

ASEA BROWN BOVERI

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# Voluntary Site Investigation
# Site Investigation Work Plan

## Table of Contents

**Section** **Title** **Page No.**

**Voluntary Site Investigation**
**Site Investigation Work Plan**

## Table of Contents

# 1.0 INTRODUCTION

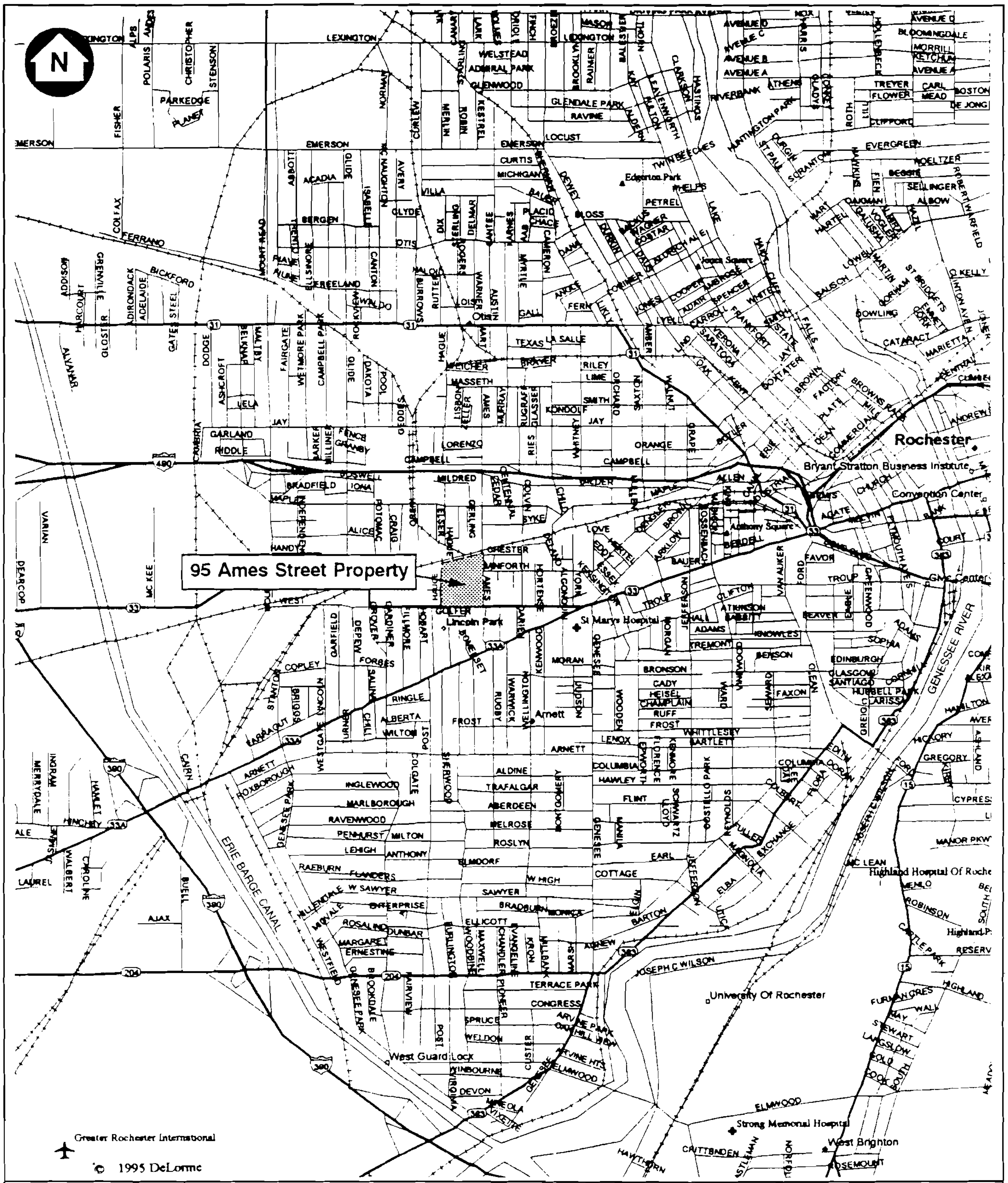
ABB Environmental Services (ABB-ES), at the request of Combustion Engineering, Inc. (CE) has prepared this Work Plan for additional investigations at the former Taylor Instruments facility at 95 Ames Street (Taylor Instrument site), Rochester, Monroe County, New York (Figure 1-1). The Work Plan summarizes previous investigations performed at the Taylor Instrument site and presents the technical approach, rationale, and methodologies for additional investigations. The major tasks presented in this Work Plan are:

- air and soil sampling to evaluate emissions of volatile mercury from site soils,
- soil gas sampling to determine the presence of VOCs in shallow soils at selected onsite and off-site locations,
- soil and groundwater sampling to provide correlative data at select soil gas sampling locations and further evaluate on-site soils
- groundwater sampling to evaluate shallow onsite overburden and bedrock water quality,
- sampling to determine levels of mercury and VOCs in on-site and off-site sewers.

These tasks will address data needs requested by and discussed with the New York State Department of Environmental Conservation (NYSDEC), the New York and Monroe County Departments of Health and Monroe County Pure Waters. Combined with information supplied by previous investigations, data generated by work described herein will provide the basis to allow development of on-site and off-site clean-up goals pursuant to the terms of the Voluntary Cleanup Agreement (VCA) between Combustion Engineering and the NYSDEC, to which this Work Plan is an Attachment. The work will also allow the opportunity for the NYSDEC to collect split samples for its own confirmatory analysis

This Work Plan is organized as follows.

- Section 2 presents current site understanding including previous investigation activities and discussion of results of the 1996 Site Investigation,
- Section 3 presents the scope of work to be completed, including a summary of the analytical program, and,
- Section 4 discusses project management, reporting of findings and projected duration of tasks.



Approximate
Scale in Miles
0 0.5 1

## FIGURE 1-1
## SITE LOCATION MAP
## SITE INVESTIGATION WORK PLAN - PHASE I
## 95 AMES STREET
## ROCHESTER, NEW YORK

ABB Environmental Services, Inc.

# 2.0 CURRENT SITE UNDERSTANDING

## 2.1 SITE PHYSICAL SETTING

### 2.1.1 Site History

The Taylor Instruments Site was a manufacturing facility from 1904 to 1993. Fluid-filled glass instruments such as mercury thermometers were produced at the site until the mid-1960's after which mercury-handling operations became a very minor aspect of facility operations. In 1993 all manufacturing operations were moved to a new location in suburban Monroe County.

Facility demolition activities were initiated in May 1995. All buildings, except metal storage Building 60, were razed. Shallow building footings, subsurface utilities, and underground storage tanks (usts) were removed. The site was rough-graded flat pending the completion of the Phase I Site Investigation, which was conducted in Spring 1996. Following Phase I sampling activities, final grading was completed and all unpaved portions of the site were paved.

Figure 2-1 shows the location of former site structures and environmental Areas of Concern (AOCs) that were identified from prior investigations and from demolition sampling results.

### 2.1.2 Site Description

The Taylor Instruments Site covers approximately 14 acres in the city of Rochester The site is bounded on the south by West Avenue, the west by Hague Street, east by Ames Street and to the north by Conrail railroad tracks. The site is essentially flat with a maximum slope of 3 percent. There are no identified wetlands or surface water bodies on-site.

The area within one-half mile of the site is primarily mixed residential and light industrial. Rochester Gas and Electric has a leased facility on the west side of Hague Street. South of West Avenue and east of Ames Street is predominantly residential.

### 2.1.3 Site Geology

Native unconsolidated soils (overburden) consist of glacially deposited sand, silt, and gravel. The overburden at the site varies from about 14 to 30 feet thick, generally thickening towards the northwest corner (30 ft at BG-02). The lowermost soil unit consists of basal till that is typically brown-gray, poorly graded and very dense. It is generally encountered beginning at 12 to 14 feet bgs.

Soils overlying the basal till are interpreted to be ablation till/stratified till deposits. The boundary between the basal (or compacted) till and the ablation till is not distinct. The shallower soils are generally lighter brown. Some borings encountered poorly graded fine sand or silty sand that are interpreted to be reworked stratified till.

Fill soils are the uppermost soil unit at the site. The fill varies from disturbed native sandy soil (without debris) to sandy or silty soil with metal, wood, glass shards, etc. A layer of crushed local rock (dolomite) was placed over the unpaved portions of the site prior to paving and is partially mixed with surface soils in parts of the site.

The bedrock underlying the site has been mapped as the Lockport dolomite. Regionally this formation consists of flat to very gently dipping medium- to thick-bedded fine-grained dolomite with interbedded shales. Two ten-foot bedrock cores were collected during the Phase I program. Bedrock is light gray dolomite with fine-grained texture and subhorizontal breaks or fractures. The highest bedrock elevations were observed in the southeast, the lowest in the northwest.

### 2.1.4 Hydrogeology

Groundwater is present within the overburden and presumably in the underlying fractured bedrock beneath the site. Water levels in most site wells were between 5 and 6 feet bgs in April 1996. Water levels declined seasonally by generally 1 to 3 feet in September 1996. The Phase I VSI Report interpreted overburden flow as being towards the northeast. Hydraulic characteristics of the shallow bedrock will be assessed by this work plan.

## 2.2 PRE-DEMOLITION INVESTIGATIONS

Since 1982, several environmental investigation efforts have been undertaken at the Ames Street Site. Limited soil sampling has also occurred relative to facility maintenance and demolition issues. This section describes the rationale and scope of each known effort. Analytical and other data associated with this work has been provided to the NYSDEC and may be found in a number of reports generated by Taylor Instruments during the 1980's; in the *Background Document* submitted by Combustion Engineering in 1995; and in the *Voluntary Site Investigation Report* (2 volumes) submitted by Combustion Engineering in 1996. Table 2-1 lists each investigative sampling event and describes the form of data submittal to NYSDEC.

In addition to the work described, a large number of building materials samples (e.g., wood, concrete) were collected during 1993 and 1994 to characterize building materials for proper disposal during facility demolition. Since all the building materials have been removed these building-related analytical results are not discussed herein. A substantial amount of this of this data, including sample locations and analytical results appeared in the *Background Document*. Results which did appear there and which have not been submitted to the NYSDEC to date consist of samples of building materials and soils which were obtained and analyzed during the 1995 facility demolition in order to gain acceptance from the disposal facilities for the various waste streams. With minor exceptions these samples represent materials which are no longer present at the site.

### 2.2.1 Class 4 Area Investigations (1981-1986)

Mercury contamination in the area north of former Buildings 34 and 40, referred to as the "Class 4 Area", was first identified in 1981 (see Figure 2-1). Glass instrument shards, some containing visible mercury, were observed on the surface and in shallow subsurface soil. In late 1981, Taylor Instrument's consultant, Lozier, installed borings and wells to provide soil and groundwater samples in the immediate shard areas. Results showed total mercury concentrations up to an estimated 52,000 milligrams per kilogram (mg/kg) in shallow soil in the shard areas with much lower levels outside the shard areas. NYSDEC was notified by Taylor Instruments and the area was listed on the New York list of Inactive Hazardous Waste Sites in early 1982. Another round of investigation, including installation of additional soil borings and shallow monitoring wells and lysimeters, was completed under NYSDEC oversight late that year. By the end of this field effort, a thorough characterization of soil within the ½-acre Class 4 Area was completed. The investigation also detected mercury in groundwater above the Class GA groundwater standards, primarily at the source (glass shard) areas.

NYSDEC subsequently approved removal of visible glass shards and installation of asphalt paving over the entire area as a remedial measure, and this was completed in late 1982 and early 1983. Quarterly groundwater monitoring was initiated and continued until September 1986, by which time mercury concentrations had generally fallen to below the Class GA standard. The Site was reclassified by NYSDEC from "Class 2" to "Class 4" and continues to be listed on the New York Registry of Inactive Hazardous Waste Sites (Registry), indicating the Site is properly closed and requires continued management.

### 2.2.2 Water Tower Area Investigation (1984-1985)

Discovery of glass shards in the area beneath the former water tower near the center of the Site led to a soil investigation in late 1984 and early 1985. Approximately 16 samples from depths of 2 to 10 feet were collected and analyzed for mercury by the EP Toxicity method. Mercury concentrations using this method ranged from non-detectable up to 0.0094 milligrams per liter (mg/l). NYSDEC approved installation of asphalt paving as a remedial measure to close this area.

This was completed in late 1986, and the location was deleted from the Registry in approximately 1990. This area is within the larger "shard" area investigated during the 1996 Phase I (see Figure 2-1).

### 2.2.3 Building 4 Sampling (1987)

According to a 1987 Taylor interoffice memorandum, an "area under the old zinc cyanide tank will have to be excavated because of poor structural integrity." The memo describes "several core samples and the soil underneath" being composited and analyzed by the EP Toxicity method for cadmium, chromium, lead and mercury in order to determine if the material would be considered a hazardous waste if removed. The results were below the EP Toxicity limits, and apparently no further sampling was performed. Although these results did not indicate the need for further investigation, the 1996 SI characterized soils beneath Building 4 to assess overall potential impact from plating-related activities.

### 2.2.4 Building 8 Sampling (1989)

According to a 1989 Combustion Engineering interoffice memorandum, a composite sample of soil from several locations beneath Building 8 was collected to characterize soil to be excavated during a construction project. Samples are presumed to have been collected just beneath the floor slab. Based on the EP Toxicity results, the soil was determined to be non-hazardous. These results and the building operational history did not indicate a potential source area and therefore no further characterization was done during the 1996 SI.

### 2.2.5 Pre-1995 Tank Closures

The Taylor Instruments site had a variety of underground and aboveground storage tanks.

Tank 2. In September 1986 this 1,000-gallon UST, located in the northern part of the Site between Buildings 34 and 40 was suspected to have been the source of gasoline releases (Figure 2-1). With NYSDEC's concurrence, Taylor sampled nearby wells and lysimeters that had been installed for the Class 4 Area investigation. No evidence of groundwater impact was found, and on this basis NYSDEC allowed the tank to be closed in place with no further groundwater or soil sampling, or remediation. The tank was closed by filling it with concrete. The Taylor correspondence file indicates that "a 12/23/86 inspection of the tank Site by the Rochester Fire Department revealed no significant soil contamination", although the scope of this inspection is not documented.

Tanks 13/14. Two aboveground TCE storage tanks (1,500 gallon and 1,000 gallon capacity, respectively) were located in a small courtyard bordered by Buildings 43, 48, and 49 (Figure 2-1). They were removed in 1992. No environmental sampling prior to or at the time of removal is believed to have occurred. Environmental samples were collected during the subsequent 1993 and 1996 site investigations.

Tank 15. An 8,000-gallon aboveground TCE storage tank was located at the northeast corner of Building 40, within the "Class 4 Area" (Figure 2-1). It was removed by ABB Kent Taylor in 1992. No environmental sampling prior to or at the time of removal is believed to have occurred. Environmental samples were again collected during the 1993 and 1996 investigations.

Tank 16. A 3,000 gallon underground tank, located near Building 35, was used to store paint thinner. It was removed in early 1993 by ABB Kent-Taylor. The initial set of soil samples from the excavation sidewalls showed levels of toluene, xylene and 4-methyl-2-pentanone above the NYSDEC Spill Technology and Remediation Series (STARS) guidelines. At NYSDEC's request, additional soil was removed from the excavation and a second set of samples was obtained. These samples indicated the impacted soil had been removed, and tank closure was granted. A soil boring (BS-21) was installed at this location during the 1996 investigation.

Tanks 20/21. Tank 20, a 250-gallon tank storing kerosene, and Tank 21, a 400-gallon tank used for (it is believed) oil storage, were aboveground tanks located next to the loading dock inside Building 49. According to NYSDEC records, both tanks were removed in February, 1993. Presumably because both were set inside on the building floor no soil sampling or other post-removal activities were necessary

### 2.2.6 1993 Site Investigation

In May 1993, ABB-ES conducted a limited Site investigation to establish the general environmental condition of the property through selected sampling of potential AOCs. Outside the buildings, ABB-ES used a drill rig to collect soil samples from borings completed near each existing underground tank; the former Building 42 solvent recovery/drum storage area, the former Tank 15 area, and several other locations. Inside the buildings, shallow soils samples were collected by hand from beneath floor slabs in several areas, including the plating and degreasing areas, Building 30 mercury filling room, Building 12 and the former Tank 13 and 14 locations. Groundwater samples were obtained from several existing monitoring wells and from two shallow soil borings.

Results of field screening, field lab analysis and off-site lab analysis of the samples indicated the presence of mercury, metals and VOCs in some areas. These findings led to a "protective filing" to the NYSDEC Spills Division pursuant to 6 NYCRR Part 595 since the source of some of the detected VOCs may have been releases from on-site storage tanks. The results suggested the need for further work in some areas and formed the basis for 1996 tank-related release investigations required under 6 NYCRR 595.2 if the identified contaminants were determined to be associated with regulated tanks. The 1993 analytical results are discussed along with the 1996 SI results.

### 2.2.7 Sub-slab Soil Sampling (1993)

During a September 1993 effort to sample concrete and other materials for demolition waste characterization purposes, several soil samples (that may have contained floor material) from beneath floor slabs were collected to augment the information from the May 1993 work. Samples were analyzed by both a field laboratory and an off-site laboratory for mercury only and were provided to the NYSDEC in the 1996 Voluntary Site Investigation report.

## 2.3 DEMOLITION OBSERVATIONS

Except for Building 60, all Site structures including buildings, foundation slabs and footings, shallow (i.e., less than approximately 2 feet below grade) inground utilities (including some), remaining USTs, etc. were removed from the Site in 1995. Demolition tasks extended into 1996 with final Site grading, storm drain installation, and paving. ABB-ES provided oversight during demolition activities and made observations of conditions with potential environmental significance (e.g., glass shards or visible mercury occurrence in surficial soils), and conducted focused interim remedial measures (IRMs). IRMs included sampling per NYSDEC regulations during removal of remaining USTs and sampling and off-site disposal of associated impacted soils.

### 2.3.1 Mercury-Related Observations

Mercury-related observations consisted of two types: a relatively small number of locations where liquid mercury was visible in soils or within inground piping, and the more widespread occurrence of broken glass instruments, i.e., "glass shards"

Liquid Mercury. Liquid mercury was observed in soil in the form of small droplets ("prills") in two general areas. One area was in association with a feature referred to as the "Building 2 tunnel", a rectangular brick/concrete trench with pipe extensions at each end which was discovered beneath the former Building 2 floor slab. This "tunnel" was not shown on any historical Site maps, and its function is unknown (although its configuration suggests wastewater conveyance). It was not connected to any of the active Building 2 sewer lines, and was guessed to represent a portion of an old system which was abandoned and covered with a new floor slab. During demolition, mercury prills were observed at several locations in soil immediately behind the Building 2 tunnel walls and at the tunnel's western and eastern ends. Although glass shards were present at various locations in the tunnel itself, no shards were found outside its walls where the prills were present.

As described in the 1996 report to NYSDEC, the visible mercury was left in place in most locations pending further investigation.

The second general area in which liquid mercury was noted in soil was beneath former Building 44. Mercury use in this building was extensive until the manufacture of liquid-in-glass instruments at the Site ceased. During removal of the old sewer lines beneath this building, small amounts of liquid mercury were observed to have pooled in the lines at two locations at or in close proximity to a sewer pipe. Since the presence of liquid mercury in soils is direct evidence of soil impact, each location where it was noted was subjected to further investigation during the 1996 field program.

Glass Shards. The presence of glass shards were observed to be more widespread than that of liquid mercury but still relatively localized. Glass shards were generated when the liquid-in-glass instruments manufactured at the facility (thermometers, etc.) were either broken during manufacture or rejected. It is known that a mercury retort process, whose equipment was for some time located in the west end of former Building 40, was used to recover the valuable liquid mercury from broken instruments. Based upon the Site history, it appears that the shards are a combination of instruments broken prior to filling with mercury; broken subsequent to filling; and material which went through the retort process. Examination of numerous shards by ABB-ES and others shows that while many contain traces of mercury, many do not.

Shards are present at the Site in two situations. First is scattered occurrence along sewer and other utility lines, where they are mixed with other backfill material such as coal ash, and glass debris. Shards have been observed in this manner along sewer lines beneath Building 5; along the western end of the Building 2 "tunnel"; and in a few locations along the underground fire protection system pipe trenches.

Second, shards appear to have been used as a bulk fill, perhaps associated with various historic construction activities. At Building 40 a one or two foot thick layer of fill containing a high density of shards is present immediately beneath the floor slab. In other locations, throughout a larger area stretching from the former Building 40 past the former Building 35 and the water tower, where the shards are concentrated in a one or two foot thick layer located two to three feet beneath the asphalt pavement surface.

Based upon the cessation of the manufacture of liquid-in-glass instruments in the mid-1960's, this is the latest that use of shard as on-site fill could have occurred. Use of shards as fill may have ended even earlier, because no shards were observed beneath Buildings 44 or 65 (construction dates 1942 and 1978, respectively, relatively new buildings in the northern portion of the Site), or anywhere in the southern half of the Site (i.e., Buildings 30 [circa 1918], Tank 13/14/Building 48 [circa 1948], Building 49 [circa 1951], and the southern parking area.).

Based both on the presence of mercury in some shards and the results of past investigations (e.g., the Class 4 area), soils containing glass shards were thoroughly characterized during the 1996 SI.

### 2.3.2 1995 Tank Removal Observations

Tanks removed by ABB-ES during the facility demolition process were done so in accordance with the requirements for tank closure administered by the NYSDEC Spills Division. Interaction with the Spills Division included reporting observed releases by telephone, visits by Spills Division personnel to the Site to observe tank removal and soil excavation activities, and follow-up correspondence. C-E intends to pursue any required additional action relative to tank closures, including soil and/or groundwater remediation, within the context of the overall voluntary cleanup agreement for the Ames Street Site.

Tank 2. In November 1995, Tank 2 was removed during demolition activities. Samples were collected from the excavation and excavated material. Results indicated VOC and SVOC levels beneath the STARS guidance values for gasoline-related compounds. However, VOCs were present in a water sample that was collected from standing water in the excavation. The excavation was backfilled with clean soil. The 1996 SI included soil borings in the immediate vicinity of this former tank

Tanks 9/1. Tank 9, a 25,000 gallon UST used to store fuel oil was removed in November 1995. The tank appeared to be intact, although some oily water was observed in the excavation. Notification was provided to NYSDEC and the liquid was removed by vacuum truck. Also, approximately 150 tons of soil were removed and sent off-site for disposal. Remaining soil was sampled and results did not indicate the presence of fuel-related constituents at levels above STARS guidance concentrations. Tank 1, a smaller gasoline storage UST located immediately adjacent to Tank 9, was removed at the same time as Tank 9 and did not exhibit impacted soil.

Tank 10. Tank 10 was an approximately 285-gallon AST used to store paint thinner which was located in a vault in the basement of Building 19. It was removed in November, 1995.. Because it was located within a building, inside a concrete vault, no post-removal sampling or soil removal was necessary.

Tanks 11/12. Two USTs which stored xylene and toluene raw material product were removed in December 1995. PID screening showed tank pit soils to be impacted and unsaturated contaminated soil was excavated as an IRM and shipped off-site for disposal. Samples were collected from pit sidewalls and bottom and from standing water in the excavation. The analytical results and a sketch map showing the location of samples are included in Appendix C. The samples contained up to 3,600 mg/kg combined toluene and xylene in the soil and 30 mg/l combined toluene and xylene in the standing excavation water. The excavation was lined with polyethylene plastic sheeting and backfilled with clean fill. The 1996 SI subsequently completed several soil borings in the immediate vicinity of the former tanks to assess residual impact.

Tanks 17/18/19. These three 54-gallon tanks located between Buildings 3 and 4 were removed during demolition in December 1995. Sampling of sidewalls and bottom of the excavation indicated some residual VOC contamination at the bottom of the excavation. An additional 3 feet of soil was excavated after which additional soil analytical results indicated no remaining contaminated soil. The contaminated soil was shipped off Site for disposal and the excavation was backfilled. No further investigation was necessary during the 1996 SI.

### 2.3.3 Other Interim Removal Measures

Three areas of impacted soil unrelated to tanks were excavated during demolition activities in 1995. Telephone notification to NYSDEC Spills Division was made for all three locations subsequent to discovery.

One area was located at the west end of former Building 49, where hydraulic pistons for the loading docks apparently leaked oil into the surrounding soil. The second area consisted of apparently VOC-impacted soil around an old brick structure found several feet below grade between former Buildings 5 and 8. At both locations, ABB-ES collected soil samples from the excavation sidewalls to evaluate whether the impacted material was completely removed. Results indicated that all soil impacted above STARS criteria was successfully removed at these locations.

A third area of impacted soil was discovered during removal of sewer lines located just southwest of former TCE storage tanks 13/14 ABB-ES was unable to remove all impacted soil (suspected to extend to a source area near the former tanks). The area was subsequently investigated as part of AOC-9 during the 1996 SI

### 2.3.4 Other Observations

Other general observations developed during demolition activities which bear on the Site as a whole are as follows:

- Of the numerous sewer lines excavated during demolition, very few had observable holes or other indications that leakage had occurred. In addition, as had been suggested by all historical drawings, all floor drains, road drains, roof drains and other water conveyance devices were confirmed to be tied into the sewer network. No evidence of "dry wells" or similar devices for draining areas internal to the property was observed. Except for a few specific instances, sewer lines were therefore not an investigation target during the SI.

- Concrete floors throughout the facility were intact, in good to excellent condition and showed little sign of previous damage or patching. The only exceptions were floor surfaces in the metals plating area in Building 4, where concrete deterioration and patching has been previously documented. However, the subsurface tunnels in this area, which conveyed spills, washdown water, etc. to the sewers, were observed to have been well-constructed and in good condition.

- In several locations, notably in an area between Building 5 and 8 and beneath Building 39, evidence of structures pre-dating the Taylor facility was found. These features included what appeared to be old sewer lines and building foundations. Although not significant to the VSI, these observations indicate that the Site does have a history of use prior to Taylor Instrument. These observations are consistent with historical documents which indicate that other areas of the Site had previously been used for industrial, commercial, or institutional uses.

## 2.4 1996 VOLUNTARY SITE INVESTIGATION

In 1996 Combustion Engineering undertook a major investigation effort designed to characterize soil and groundwater conditions at the Site and to assess potential risks to human health and the environment. The SI's scope of work consisted of explorations within the Site property boundary to collect and analyze soil and groundwater samples. Soil sampling included soil borings and geologic borings. Soil borings were drilled at potential "areas of concern" (AOCs) to characterize overburden soils and determine the presence of Site-related COCs. The work performed was described in the *Phase I Site Investigation Work Plan* submitted to the NYSDEC in 1995, with results described in a two-volume report. The following summarizes the site investigation, but not the risk assessment, results.

### 2.4.1 Soil Results - Distribution by Chemical Type

Contaminants of Concern (COCs) were grouped into three categories based on information developed during preparation of the Phase I Work Plan: mercury, VOCs, and inorganics.

2.4.1.1 Mercury. More than 500 soil samples from 56 borings were analyzed for mercury. Samples were analyzed for the presence of mercury by two on-site methods: screening by XRF and analysis by the Leeman (CVAA) instrument. Twenty-eight split samples were also analyzed by an off-site laboratory by using the same CVAA method to provide confirmation of field results. Sample totals cited in the following discussion do not include duplicate or QA analyses.

XRF Results. A total of 524 soil boring samples were screened for mercury using XRF. The PQL for mercury by XRF is 100 mg/kg. Mercury was detected in 17 of these samples, from 9 borings, at concentrations ranging from 100 to 2,100 mg/kg. This method was used primarily to assess the gross concentration of mercury present in samples, thus identifying samples that required dilution for subsequent CVAA analysis. All samples with detectable levels of mercury via XRF were subsequently quantified using the CVAA method. Since the CVAA data are of higher quality and had a much lower PQL (approximately 0.11 mg/kg), they were used to assess distribution of mercury at the Site.

On-site CVAA Results. A total of 529 soil boring samples plus one hand-collected surface soil sample were analyzed QGs. by CVAA. The PQL for the majority of these analyses was 0.11 mg/kg, although a few were higher (between 0.11 and 1 mg/kg). Mercury was detected in 259 of the samples at concentrations ranging from 0.11 to 3450 mg/kg. No mercury was detected in 270 of the samples.

Off-site CVAA Results. A total of 41 samples were collected as splits and submitted for off-site analysis. Mercury was detected in 20 of these samples at concentrations ranging from 0.117 to 153 mg/kg. A discussion comparing the QGs and off-site data results was presented in the report; in summary, the off-site laboratory results closely support the findings of the on-site laboratory. The larger CVAA database from the SI is therefore considered the most comprehensive and accurate set of results for interpreting chemical distribution and is the basis for the following discussion.

Distribution. Mercury was detected in at least one sample from 55 of the 56 mercury borings. The presence of low but detectable concentrations of mercury at nearly all boring locations, especially locations where no significant shallow mercury source was identified, suggests that low-level but widespread mercury presence is probably a result of the long history of mercury handling and use on the property. The data clearly show, however, that mercury at higher concentrations (>10 mg/kg) is depth-limited and is present only at definable mercury source areas. All 19 samples with mercury concentrations above 100 mg/kg and 42 of 47 samples with mercury above 10 mg/kg were from samples collected within 8 feet of the ground surface.

Throughout the Site, deeper than 8 feet mercury concentrations drop abruptly to levels below 1 mg/kg. For example, in BS41, mercury levels decrease from 3,450 mg/kg (8 ft) to 2.58 mg/kg (10 ft) and 0.445 mg/kg (12 ft). All borings with elevated shallow mercury results show this pattern of rapidly decreasing concentration with depth. The three borings that had samples with mercury above 10 mg/kg at depths below 8 ft bgs (BS-18, BS24, BS38) are all located within the area of shard fill. One of these (BS18) was located in a layer of shard and debris and had mercury at depths to 14 ft bgs. BS24 and BS38 had single isolated hits at 18 ft bgs of about 23 mg/kg.

Mercury was detected above 100 mg/kg in samples associated with two potential source areas; 1) shallow fill soils containing glass shards and 2) a former subsurface trench below former Building 2.

As described in the Work Plan, shallow fill is present at various points in the northwest part of the property. Some of this fill contains debris and/or ash with glass instrument shards. The approximate limit of fill containing shards is known from a combination of demolition observations, historical Site investigation and SI soil borings. There is also a small separate area of shard fill located near former Building 62 apparently within a utility trench. Within these areas, a number of Phase I borings encountered glass shards. The results indicate that some of the samples from fill soils containing shards or immediately beneath shards have elevated concentrations of mercury. Nine borings completed within this part of the Site had mercury in shallow soils between 104 and 606 mg/kg.

A layer of fill containing shards was also observed in the sidewall of an excavation in the middle of the Site. This excavation was created when former USTs 1 and 9 and an adjacent building basement were removed during demolition. The shard layer was visible about two feet below the ground surface on the west side of the excavation. Because the pit could not be accessed with a drilling rig, a sample was collected from the shard layer using a shovel to expose fresh soil face. This sample, SS03, had a mercury concentration of 202 mg/kg.

The second area of the property containing high concentrations of mercury is a former concrete-lined trench that was discovered during facility demolition beneath the floor slab of Building 2. During removal of the concrete, mercury droplets were observed in soils underneath and on the sides of the trench. This trench was not associated with glass shards and may represent a process-related release. The high mercury values detected were confined to the area of the trench and the immediately surrounding soils. Four borings (BS40-BS43) were drilled through the former position of the trench. One or two samples from each of BS40, BS41 and BS42 contained mercury in shallow soils at concentrations above 1000 mg/kg representing the highest concentrations detected in Site soils during the SI. BS43, located furthest east, did not exhibit high levels of mercury, nor did two borings drilled within 15 feet of the trench along its north side (BS73 and BS74). Mercury concentrations above 100 mg/kg therefore appear to be confined to the immediate trench-adjacent soils.

2.4.1.2 Volatile Organic Compounds. During the 1996 SI soil samples were analyzed for 11 VOC COCs in the on-site laboratory. Soil split samples were submitted for off-site confirmatory laboratory analysis at a rate of ten percent. Also, four samples were analyzed off-site to ensure that hold time requirements were not exceeded between field shifts.

Samples were selected from borings located near specific potential sources as described in the Work Plan. Additional samples were selected based on positive PID results noted when samples were retrieved and split-spoons were opened. Towards the end of the field program, samples from a number of mercury borings were analyzed for VOCs to determine if low levels of chlorinated compounds were present in saturated soils in the northeast (downgradient) part of the Site.

Eight of 11 target COCs were detected by on-site laboratory analysis. The compound detected most frequently and at the highest concentrations was the chlorinated solvent TCE. PCE was occasionally found in association with TCE but at much lower concentration. Trace amounts of 1,1-DCE, trans 1,2-DCE, and 1,1,1-trichloroethane were identified in a few samples. A few samples contained the ketone 4-methyl-2-pentanone or aromatic hydrocarbons such as toluene, ethylbenzene, or xylenes. The results and distribution of VOCs are discussed by compound type below. Referenced sample totals do not include duplicate or QA analyses.

TCE. TCE was present in 56 of 92 samples analyzed by the field laboratory at concentrations greater than 10 µg/kg. The highest TCE results are found at two specific source areas, corresponding to two of the three primary areas of the Site at which TCE was stored or used. These two areas are referred to as the "Tank 13/14/Building 48 TCE Area" and the "Tank 15/Building 34 TCE Area".

The Tank 13/14/Building 48 TCE Area included several TCE storage or usage areas. These included former TCE ASTs (T-13/14), and the location of the actual TCE degreasing equipment (Work Plan AOC-9). BS05, (drilled at the sump which held the degreasing equipment), and BS04, (drilled adjacent and north of the former AST locations) had TCE at concentrations up to 280,000 µg/kg and 17,000 µg/kg, respectively. Four nearby borings (BS75-BS78), had TCE that ranged from 19 to 12,000 µg/kg.

The Tank 15/Building 34 TCE Area is in the northern part of the Site in the vicinity of BS55 and the former AST Tank 15 and Building 34. BS55 is located at the position of former Tank 15. Building 34 (Work Plan AOC-4), located immediately to the southeast of BS55, was used as a hazardous waste drum storage area and an adjacent part of Building 40 (Work Plan AOC-5) was a TCE dispensing/degreasing area. TCE was found in BS55 in soils just below the tank's floorslab at a concentration of 160,000 µg/kg. Surrounding borings, (including BS52 and BS54), had TCE in deeper saturated soils at levels between 50 and 1500 µg/kg.

Although other VOCs are present, TCE is the predominant compound present at both the source areas described above. TCE was also detected in soil samples from borings drilled within former Building 5 (Work Plan AOC-2), which housed various painting operations, and in borings from former Building 4 (Work Plan AOC-3), which was the third primary TCE storage/use location. (The Building 4 degreasing station was smaller and did not have a storage tank associated with it.) The highest concentrations detected are 560 µg/kg (BS16 in Building 5) and 340E µg/kg (BS29 at the degreasing station in Building 4). The VOC data from nine borings from this central part of the Site show a similar pattern of higher TCE concentration in the deeper of the two samples collected from each boring. This suggests that the TCE in these borings reflects dissolved-phase concentrations in overburden groundwater rather than the presence of significant TCE sources within overlying soils. This TCE groundwater contamination is thought to originate primarily from the two major source areas, Tank 13/14/Building 48 and Tank 15/Building 34.

PCE. PCE was detected in 8 samples at concentrations between 10 and 250 µg/kg. It was found in association with TCE, which was present generally at much higher concentrations.

Other Chlorinated COCs. The field laboratory analyzed soil samples for five related compounds in addition to PCE and TCE: 1,1,1-trichlorethane (TCA), cis-1,2-dichloroethene (c-1,2-DCE), trans-1,2-dichloroethene (t-1,2-DCE), 1,1-dichlorethene, and vinyl chloride. TCA was identified in only two soil samples at trace concentrations. Trans-1,2-DCE was detected in one sample at a low concentration (14 µg/kg in BS49). Cis-1,2-DCE could not be quantified on-site, primarily due its presence in method blanks. However, based upon the data from the off-site laboratory it is not believed to be present in the soil at significant concentrations in the areas sampled. Vinyl chloride and 1,1-DCE were not identified in any of the 92 samples.

4-Methyl-2-pentanone. This compound, a ketone, was identified in 9 of 92 soil samples and is believed to be associated with lacquer thinner used in painting operations. It was found in borings BS13 and BS16 (from the Building 5 paint finishing area) and in BS55 and BS52 from the Tank 15/Building 34 TCE Area in the north part of the Site, both locations where paint-related operations occurred. The highest concentrations of 4-methyl-2-pentanone were detected in samples from BS21 and BS44, where a concentration of 13,000E µg/kg was present in a sample from 18 ft bgs in BS21. This boring was drilled at the location of a small former lacquer thinner UST (Tank 16) that was removed in 1992. At the time of removal soils beneath this UST were removed to a depth of approximately 8 feet. The 4-methyl-2-pentanone result in this area is interpreted to indicate residual impact to saturated deeper overburden soils. 4-methyl-2-pentanone was also detected in two samples from BS44; its presence at this location may be associated with a drum storage area formerly located in this area (AOC-6).

These occurrences of 4-methyl-2-pentanone are interpreted to represent local impacts that do not indicate the presence of a large volume of impacted soil but do indicate some local impact in the immediate area of the detections.

Benzene. Benzene was not detected in any of the 92 soil samples.

Toluene, Ethylbenzene, and Xylenes. With two exceptions, these hydrocarbons were detected sporadically in 22 of 92 soil samples at low concentrations. Except for BS44 and BS45, they were found at concentrations below 200 µg/kg and are interpreted to reflect incidental impact consistent with the past industrial use of the property. At BS44 and BS45 xylenes were detected at concentrations of approximately 2,000 and 60,000 µg/kg, respectively. The samples collected immediately below these higher results contained no quantifiable hydrocarbons. These borings are at AOC-6, a former drum storage area. They are also about 100 feet west of the location of former USTs 11 and 12 which are known to have been a source of toluene and xylene release. (During demolition activities in 1995 impacted soils were removed along with the USTs samples collected from the excavation sidewalls and bottom showed remaining elevated levels of toluene and xylene up to 1,800 mg/kg). However neither boring B47 which was installed through the middle of the excavated area nor boring B48, installed adjacent and slightly downgradient of the excavated area, encountered field indications (i.e., elevated PID readings) or in the case of B47 (B48 was not analyzed for VOCs) produced results indicating xylene, toluene or any other VOC impact.

2.4.1.3 Inorganics. Soil analysis for non-mercury inorganic COCs was conducted on samples obtained from borings drilled at the location of former Building 4 (Work Plan AOC-3), where electroplating activities were housed. Samples from this area were analyzed off-site for cadmium, chromium, lead, nickel, zinc, mercury, hexavalent chromium, and cyanide. QGs. XRF screening also provided approximate concentrations of cadmium, chromium, lead, nickel, and zinc for samples analyzed for mercury throughout the Site as an outgrowth of the XRF screening process for mercury. Although capturing this data was not a requirement of the Phase I Work Plan it was used to examine the general distribution of metals in Site soils.

Plating Area Inorganics. A total of 14 soil samples plus one duplicate were analyzed off-site for metals and cyanide. Two samples were submitted from each of the seven borings completed within Building 4 (Work Plan AOC-3a,b,c,). The off-site data showed that two borings (BS25 and BS27) exhibit metal concentrations above apparent background levels (as indicated from the concentration ranges of metals in the remaining samples). Cadmium, nickel, zinc, lead, and cyanide are present at elevated (as compared to background) concentrations in BS27. Nickel and zinc are elevated in BS25. Hexavalent chromium, analyzed to provide speciation data for risk calculations, was present in only three of the 14 samples, including BS25 and BS27.

XRF data confirmed the off-site laboratory results in a general sense, with elevated (as compared to background) nickel, zinc, and cadmium in BS27 and BS25. However, the XRF data does not correlate particularly well with the corresponding off-site lab results, and is useful as qualitative screening level data only (i.e., not suitable for direct comparison to risk-based QGs ).

XRF Results - Site-wide. The XRF screening results were also examined by plotting maximum concentrations found at each boring and examining the pattern and magnitude of highest hits. Although the data is screening level only and is therefore not indicative of true soil concentrations, the plots reveal some information about potential areas with elevated metals. Plots of cadmium and chromium show a pattern of consistent values regardless of boring location. This suggests that these metals are present at a consistent background concentration across the Site and are not the result of specific source releases.

Lead, zinc, and nickel are present at a fairly consistent range of values at most locations but are sharply elevated in a few borings. The highest values for lead and nickel are from borings BS18, BS19, BS20, BS37 and BS69. These are all borings from the area of mercury impact associated with debris fill and glass shards. Zinc has a broader range of detections but the highest hits are also from shard borings BS37 and BS18.

### 2.4.2 Soil Results - Summary by Work Plan AOC

The Phase I Work Plan identified and focused explorations on AOCs that were thought to most likely exhibit impact from historic plant operations. Types of AOCs included point sources such as tanks or degreasing sumps, potential non-point sources such as soils beneath floors which were required to be handled as hazardous waste when removed, and broad areas of potential impact such as footprints of buildings where heavy mercury use occurred or areas of the Site where glass shard containing fill was placed. The Work Plan listed the AOCs, summarized known impacts, and presented rationale for Phase I explorations. AOCs are shown on Figure 2-1.

The highest concentrations of COCs detected in Site soils can be associated with specific source areas. The highest levels of mercury were found in shallow soils associated with glass shards (AOC-8) and in soils in the immediate vicinity of a former concrete-lined trench beneath Building 2 (AOC-10). No other AOCs were found to contain mercury at concentrations greater than 10 mg/kg. AOC-8 is defined as an area of the Site with occasional deposits of fill soils that contain glass shards. This shard fill is interpreted to be the primary source of mercury in Site soils within this AOC. At AOC-10, mercury is interpreted to have infiltrated soils immediately beneath and adjacent to the former trench during mercury handling operations occurring in the above building. These soils were disturbed surficially when the concrete lining the trench was removed, however care was taken to leave these soils in place and the results show that high concentrations of mercury are confined to near surface soils beneath and adjacent to the trench footprint.

The highest concentrations of VOCs were found associated with point source AOCs. In the southern part of the Site, AOC 9 (former degreasing sump) and the former Tank area (collectively Tank 13/14 Building 48 TCE area) are adjacent point sources of VOCs (principally TCE). Concentrations suggest one or more releases of product that has resulted in groundwater plume containing dissolved-phase TCE.

A similar source area for VOCs (also principally TCE) exists in the vicinity of AOC-4, i.e., the Tank 15/Building 34 area. Shallow soils are impacted with concentrations that suggest one or more releases of product and nearby and downgradient boring soils from within the water table indicate TCE impact within a groundwater plume.

Lesser sources of VOC impact include a former UST (Tank 16) at the location of BS21 (ketoses), paint-finishing operations associated with AOC-2, and xylene/ketone presence beneath AOC-6 and possibly the former location of Tanks 11/12. These lesser sources do not appear to indicate significant discreet remediable soil sources.

### 2.4.3 Groundwater Analytical Results

This section presents results from groundwater samples collected during the 1996 SI investigation from Site monitoring wells and temporary wells. Samples were collected from a total of 30 wells and analyzed by the off-site by laboratory. Results are discussed by analysis and compound type below.

VOCs. All 30 well samples were analyzed for TCL VOCs. TCE was the principal VOC detected. TCE was identified in 16 of 30 samples at concentrations ranging from 3.1 μg/L to 4,100 μg/L. Concentrations exceeded 100 μg/L in 10 of the samples. Other chlorinated VOCs

(1,2-DCE and/or TCA) were found at low concentrations (4.3 to 26 µg/L) along with TCE in 9 samples.

Toluene (21 µg/L), xylenes (710 µg/L), and ethylbenzene (94 µg/L) were identified in the sample from MW 0-0. This well is located near AOC-6, a former drum storage area. A few soil samples from 1993 and 1996 locations found toluene and xylene sporadically within soils from AOC-6. Toluene and xylene are also present in soil near former USTs 11 and 12, and although the impacted area is again interpreted to be limited and is hydraulically downgradient or crossgradient of well MW0-0. No other samples had aromatic hydrocarbons with the exception of TW02, which contained toluene at trace concentration (2.1 µg/L).

Vinyl chloride was also identified in the sample from MW 0-0. It was detected at 9.2 µg/L by the TCL method and 12.5 µg/L by the low-level vinyl chloride (LLVC) protocol. Vinyl chloride was not detected in any other of the 30 well samples based on the method quantification limit for LLVC of 1 µg/L. Vinyl chloride has not otherwise been detected in samples from this well or in any other soil or water sample from the Site.

Acetone and chloroform were identified in several samples at concentrations between 4 µg/L and 43 µg/L. They were also present in various quality control samples (trip blanks, rinsate blanks, etc.) at similar concentrations and are therefore interpreted to be analytical artifacts and not Site-derived compounds. There was no known historical use of these chemicals at the Site.

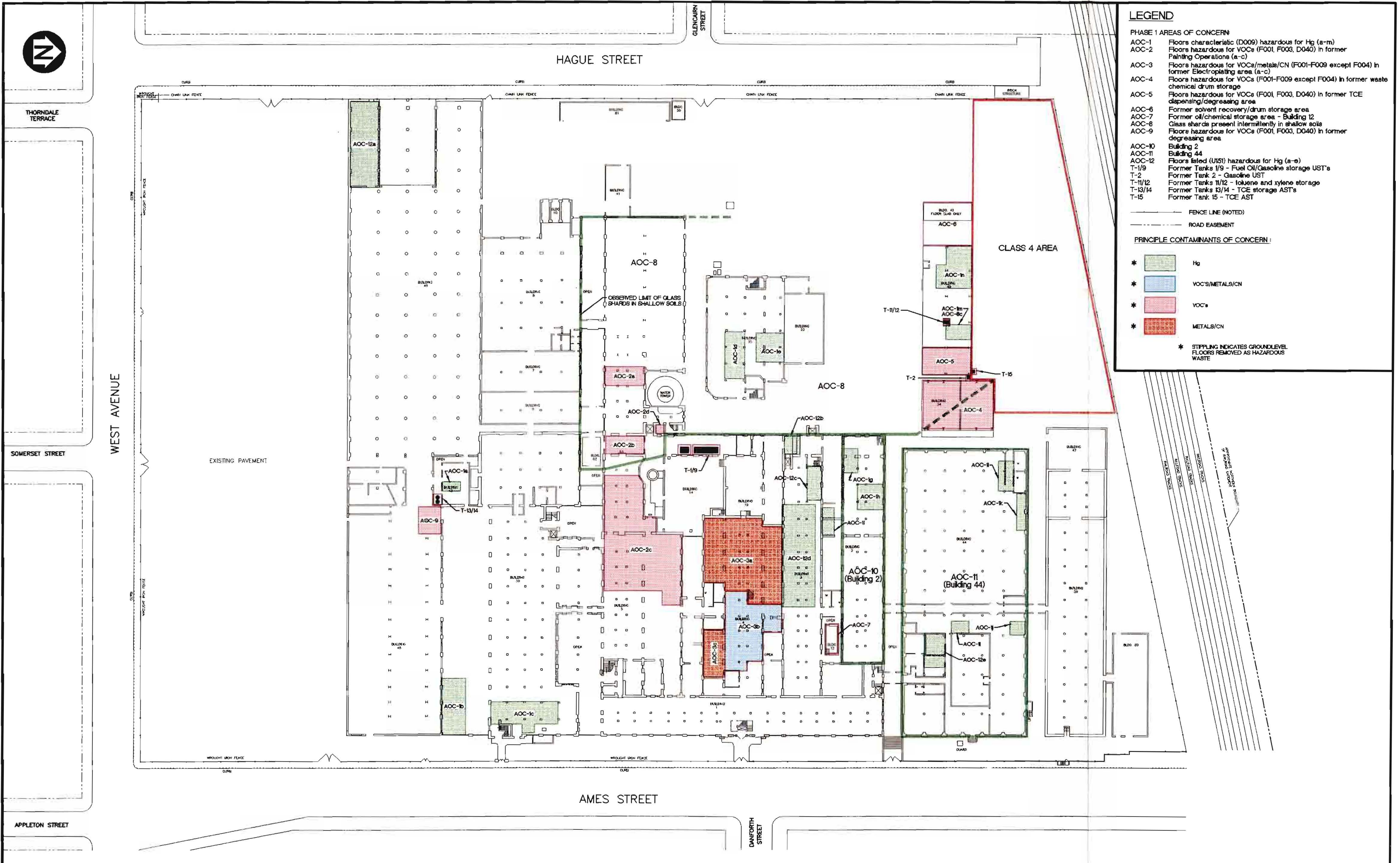
<u>Mercury</u>. All 30 well samples were analyzed for total mercury. Five samples were also collected as splits using in-line filters and analyzed for dissolved mercury. Total mercury was detected in 10 samples. Concentrations were all below 1 µg/L except for TW69 and TW07, which had mercury at 12.2 and 67.7 µg/L, respectively. TW69 is an interior well installed within the shard fill area in a soil boring with high mercury (soil) concentrations. TW07 is a perimeter well located east of former Building 2.

Dissolved mercury was identified in two of the five samples analyzed. Dissolved mercury was measured at 3.64 µg/L in TW69, compared to 12.2 µg/L total. At MW0-0, the reported dissolved mercury level of 0.35 µg/L is higher than the reported total mercury level of <0.2 µg/L. Both results are very close to the laboratory's quantification level; therefore, the only firm conclusion that can be reached is that there was little to no quantifiable mercury, dissolved or otherwise, present in this sample. No general (e.g., Site-wide) relationship between total and dissolved mercury can be described.

Inorganics. Fifteen samples were analyzed for target metal COCs ( total cadmium, chromium, lead, nickel, and zinc). Wells sampled included three upgradient wells, three interior wells, and nine perimeter wells downgradient of the former electroplating (AOC 3) and Building 2 trench areas. Metal compounds were detected in just two of these samples. Chromium (26.4 µg/L), lead (21.7 µg/L), nickel (30.2 µg/L), and zinc (100 µg/L) were reported in the sample from TW19, a perimeter monitoring well near the northeast corner of the property. Nickel was also identified in a sample (958.3 µg/L) and a sample duplicate (22.9 µg/L) from TW74, an interior well in the vicinity of the Building 2 trench.

Similar to mercury, five of these samples were collected as splits using in-line filters and analyzed for dissolved metals: TW19 did not have detectable levels of dissolved metals and TW74 was reported to have dissolved nickel at 18.4 µg/L (compared to 958 µg/L total result). As most samples had neither detectable or total dissolved metal concentrations no relationship between the two can be described.

Cyanide. Seven samples were analyzed for cyanide. These included two upgradient wells and five perimeter wells that are located downgradient of former plant electroplating processes. Cyanide was detected only in the sample from TW07 (0.028 µg/L).



# FIGURE 2-1
# LOCATIONS OF FORMER STRUCTURES AND 1996 INVESTIGATION AREAS OF CONCERN
# VOLUNTARY SITE INVESTIGATION
# 95 AMES STREET, ROCHESTER, NEW YORK

ABB Environmental Services, Inc.

## Table 2-1

## Site-Related Data - Summary of Data Locations

| Data Source (Sampling event or investigation) | Work Plan Sec. # | Report Reference/File Location |
|---|---|---|
| Class 4 Area Investigations | 2.2.1 | Index to documents previously provided to NYSDEC contained in 1995 Background Doc.(1)at Tab 4. Some data duplicated in VSI Report (2), App. C-3a. |
| Water Tower Area Investigations | 2.2.2 | Index to documents previously provided to NYSDEC contained in 1995 Background Doc.(1) at Tab 4. |
| Building 4 Sampling | 2.2.3 | Results summarized in 1995 Background Doc.(1) at Tab 9. Actual data in ABB-ES files. Results used qualitatively to identify areas for re-sampling in 1996. |
| Building 8 Sampling | 2.2.4 | Described in § 2.2.4 of the VSI. Actual data in ABB-ES files. Results used qualitatively to eliminate as area needing re-sampling in 1996 |
| Pre-1995 Tank Closures | 2.2.5 | Results summarized in 1995 Background Doc.(1) at Tab 9. Actual results in ABB-ES files. |
| 1993 Site Investigation | 2.2.6 | VSI Report, App. C-3b. Results summarized in 1995 Background Doc.(1) at Tab 3. |
| Sub-Slab Soil Sampling | 2.2.7 | VSI Report, App. C-3b. Results summarized in 1995 Background Doc.(1) at Tab 3. |
| Pre-Demolition Waste Characterization | Not Discussed | Correspondence w/ NYSDEC Reg. 8 (M. Khalil) dated June 17, 1994, January 6, 1995 and July 7, 1995. |
| Petition for a Beneficial Use Determination | Not Discussed | Submitted to NYSDEC Reg. 8 D. David) May 19, 1995. |
| Demolition-Related Observations | 2.3 | VSI Report, App. C-3c. |
| 1995 Tank Removal/IRM Data | 2.3.2 | VSI Report, App. C-3c. |
| 1996 Phase I VSI | 2.4 | VSI Report, summarized in § 4.2.1 and 4.2.2.. Actual data in App. C-1. |

Complete References:

(1) Background Documents Ames Street - Former Taylor Instrument Site, 95 Ames Street, Rochester New York. Complied by ABB-ES and NHDD, 1995

(2) Phase I - Voluntary Site Investigation Report, ABB-ES, November 1996

# 3.0 SCOPE OF WORK

## 3.1 MERCURY INHALATION EXPOSURE CHARACTERIZATION

In response to questions raised by the New York and Monroe County Departments of Health, CE agreed to collect additional data in order to verify and refine the Phase I Human Health Risk Assessment's (HHRA) conclusions. The HHRA was completed as part of CE's 1996 Site Investigation. To further evaluate potential inhalation exposures to occupants of future onsite structures, CE will attempt to collect actual volatile mercury emission and soil gas concentration data. This data will still need to be utilized in an appropriate mathematical model to characterize inhalation risk to future site users, but, if successful the data will reduce some of the inherent uncertainty in a model-based analysis. The data will be used both to re-model the "safe" soil concentrations and to understand better what risk the site poses under current conditions.

To further evaluate potential for inhalation exposures to workers who may perform construction, underground utility or related work at the Taylor Instrument site in the future, industrial hygiene-type sampling under conditions representative of that exposure,i.e. personnel entering into subsurface excavations, will be performed. This data will then be compared to established EPA inhalation reference dose values and to OSHA and NIOSH worker protection standards.

### 3.1.1 Volatile Mercury Emissions and Soil Gas Characterization

To characterize mercury in soil gas, CE will attempt to evaluate volatile mercury emissions and collect and analyze soil gas samples for mercury at 10 locations established in a rough grid across the Taylor Instrument property.

It is important to note that while a variety of accepted methods are available for the collection and analysis of air samples for volatile mercury, there are no corresponding standard methods for the evaluation of volatile mercury emissions from soils nor the sampling of soil gas for volatile mercury. For emissions from soils (the rate per area of which is referred to as the "flux"), several groups are engaged in evaluating slightly different methods. One of the most prominent of these researchers is Dr. Steven Lindberg from the Oak Ridge National Laboratory in Tennessee, who will direct the emissions evaluation at the Taylor Instruments site. Information on Dr. Lindberg's qualifications is provided in Appendix A-1 along with several of his publications on the subject.

Appendix A provides the procedure for making the emissions measurements. Briefly, the procedure consists of setting an enclosure - the "flux chamber" - at the area of interest and making a series of very precise measurements of volatile mercury in the air within the chamber. Measurements are made with a Tekran® near real-time mercury analyzer, an instrument which is the standard for real-time analysis of ambient air and combustion source emissions. The series of measurements are then analyzed using an established mathematical model to produce an emissions flux estimate.

The flux chamber will be deployed at a series of ten locations across the site as shown on Figure 3-1. The grid and specific locations will be adjusted as necessary to ensure that samples are collected from areas representing the spectrum of subsurface mercury impact as indicated by the previous site investigation work. These include largely unimpacted conditions beneath the former parking area that comprised the southern portion of the property, areas of historic mercury manufacturing or post-manufacturing use (e.g. Buildings 2 and 44) and areas of identified mercury shard debris (e.g., the Class 4 Area). At each location CE will remove the asphalt and asphalt base material before prior to deploying the flux chamber. Dr. Lindberg will supervise the set-up and oversee the start of data collection.

Compared to the emissions estimates, soil gas concentration data requires a greater degree of modeling to produce risk estimates. However, measurements of volatile mercury in the shallow soil will also be made using accepted VOC soil gas sampling techniques. For these measurements ABB-ES will use the EMFLUX® soil gas detection system by Quaddrel Services, Inc., similar to the devices which will be utilized to evaluate VOCs in soil gas as described in Section 3.2. This device consists of an adsorbant-containing cartride which is deployed into the shallow subsurface. Gaseous mercury adsorbs into the material over a period of days, after which the cartridge is retrieved and sent to an off-site laboratory analysis.

Although well-tested for VOCs, the EMFLUX® method is poorly tested for mercury (for reasons similar to the emissions measurement technique). However, similar to its VOC counterpart and to the emissions measurement method, the EMFLUX® method utilizes a standard mercury analysis technique (cold vapor atomic absorption) to quantify the mercury collected on the adsorbant material. Additional information, including the methods of deployment and analysis, is provided in Appendix A.

The EMFLUX® method will be employed at the same ten locations as the flux chamber method.

### 3.1.2 Worker Exposure Simulation

This task will provide data on potential construction-type worker exposure to mercury vapor by simulating conditions during future on-site activity such as excavation for utility work. Samples will be collected from three test trenches (Figure 3-1). Two trenches will be located within areas containing shard debris and one trench will be located in former Building 44, an area of historic mercury manufacturing activities. All of these locations represent "worst-case" locations. No trench is proposed at the Building 2 mercury source area because this area was well-defined spatially by previous investigations and is expected to be remediated under any potential clean-up scenario.

Each trench will consist of a backhoe excavation at least 4 feet wide and 10 feet long. The trenches will be at least 6 feet deep. Excavated materials will be placed alongside each trench and will be replaced in the test hole once sampling is complete.

Two types of data will be collected. Instantaneous measurements will be made on a continuous basis using a handheld Jerome MVA and possibly the Tekran® instrument also being used for the emission estimate work. Readings will be made from positions near the ends of each trench at elevations two to three feet above the trench floor and at the midpoint between the trench walls.

Second, samples will be collected in strict accordance with NIOSH Method 6009 for mercury vapor in air. This method, included in Appendix A-2, requires a known volume of air to be drawn through a solid sorbent tube using a personal sampling pump. Each sample will be obtained by operating the sampling pump for at least 15 minutes to obtain a sample of at least 3 liters volume (in compliance with the method). Duplicate measurements may also be collected over a longer duration to ensure that enough mercury, (if present at very low concentrations) is collected within the sorbent tube. The NYSDEC and NYSDOH will be notified 5 days in advance of this work to provide opportunity to observe sample collection. It is ABB-ES' understanding that NYSDOH will be present during sampling so that field modifications can be suggested and agreed to at that time.

The NIOSH-type samples will be collected under three conditions. One set of samples will be collected after the trenches have been open for approximately one hour. The trenches will then be covered with plastic sheeting for at least an 8-hour period. The second set of samples will be collected prior to and the third set after removing the cover. Samples will be collected from a point two to three feet above the trench floor and approximately midpoint from the trench walls. The samples will be sent to an off-site laboratory and analyzed by CVAA for mercury as specified in the method.

Excavated soil will be placed back into the trenches following the tests, and will be covered with plastic sheeting during the testing period to reduce potential for exposure or contaminant migration.

## 3.2 VOC SOIL GAS SAMPLING

The primary objective of VOC soil gas sampling is to assess VOCs (primarily TCE) in off-site soil gas. These measurements will be used to evaluate health risks, if any, to off-site industrial, commercial and residential receptors. Along with assessing current conditions, sampling will also be conducted in order to assess potential for changes in these conditions based on the relationship between VOC concentrations in overburden groundwater (i.e., the source of the VOCs in soil gas), VOC concentrations in soil gas and the shape and projected movement of the VOC-impacted groundwater.

Samples will be collected from 7 off-site locations and from 4 on-site locations to assess the presence of VOCs in vadose zone soils (Figure 3-1). The off-site locations will determine the presence or absence of VOC vapors in unsaturated soils in the industrial/commercial and residential areas generally downgradient (to the north and east) of the site. On-site locations will quantify VOCs in soil gas at locations of select perimeter groundwater wells known to contain VOCs. Soil and groundwater sampling (described below) at each location will provide the data necessary to understand the groundwater/soil/soil gas relationship.

Off-site locations to be sampled are:

| | |
|---|---|
| SGV-1 | east of Ames Street in the northwest corner of the Danforth Community Center property, |
| SGV-2 | east of Ames Street at the corner of Danforth and Ames Streets, |
| SGV-3 | east of Ames Street at the corner of Zena and Chester Streets, |
| SGV-4 | north of the Taylor Instruments site at the corner of Klue and Oneil Streets, |
| SGV-5 | north of the Taylor Instruments site at the south end of Gerling Street, |
| SGV-6 | northeast of the Taylor Instruments site along the Ames Street as close to the railroad overpass as possible |
| SGV-7 | north of Ames Street near the SW corner of the Davenport Machine building (if access can be obtained) |

These locations were selected, using input from DEC and DOH, because 1) they represent downgradient locations where groundwater conditions would be expected to approximate those of potential receptors (i.e., nearby businesses and residences), and, 2) they avoid access difficulties onto private property (with one exception), including Conrail.

On-site locations to be sampled are:

| | |
|---|---|
| SGV-8 | adjacent to existing well TW-17 |
| SGV-9 | adjacent to existing well MW-5 |
| SGV-10 | adjacent to existing well TW-09 |
| SGV-11 | adjacent to existing well TW-07 |

These locations are within the identified areas of overburden groundwater impact and therefore will serve to help establish the groundwater/soil/soil gas relationship.

The primary technology used to characterize soil gas concentrations will be the EMFLUX® passive sampling device from Quaddrel, Inc. (literature provided in Appendix A-3.) This technology is suited to the data needs because it is well-tested for the primary contaminant of interest (TCE), and because it seeks to define potential maximum concentrations. This is done by collecting data over a period of theoretically maximum soil gas movement. The collector is placed in a borehole for a period of 72 hours and then sent back to the vendor where the collection media is desorbed and analyzed by GC/MS (EPA Method 8260). The sample concentration is then combined with the calculated flux over the emplacement period to arrive at a soil gas concentration in mg/m$^3$. For this work, the devices will be placed at a depth just above saturated soils or at a maximum depth of 7 feet (equivalent to the approximate depth of a basement floor). Devices will placed by a Geoprobe or similar drilling equipment. Samples will be analyzed for halogenated VOCs that were identified in site groundwater samples.

## 3.3 SOIL SAMPLING

Subsurface soil samples will be collected to support the soil gas investigations, support the groundwater investigations and to provide confirmatory and supplemental data to the previous site investigations.

### Mercury Emissions Estimation/Soil Gas Sampling and Worker Exposure Simulation

Soil samples will be collected at each of the ten on-site mercury soil gas sampling locations to provide correlative data to help assess the soil gas results. The samples will be collected using hydraulic-push sampling methodology (i.e. Geoprobe) or from driven split-spoons and will be obtained from the depth corresponding to the location of the soil gas emplacement. Results will be compared to the soil gas and emissions data.

A composite soil sample consisting of sub-samples from the 4 trench walls plus its floor will be collected at each test trench location. These samples will be obtained with hand sampling equipment and will be compared to the mercury-in-air sampling results.

Samples from the above locations will be analyzed for mercury.

VOC Soil Gas Sampling

Shallow soil samples will be collected at each of the 4 on-site VOC soil gas sampling locations (SGV-8 through SGV-11). The samples will be collected using hydraulic-push sampling methodology (i.e. Geoprobe) or from driven split-spoons and will be obtained from the depth corresponding to the location of the soil gas emplacement.

Samples from these locations will be analyzed for TCL VOCs.

Groundwater Well Installation

At each of the two monitoring well clusters installed in the TCE source areas (see Section 3.4) soil samples will be collected from the most highly impacted depth as suggested by field instrument readings and other observations. These two samples will be analyzed for the full TCL and by the TCLP for all TCLP compounds. Two additional samples, one each from the unsaturated and saturated zone and again keyed to field observations, will be collected at each well cluster and analyzed for TCL VOCs only. The full TCL and VOC data will help characterize the soil and confirm previous investigation data. TCLP data will be used for waste characterization.

Previously Observed Highest Mercury Location Sampling

Five soil borings will be completed at locations which correspond to the high mercury levels observed in site soils during previous investigations. These borings are shown as BS101 through BS105 on Figure 3-3. At each location a sample will be collected at the depth of the previously observed highest mercury result. This sample will be analyzed for the full TCL and by the TCLP for TCLP compounds. A second sample will also be collected from a depth of 10 to 12 feet bgs at each location and analyzed for mercury only

## 3.4 GROUNDWATER SAMPLING

This task will consist of groundwater sampling efforts within the overburden and bedrock flow systems. Overburden groundwater sampling will provide additional information on impact to shallow subsurface waters to assist with the VOC soil gas sampling effort and confirm previous site investigation results. Bedrock groundwater sampling will characterize this media relative to site-related and other contaminants and establish the direction of flow and hydraulic gradient of the shallow bedrock flow system.

### 3.4.1 Overburden Groundwater Sampling

To provide correlative data to the soil gas sampling, groundwater samples will be collected at each of the off-site soil gas locations described in Task 3.2 above (Figure 3-1). Samples will be collected using hydraulic push technology to advance a small-diameter steel probe approximately 2 feet into the water table (or as far as necessary to collect a water sample). Water will be evacuated from within the probe using either a peristaltic pump or by repeated bailing with a micro-bailer. Following purging and sampling the probe will be removed and the hole sealed by grouting. These samples will be analyzed for TCL VOCs.

To provide correlative data and as confirmation of previous investigation results, groundwater samples will be collected from all existing on-site overburden wells plus two new on-site overburden wells to be installed at the TCE source areas.

The two new wells, designated OB-4 and OB-5, will be installed adjacent to the co-located bedrock wells BR-4 and BR-5 described in Section 3.4.2. These wells will be installed using Hollow-Stem Auger drilling technique as 2-inch ID flush-threaded schedule 40 PVC wellscreen and riser. Wellscreen will have 0.010-inch machine slots and will be 15 feet long installed, 10 feet below the water table. Open annular space will be filled with clean silica sand and a 2-foot bentonite seal will be installed above the wellscreen. The wells will be completed with locking steel standpipes grouted in place. Wells will be developed by removing a minimum of 3 volumes.

Sampling of the overburden wells will duplicate methods followed during the previous Phase I investigation and in accordance with Section 3.6 of this Work Plan. As per the project QAPP water will be removed during pre-sampling purging using low-flow peristaltic pumps to minimize turbidity. Field measurements of pH, conductivity, temperature, and turbidity will be collected during purging. Sampling will commence once turbidity has dropped to below 50 NTUs or at least three well volumes have been removed, whichever is achieved first. Development and purge water and drilling spoils will be containerized for proper treatment and disposal.

Samples from existing overburden wells TW-04, TW-09, TW-17 and the new wells W-7 and W-8 will be analyzed for the full TCL. All other existing wells will be analyzed for ~~TCL~~ VOCs, SVOCs and metals.

CB-4
05-5

### 3.4.2 Bedrock Groundwater Sampling

There are no existing bedrock wells at the Taylor Instruments site. This task involves the installation of seven on-site wells and sampling to characterize shallow bedrock groundwater quality and determine flow direction.

The locations of the wells, shown on Figure 3-1, are:

| | |
|---|---|
| BR-1 | adjacent to existing well TW-17 along the northern site perimeter, |
| BR-2 | adjacent to existing well TW-09 along the eastern perimeter, |
| BR-3 | adjacent to existing well TW-04 along the eastern perimeter, |
| BR-4 | within the previously established AOC-9 TCE source area, |
| BR-5 | within the previously established AOC-5 TCE source area, |
| BR-6 | adjacent to the existing overburden well W-2 |
| BR-7 | adjacent to the existing overburden well W-4 |

These locations were selected to provide data near each of the two major TCE source areas and spatially separate groundwater elevations to determine flow gradient and direction.

Each well will consist of an HQ size (3.8-inch diameter) corehole drilled beneath 4-inch ID steel casing that has been grouted 3 feet into rock to form a socket. Typically, each borehole will be advanced through the soil and into bedrock using hollow-stem auger drilling technique. The augers are withdrawn and steel casing is advanced and seated into the 3-foot rock socket. Bentonite-cement grout is introduced within and surrounding the steel casing and allowed to set. Grout and the underlying bedrock is then cored to the required depth. Each well will be cored to a depth of 20 feet below the top of rock, leaving an open interval of 17 feet. Wells will have either flushmount or aboveground steel protective casing.

The wells will be developed to remove any drilling water that may have been introduced while coring and to ensure a hydraulic connection with the surrounding bedrock fractures. Each well will be pumped to remove at least three well volumes or 1.5 times the volume of water lost while coring, whichever is greater. If a well has low recharge, it will be pumped down and allowed to recover 3 times.

The seven new bedrock wells will be sampled no earlier than 48 hours following development. All samples will be analyzed for the full TCL.

Water level measurement will be collected from all existing and newly installed site wells and analyzed to assess flow direction and hydraulic gradients. Slug tests will be performed on two of the bedrock wells to provide an estimate of hydraulic conductivity.

Development and purge water and drilling spoils will be containerized for proper treatment and disposal.

## 3.5 SEWER INVESTIGATION

This section discusses the projected overall scope of on-site and near-site sewer investigations for the Taylor Instruments site, and describes the short-term objectives and sampling effort which CE proposes to undertake.

### 3.5.1 General Scope and Objectives

Periodic sampling of near-site sewers by MCPW has detected mercury in flowing water and/or sediments in near-site sewers located in Ames and Hague Streets. Levels detected to date have been below the MCPW's general sewer use limits. However, in response to probable reductions in the allowable discharge levels of mercury as a result of the Great Lakes Initiative, MCPW has initiated a mercury pollution prevention program aimed at minimizing mercury contributions to its sewers.

The data is not conclusive as to whether the specific source of elevated mercury in the sewers is mercury-containing runoff from the on-site sewers entering downgradient near-site sewers; infiltration of potentially mercury-impacted groundwater directly into the near-site sewers; ongoing release from mercury-impacted sediments present in the near-site sewers; or a combination of these or other factors.

CE recently met with MCPW to discuss an initial conceptual approach to the sewer investigation. Based on this discussion CE proposes the following approach:

- CE will perform additional investigation necessary to determine whether the on-site sewers are a contributing source of mercury to off-site sewers.
- Should the on-site sewers be found to be a contributing source, CE will undertake actions to reduce or eliminate any sources at the Taylor Instruments Site.

### 3.5.2 On-Site Sewer Investigation

The primary objectives of the on-site sewer investigation are to 1) identify whether the on-site sewers are potentially contributing mercury to the near-site sewers, 2) determine the specific source of any identified contribution and 3) assess current conditions at several off-site locations near the site. In order to achieve these objectives CE will perform the three tasks described below[1].

No Flow Conditions Inspection and Sampling

The first task is to establish whether there is sewer flow from Ames Street under dry conditions and if so, to sample that flow and analyze it for mercury. Doing so will establish whether groundwater is infiltrating into the on-site sewers and, if so, whether it is a possible contributor of mercury to the near-site sewers. This task will be accomplished by simply inspecting each opening into the sewer system for the presence of flowing water during a no-precipitation period, and collecting grab samples of the flow if present. This work will be performed during an expected period of high local water table elevation, i.e., spring. Locations to be inspected/sampled include each on-site, non-line end catch basin (CB-3, CB-4, CB-13, CB-14, CB-15) and on-site manhole (MH-6, unnamed "steel cover" on Line "D"); the off-site manholes at the terminus of Lines "A" and "E"; the off-site catch basin downstream from CB-1 if it is determined to access the unnamed 4" tile line (see Figure 3-2); and manholes MH-522.52, 516.32 and 501.72 in Ames Street and MH-517.83 and MH-519.91 in Hague Street.

As part of this task CE will establish on-site line elevations relative to the groundwater elevation, which may assist in the process of identifying the specific source of any near-site contribution. CE will also review results of previous complete camera survey of all on-site lines to confirm it does not show any possibly leaking line.

Flow Conditions Sampling

The second task of evaluating whether there is an on-site contribution is sampling during simulated or actual stormwater runoff conditions. (Because there are no active site operations, stormwater control is the only function of the on-site sewers.) In general, CE would prefer to sample actual stormwater runoff conditions. However, depending on the schedule for the

---

[1] Due to access difficulties and other considerations, CE may request Monroe County Pure Waters perform the described sampling in the Ames Street manhole locations.

investigation coupled with the occurrence of enough precipitation to produce runoff, CE may choose to run water into the catch basins in order to simulate runoff.

During this task the same locations as indicated for dry conditions would be sampled.

Sediment Sampling

Dry conditions and flow conditions sampling will establish whether there is a contribution from on-site sewers. Completion of the above-described tasks should provide at least an indication of whether the primary contribution source is infiltrating groundwater, or whether mercury-contaminated sediment/liquid mercury lying in the lines themselves. (It is possible that the source could vary from line to line.) To investigate which is the sole or primary source, CE will attempt to collect sediment samples from within those lines which either the dry or flow conditions sampling suggest may be a contributing source. In any event, however, sediment samples will be collected from the five off-site manhole locations (if sediment is present.)

The technique for sample retrieval will probably vary with the difficulty of access. Using the previously completed - or possibly additional - camera work, CE will attempt to locate concentrations of sediments within the contributing lines. Where possible CE will then run a sampling tool into the line through a catch basin or manhole and retrieve a sample. If this is not possible, CE will re-evaluate the priority of a sample at that location and make a decision as to whether to excavate and break the line in order to obtain a sample or to forego collection. Where possible, CE will collect samples every 100 feet or so in order to obtain a profile along the particular line.

For this investigation all samples are anticipated to be grab samples; flow proportional or other sampling is not considered necessary to achieve the goals of identifying contribution sources.

All samples collected will be analyzed for mercury and TCL VOCs. Due to the potential importance of the relative contribution of sediment and infiltrating groundwater, dual-phase samples will be separated and analyzed separately. CE also intends to filter several representative samples to determine whether colloidal transport of mercury is occurring.

### 3.6 PROJECT QUALITY ASSURANCE

Investigative activities at the Taylor Instruments site will be performed by ABB-ES in general compliance with the "Quality Assurance Program Plan (QAPP), NYSDEC Superfund Standby Contract, Contract Number D002472 (ABB-ES, 1995).

General procedures described in the QAPP that apply to the field tasks within this Work Plan include:

| | |
|---|---|
| Section 5.0 | Sample Custody |
| Section 6.0 | Calibration Procedures |
| Section 9.0 | Internal Quality Control |
| Section 11.0 | Preventive Maintenance |
| Section 12.0 | Data Assessment |
| Section 13.0 | Corrective Action |

Field sampling tasks and procedures set forth in QAPP include:

| | |
|---|---|
| Section 4.1 | Sample Labels and Records |
| Section 4.2 | Sample Container and Preservation Requirements |
| Section 4.3 | Decontamination Procedures |
| Section 4.4 | Exploratory Drilling |
| Section 4.5 | Sampling Techniques |
| Section 4.6 | Geoprobe |
| Section 4.8 | Aquifer Characterization |
| Section 4.9 | Surveys |
| Section 4.10 | Management of Investigation-Derived Wastes |

A summary of the sampling and analytical program described in the above tasks is presented in Table 3-1. Field quality control procedures will be followed in accordance with the NYSDEC QAPP. These include the collection of QC samples including trip blanks, field duplicates, and equipment rinseates. The rate of sample collection is specified in the QAPP. As discussed in the QAPP, maintenance and calibration logs will be kept for all direct reading equipment (e.g., PID, Jerome MVA).

All work will be performed in compliance with the site specific Health and Safety Plan (HASP) presented in the Phase I VSI Work Plan. A Phase II task-specific HASP has been prepared to supplement the site HASP and is presented in Appendix B.

### 3.6.1 Data Quality Objectives

The primary objective of the Ames Street VSI is to produce definitive data, as defined in the "USEPA's Data Quality Objectives for Superfund" (USEPA, 1993). Analytical results will be suitable for several uses including site characterization, remedial action selection and design, and risk assessment.

The tasks presented on this Work Plan represent data provided by onsite instantaneous measuring equipment (e.g. PID and Jerome MVA) and by off-site analytical laboratories. All soil and groundwater samples will be analyzed by a NYSDOH ELAP CLP-certified laboratory. Level B deliverables will be provided for all mercury and VOC analyses. Data provided by off-site laboratory analysis of soil gas samples will be functionally equivalent to Level III quality but will not, due to the specialized work involved, be performed by an ELAP-approved laboratory. On-site measurements such as PID and MVA readings provide Level I data quality. Tekran® measurements are equivalent to Level III data.

Both on-site and off-site analytical results will undergo an evaluation to determine data usability. The evaluation will include the following:

- blank contamination to determine the potential for laboratory and/or field sampling contamination,
- surrogate standard recoveries for organic analyses to assess analytical accuracy,
- field duplicate analysis to assess sampling precision and environmental matrix heterogeneity, and
- matrix spike/dup sample results to assess potential for matrix interferences and analytical accuracy.

Once the data have been reviewed by an ABB-ES chemist, data flags will be assigned as necessary to qualify the data before use.

Sample Identification. Sample identification will adhere to the QAPP with the following exceptions:

- Digits 1,2,3 will be used to identify the sample type (e.g. SGV = soil gas for volatile analysis)

- Digits 4,5 will refer to unique horizontal sample locations (e.g. 01, 02, etc.)
- Digits 6,7 will refer to sample depth, if appropriate (e.g. 12 = twelve feet bgs)
- Digits 8,9 will be used to designate whether sample is type sample or a QC sample (e.g. XD = duplicate sample)

An example code would therefore be SGV0104XD.

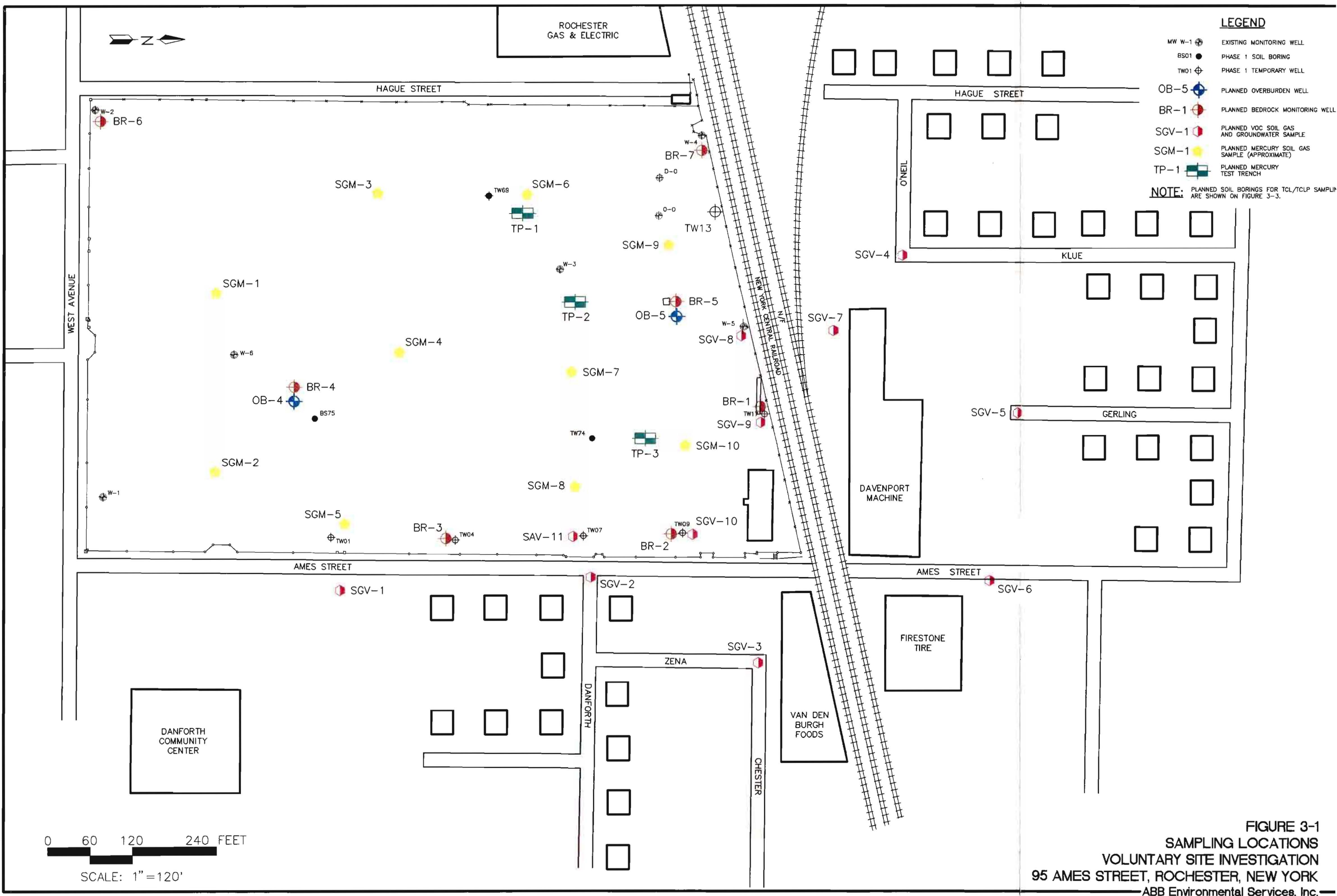
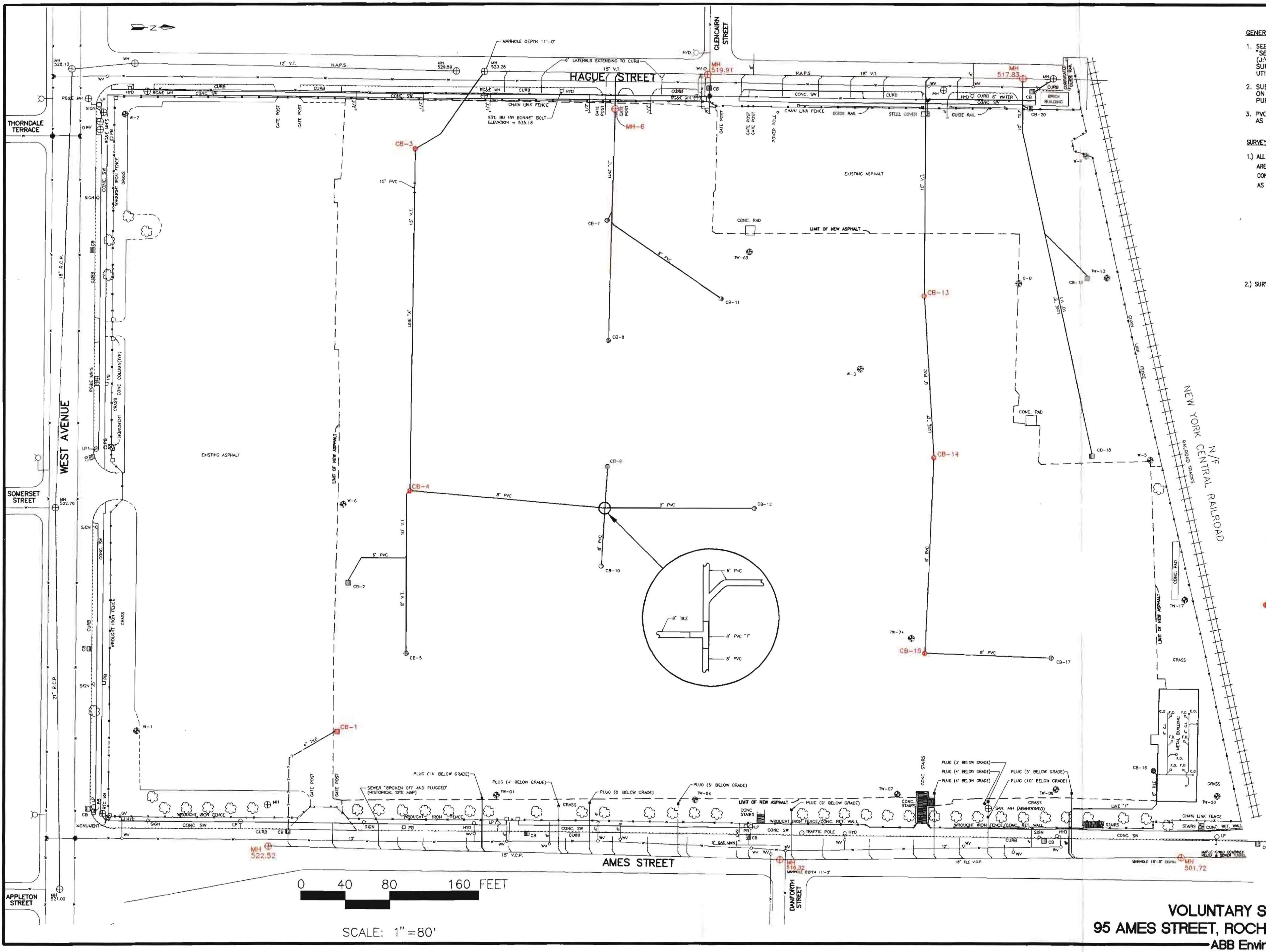


FIGURE 3-1
SAMPLING LOCATIONS
VOLUNTARY SITE INVESTIGATION
95 AMES STREET, ROCHESTER, NEW YORK

ABB Environmental Services, Inc.



GENERAL NOTES:

1. SEE ABB ENVIRONMENTAL SERVICES DRAWING "SEWER PLUG AND BARRIER INSTALLATION" (J:\7198-08\FIG\GENEAB1.DWG) FOR SEWER PLU SURFACE FLOW DIRECTION, AND OUT OF SERVICE UTILITY LINE DETAILS.
2. SUBSURFACE PIPE RUNS ARE APPROXIMATE, BASE ON HISTORICAL SITE INFORMATION, MONROE COUN PURE WATERS MAPS AND FIELD OBSERVATIONS.
3. PVC SEWER LINES ARE SDR 35, ASTM 3034, SIZI AS NOTED.

SURVEY NOTES

1.) ALL LOCATIONS AND ELEVATIONS ON THIS MAP ARE BASED ON HORIZONTAL AND VERTICAL CONTROL PROVIDED BY DOUGLAS C. MEYERS, P.C. AS FOLLOWS:

| | |
|---|---|
| P.O.L.-22 | P.K. #2<br>ELEV. - 534.18 (HELD)<br>N - 1149397.78<br>E - 749912.92 |
| P.I.-30 | P.K. #1<br>ELEV. - 529.70 (529.68)<br>N - 1149928.96<br>E - 749918.54 |

2.) SURVEYED JULY, 1996.

LEGEND

| | |
|---|---|
| ⊠ | CONCRETE MONUMENT |
| ∘ | EXISTING STAKE |
| WV GV ○ | WATER VALVE/GAS VALVE |
| HYD | HYDRANT |
| ⊞ | PLUG LOCATION ON SEWER LATERAL |
| ▥ ◍ | CATCH BASIN |
| PB ☐ | ELECTRIC PULLBOX |
| LP | LIGHT POLE |
| 529.59 ⊕ | SEWER MANHOLE W/MCPW INVERT ELEVATION |
| ⊕ | MONITORING WELL |
| ✿ | TREE |
| —E— | SERVICE TERMINATION (BY UTILITY COMPANY) |
| —W— | WATER |
| CURB | CURB |
| ┼┼┼ | RAILROAD TRACKS |
| —— | STORM SEWER PIPE IN SERVICE |
| —?—?— | STORM SEWER PIPE IN SERVICE, ROUTING/CONNECTION NOT ESTABLISHED |
| N.A.P.S. | NOT A PUBLIC SEWER |
| ● CB-14 | PLANNED SEWER SAMPLE LOCATION |

## FIGURE 3-2
## ON-SITE SEWERS
## VOLUNTARY SITE INVESTIGATION
## 95 AMES STREET, ROCHESTER, NEW YORK

**ABB Environmental Services, Inc.**

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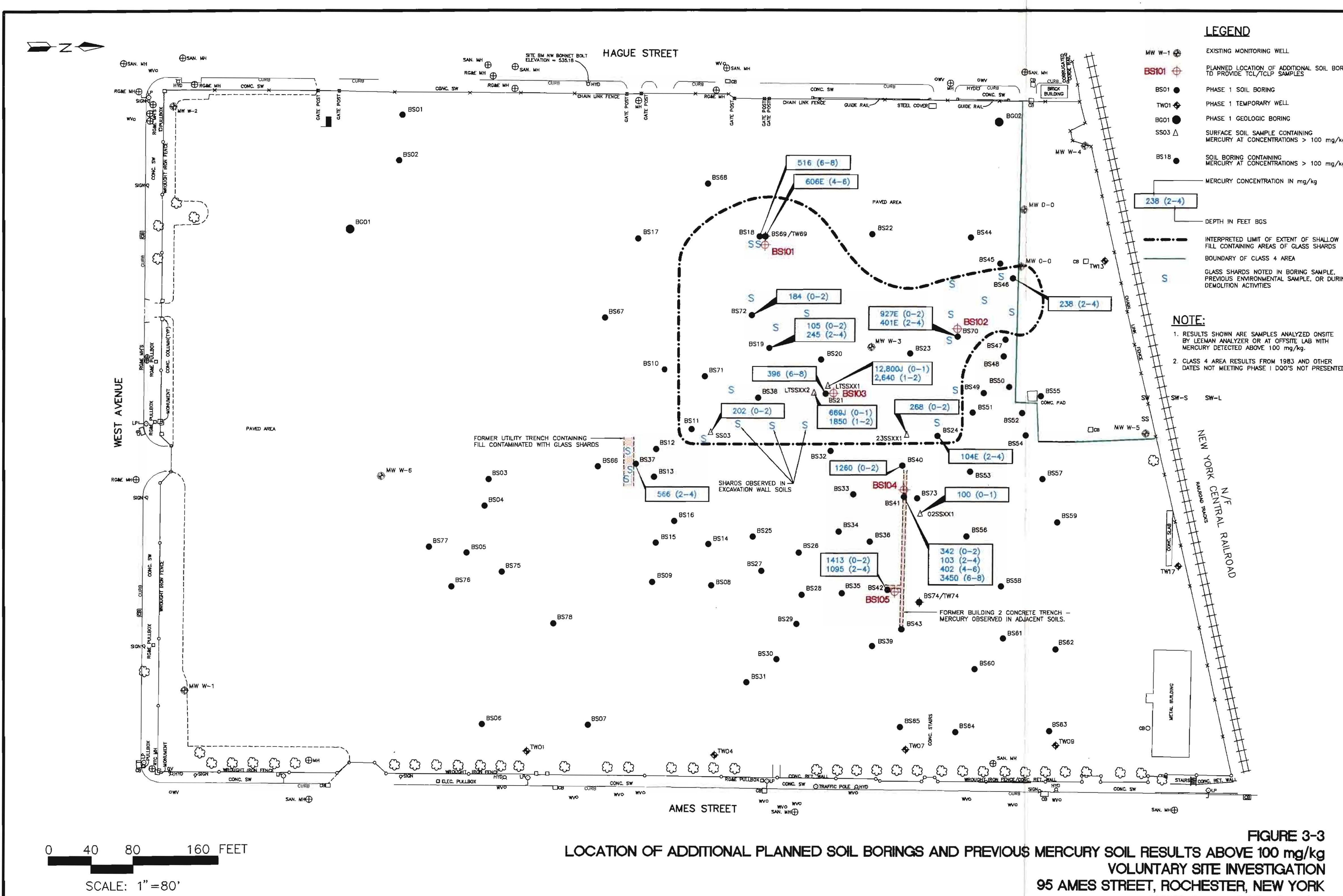

## LEGEND

| | |
|---|---|
| MW W-1 ⊕ | EXISTING MONITORING WELL |
| BS101 ⊕ | PLANNED LOCATION OF ADDITIONAL SOIL BOR<br>TD PROVIDE TCL/TCLP SAMPLES |
| BS01 ● | PHASE 1 SOIL BORING |
| TW01 ◆ | PHASE 1 TEMPORARY WELL |
| BG01 ● | PHASE 1 GEOLOGIC BORING |
| SS03 △ | SURFACE SOIL SAMPLE CONTAINING MERCURY AT CONCENTRATIONS > 100 mg/k |
| BS18 ● | SOIL BORING CONTAINING MERCURY AT CONCENTRATIONS > 100 mg/k |
| 238 (2-4) | MERCURY CONCENTRATION IN mg/kg<br>DEPTH IN FEET BGS |
| –·–·– | INTERPRETED LIMIT OF EXTENT OF SHALLOW FILL CONTAINING AREAS OF GLASS SHARDS |
| —— | BOUNDARY OF CLASS 4 AREA |
| S | GLASS SHARDS NOTED IN BORING SAMPLE, PREVIOUS ENVIRONMENTAL SAMPLE, OR DURIN DEMOLITION ACTIVITIES |

## NOTE:

1. RESULTS SHOWN ARE SAMPLES ANALYZED ONSITE BY LEEMAN ANALYZER OR AT OFFSITE LAB WITH MERCURY DETECTED ABOVE 100 mg/kg.
2. CLASS 4 AREA RESULTS FROM 1983 AND OTHER DATES NOT MEETING PHASE I DQO'S NOT PRESENTE

FIGURE 3-3
LOCATION OF ADDITIONAL PLANNED SOIL BORINGS AND PREVIOUS MERCURY SOIL RESULTS ABOVE 100 mg/kg
VOLUNTARY SITE INVESTIGATION
95 AMES STREET, ROCHESTER, NEW YORK
ABB Environmental Services, Inc.

J:\7198-24\REPORT\7198R011.DWG 8-1-97

## Table 3-1
## Summary of Sampling and Analytical Program

| TASK | DESCRIPTION | SAMPLE ANALYSIS |
|---|---|---|
| **Mercury Emissions Estimation and Soil Gas Sampling** | Emissions measurements using dynamic flux chamber and soil gas collection using passive soil sorbent devices at 10 on-site locations. | • Emissions measurements on-site using Tekran® real-time measurement instrument and Jerome MVA<br>• Passive adsorbent analyzed by CVAA at off-site laboratory |
| **Worker Exposure Simulation** | Three test trenches dug with backhoe followed by measurement of trench vapors at timed intervals after excavation and collection of vapors onto sorbent tubes using NIOSH method | • Instantaneous time-interval measurements via Jerome MVA and possibly Tekran® instrument<br>• Sorbent tube analysis via NIOSH Method 6009 (CVAA) at off-site laboratory |
| **VOC Soil Gas Sampling** | 11 small-diameter boreholes installed off-site (7) and on-site (4) using hydraulic push technology; sample collection by passive device | • Passive sorbent collector analyzed for target VOCs at off-site laboratory by EPA Method 8260 |
| **Soil Sampling - Soil Gas Measurement and Trench Locations** | • Soil samples collected at each soil gas location.<br>• Five samples collected at each trench location and composited (3 composite samples) | • Mercury-related location samples analyzed at ELAP-approved off-site laboratory for mercury by EPA Method 7470<br>• VOC-related location samples analyzed at ELAP-approved off-site laboratory for TCL VOCs by EPA Method 8260<br>• Level B deliverable for all analyses |
| **Soil Sampling - Groundwater Monitoring Well Locations** | • One sample from highest PID plus one saturated and one unsaturated zone collected from each new well cluster at TCE source locations. | • High PID samples analyzed for TCL list compounds by EPA 8260, EPA 8270, EPA 8080 and EPA 6000 series (except mercury by 7470), and TCLP compounds using TCLP and same analytical methods.<br>• Other samples analyzed for TCL VOCs by EPA Method 8260<br>• All analysis by ELAP-approved off-site laboratory<br>• Level B deliverable for all VOC and mercury analyses |

## Table 3-1
## Summary of Sampling and Analytical Program

| | | |
|---|---|---|
| **Soil Sampling - Previously Observed Highest Mercury Locations** | Five borings installed at locations of previously observed highest soil concentrations of mercury. One sample obtained from depth of highest concentration, one deeper. | • Upper depth samples analyzed for TCL list compounds by EPA 8260, EPA 8270, EPA 8080 and EPA 6000 series (except mercury by 7470), and TCLP compounds using TCLP and same analytical methods<br>• Deeper sample analyzed for mercury by EPA Method 7470<br>• All analysis by ELAP-approved off-site laboratory<br>• Level B deliverable for all VOC and mercury analyses |
| **On-site Overburden Groundwater Sampling** | Installation of 2 new overburden wells and sampling of these plus all existing overburden wells. | • Analysis of all samples for TCL list VOCs, SVOCs and metals by EPA Methods 8260, 8270 and 6000 series (except mercury by 7471).<br>• Analysis of samples from wells TW-04, TW-09, TW-17 and two new wells for above, plus pesticides/PCBs by EPA 8080<br>• All analysis by ELAP-approved off-site laboratory<br>• Level B deliverable for all VOC and mercury analyses |
| **Off-site Overburden Groundwater Sampling** | Collection of 7 samples at off-site VOC-in-soil-gas sampling locations using hydraulic push technology and micro-bailer. | • Sample analysis for TCL VOCs by EPA Method 8260<br>• Analysis by ELAP-approved off-site laboratory<br>• Level B deliverable |
| **Bedrock Well Sampling** | Installation and sampling of 7 bedrock wells at onsite locations | • Analysis of all samples for TCL list VOCs, SVOCs and metals by EPA Methods 8260, 8270 and 6000 series (except mercury by 7471).<br>• Analysis of samples from wells BR-01, BR-02 and BR-03 and two wells at VOC source locations for above, plus pesticides/PCBs by EPA 8080<br>• All analysis by ELAP-approved off-site laboratory<br>• Level B deliverable for all VOC and mercury analyses |
| **Sewer Sampling** | Water and sediment samples from on-site and near-site locations | • Mercury via EPA Method 7471 (water) and 7470 (solid), and for TCL VOCs by EPA 8260.<br>• Analysis by ELAP-approved off-site laboratory<br>• Level B deliverable |

# 4.0 REPORTING AND WORK SCHEDULE

## 4.1 REPORTING

Following completion of all field activities, ABB-ES will prepare an investigation report summarizing the data and presenting the findings. The report will include a description of the actual scope of work performed, discussion of sampling observations, presentation of all field measurements and laboratory analytical results, and discussion of findings. The report will be provided to NYSDEC and DOH on the schedule described in the voluntary cleanup agreement. Data may be provided with NYSDEC in advance of the final investigation report if doing so will advance negotiation of cleanup objectives.

Report appendices will include field data sheets, laboratory deliverables, and other supporting documentation.

In order to meet the stated needs of DOH and DEC, ABB-ES intends to provide at least the following for each of the sampling efforts:

Inhalation Hg exposure characterization

- Application of the collected data to the inhalation model used in the Phase I VSI in order to estimate risk to a commercial worker in an on-site structure similar to that envisioned by the TOPs development project. The model will utilize the same assumptions, constants, etc. as provided in detail in the Phase I HHRA with the exception of the newly acquired data. The model output will characterize the risk, if any, posed by the site under current conditions.

Worker exposure characterization

- Comparison of the data obtained to both the EPA inhalation RfC for mercury and OSHA- and NIOSH-promulgated values for worker protection.
- Estimation of the soil concentration for mercury necessary to produce an exceedance of the above values under the conditions represented by the sampling (i.e., excavation).

VOC in soil gas assessment:

- Application of the collected data to the inhalation model used in the Phase I VSI in order to estimate risk to a commercial worker or resident in an off-site structure with basement. The model will utilize the same assumptions, constants, etc. as provided in detail in the Phase I HHRA with the exception of the newly acquired data. The model output will characterize the risk, if any, posed by VOCs in off-site soil gas under current conditions.

- Comparison of types and concentrations of VOCs measured off-site in soil gas and groundwater to those measured on-site.
- Using the combined groundwater, soil and soil gas data set project possible changes in off-site soil gas concentrations, and therefore changes in risk, if any, posed to off-site receptors.

Soil Sampling

- Comparison of the analytical results to previous investigation results.
- Where applicable, comparison of results to corresponding soil gas results.
- Evaluation of TCLP results relative to waste characterization.

Groundwater quality

- Discussion of basic geology and hydrogeology as indicated by the work
- Discussion of bedrock groundwater quality on-site and likelihood of off-site impact, if any, in comparison to NY standards and risk analyses performed in during the Phase I VSI.
- Simple groundwater modeling as needed to support preceding analyses.

Sewer sampling

- Data analysis relative to the specific source(s) of mercury or VOC contribution to near-site sewers.
- Summary of proposed actions in order to further define and/or reduce or eliminate on-site sewers as a contributing source.

## 4.2 SCHEDULE

This Work Plan describes tasks that can be scheduled and completed independently (e.g. mercury soil gas/soil sampling, VOC soil gas/groundwater sampling, bedrock well installation/sampling, and sewer sampling)

Each major task is estimated to vary from two to seven days in duration. ABB-ES' anticipated schedule to complete the work includes:

- Project start-up, contracting, scope finalization (3 weeks)
- Field work (3 weeks)
- Laboratory analysis (3 weeks)
- Reporting (4 weeks)

ABB-ES will provide the NYSDEC at least five working days notice prior to any field activities to allow opportunity for split sample collection. Field work is currently scheduled to commence the week of August 25, 1997.

# APPENDIX A-1

# SOIL GAS VENDOR TECHNOLOGY - ORNL DYNAMIC ENCLOSURE CHAMBER

## Summary of Mercury Emissions Flux Estimate Methodology

### Development of Expertise

The Environmental Sciences Division, Oak Ridge National Laboratory has recognized expertise in Hg research. Many of the recent methodology advances in the study of the air/surface exchange of Hg and its speciation were developed at Oak Ridge. As part of an extensive new project originally supported by the Electric Power Research Institute (EPRI) and the US DOE Atmospheric Chemistry Program, ORNL in collaboration with the local NOAA laboratory (ATDD) has developed and tested advanced methods to measure the atmosphere/surface exchange of Hg over environmental surfaces such as soils, vegetation, and water since 1990. Several independent methods are in use to allow us to compare and contrast results for the purpose of reducing uncertainties in deposition, speciation, and emission flux measurements. Some methods have been specifically designed for certain environments, while others were designed to address different spatial or temporal scales. The most unique methods involve state-of-the-art micrometeorological approaches which have been modified for application to Hg for the first time. These methods have now been widely published in the open literature, and many have been adapted by various research groups throughout North America and Europe. Currently, the Oak Ridge group has more than 12 papers published or in press in the open literature describing the development and testing of these new methods for Hg (list attached in PI's abbreviated vita).

### Methods

The Oak Ridge Lab's methods include (1) field dynamic soil flux chambers (FC), (2) automated, near-real-time Hg analyzers, and (3) the Modified Bowen Ratio (MBR) trace gas gradient micrometeorological flux method. Brief method descriptions follow:

1. The flux chamber method uses an all-teflon enclosure to directly measure the change in Hg concentration in air over a known surface area of soil, from which emission rates can be computed given the overall air exchange rate of the chamber. The FC approach allows for measurements of spatial flux patterns and for testing of Hg flux mechanisms through surface and atmospheric manipulations such as temperature, radiation, and airborne Hg concentration, and has been employed successfully in several studies over soils and waters. A recent intercomparison of the FC with MBR methods over soils and waters and found reasonable agreement with fluxes. The Oak Ridge group has published six papers on several variations of this method, including four over contaminated surfaces.
2. The MBR method uses atmospheric concentration gradients measured over the surface of interest to quantify both dry deposition and emission of gas phase Hg species such as elemental Hg vapor. The method differs from chamber approaches in that it allows estimates of average emission rates over larger surface areas than can be quantified with chambers alone. The MBR gradient method requires the highest possible precision in

both sampling and analytical methods since the gradients are extremely small. The Oak Ridge group has developed a unique system and methodology to achieve such precision (~0.5-3% as relative standard error) at background levels of airborne Hg (~1.5-3 ng/m$^3$). All Hg analyses are done in a class 100 clean air bench using cold vapor atomic fluorescence spectroscopy (CVAFS). The measured gradients are used with estimates of atmospheric turbulence based on simultaneously measured flux-gradient relationships to compute areal Hg fluxes. The method has been successfully used over soil, plant canopy, and lake surfaces, and the first published demonstration of the method was over contaminated soils at a DOE industrial complex in Oak Ridge, TN, a site now undergoing remediation.

3. The Tekran mercury analyzer allows for continuous collection of 5-minute air samples for Hg analysis. The capability for rapid, onsite analysis using the Tekran is necessary for some flux measurements, provides near-real-time concentration and flux data for use in optimizing onsite sampling designs, and is amenable to remote sampling in enclosed spaces without the accompanying worker exposure. The Oak Ridge group has used the Tekran since 1995 in Oak Ridge, South Florida, and Germany for extensive studies of Hg concentrations and fluxes over various environmental surfaces, and currently has 6 such analyzers in operation. A recently developed semi-automated flux measurement capability has been achieved by combining the FC and MBR methods with Tekran analyzers (Lindberg et. al. 1997).

## Project Specific Approach

The Taylor Instruments site will be sampled using at least two of the methods described above. The ORNL teflon FC system will be deployed to determine temporal and spatial variability of Hg fluxes over the surfaces of interest. In addition, the diurnal cycle of Hg emissions at selected sites will be quantified using the FC system. These data, along with the landfill design specifications, will provide the necessary input for the assessment exercise. Because of the well known dependence of Hg emissions on climatological parameters (e.g. solar radiation, soil temperature, Carpi and Lindberg 1997), the Oak Ridge group will employ its routine methods to measure relevant conditions during our sampling campaign.

As a check on the larger scale fluxes, the ORNL MBR gradient method will be employed to determine spatially averaged fluxes over uniform surfaces if feasible. These measurements would also be performed over a diurnal cycle. If desired (and feasible), 24h continuous sampling of ambient air downwind of the former plant will be performed for both total Hg vapor and particle-associated Hg. These data can provide information on the overall Hg release rate from the facility (in conjunction with upwind, background data), as well as off-site exposure levels.

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# DESIGN AND INITIAL TESTS OF A DYNAMIC ENCLOSURE CHAMBER FOR MEASUREMENTS OF VAPOR-PHASE MERCURY FLUXES OVER SOILS

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Oak Ridge, TN 37831

**Abstract.** In an effort to establish reliable methodologies for measuring fluxes of mercury (Hg) across the soil-air interface, we have developed a field flux chamber built with FEP Teflon. To evaluate our field flux chamber system, a series of laboratory and field tests were performed. The observations of relatively low chamber blanks and low blank-to-sample ratios for the FEP Teflon chamber suggest its potential in Hg flux investigations. Despite its potential, Hg exchange rate measurements using the field flux chamber method must be made with great caution since it can be subject to contamination problems associated with the selection of chamber materials.

## 1. Introduction

The transfer of various pollutant chemicals across the biosphere and atmosphere interface is influenced by both anthropogenic and natural processes. It is known that, compared to the generally intense, localized anthropogenic processes, natural processes tend to occur over large areal scale with low flux density. As in the case for many other trace gases of biological origin, the world oceans have been identified to be a major component of the global atmospheric mercury (Hg) budget, with an annual emission rate of approximately 2 Tg $yr^{-1}$ (Fitzgerald, 1989). Terrestrial sources are also suggested to play an important role in the global atmospheric Hg cycling. However, previous estimates of the total terrestrial flux of Hg are highly uncertain due to lack of reliable methodologies and of published data.

Only a small number of experimental techniques have been used for direct exchange rate measurements of atmospheric Hg in terrestrial environments. The pioneering field flux measurements for Hg were conducted using flux chamber techniques (Schroeder *et al.*, 1989; Xiao *et al.*, 1991). Application of a micrometeorological approach, which is generally considered as a more reliable method, has not been attempted

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until recently (Kim *et al.*, in press; Lindberg *et al.*, submitted). Previous dynamic flux chamber studies performed in a boreal forest (Xiao *et al.*, 1991) indicate (1) similarly important roles of both emission and deposition processes over daily cycles and (2) seasonal variabilities in exchange patterns (e.g., emission-dominant summer and deposition-dominant winter). By contrast, initial results from micrometeorological studies in a background, temperate forest environment in Tennessee have shown somewhat opposing features characterized by (1) the generally enhanced magnitude of and frequent occurrences of emission (vs deposition) over daily cycles and (2) consistently emission-dominant trend over seasonal cycles (Kim *et al.*, in press). Kim *et al.* concluded that the level of difference in measured fluxes and temporal exchange patterns may still be explainable considering all different environmental and methodological factors involved in different studies.

In the initial stage of our MASE (Mercury Air/Surface Exchange) project, we have been extensively involved in establishing accurate experimental methods of measuring Hg exchange rates, in particular the micrometeorological modified Bowen ratio (MBR) method. The results of our initial application of the MBR approach to Hg flux measurements have been reported elsewhere (Kim *et al.*, 1993, in press; Lindberg *et al.*, submitted). As a part of our extended effort to accurately quantify Hg exchange rates, we have also been involved in development and application of flux chamber measurement techniques. Here we present and discuss some preliminary results of our flux chamber studies obtained during evaluation periods.

## 2. Materials and methods

The stainless steel chamber of Xiao *et al.* (1988, 1991), which was built on the basis of their studies of chamber material evaluation (between stainless steel and pyrex glass), still suffered from quite substantial chamber blank problems. Noting the good performance of FEP teflon in various trace gas flux chamber studies (e.g., reduced S: Kuster and Goldan, 1987), we selected it as a chamber material. An FEP-Teflon chamber was constructed with an open bottom and deep stretching skirts (dimension of 60x20x20 cm) and was supported by an external Al frame (Figure 1). This chamber was built to facilitate

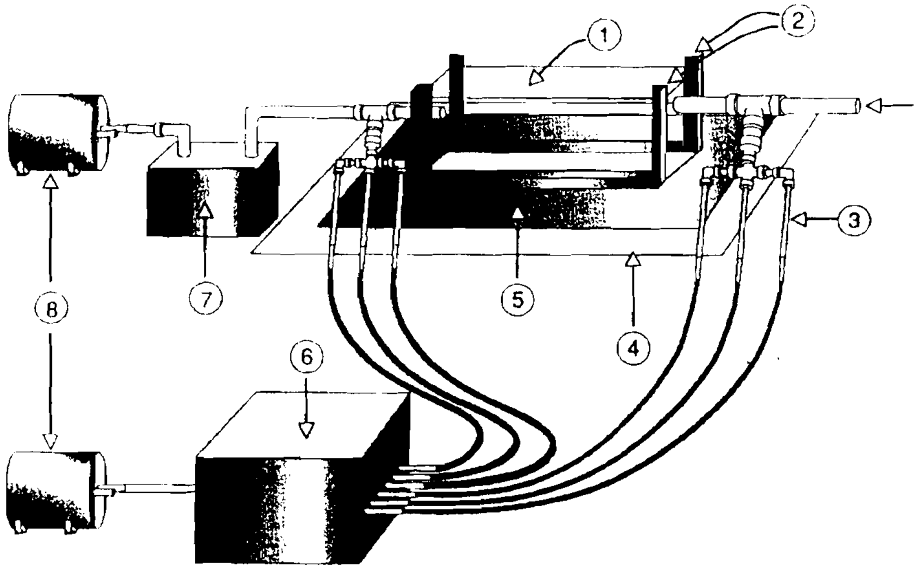

Figure 1. A schematic diagram of flux chamber system: (1) FEP enclosure chamber, (2) external Al-supporting rod, (3) Au-coated sand amalgamation trap, (4) bottom skirt of chamber, (5) frame of Al-supporter, (6) ORNL MFC system for six-replicate sample collection (maximum capacity for each individual MFC unit ~0.5 l $min^{-1}$), (7) MFC for flushing rate calibration (~15 l $min^{-1}$), and (8) vacuum pump.

simultaneous collection of three replicate air samples from both inlet and outlet ports to better characterize the true mean concentrations of $Hg^o$ entering and exiting the flux chamber. For each experiment, the air stream at the inlet and outlet port was sampled simultaneously at constant flow rate of about 400 ml $min^{-1}$. Air samples were drawn for periods of approximately 2 h using a multiple replicate sampling system equipped with six seperate mass flow controllers (MFCs) (Kim and Lindberg, 1994). Flow into and out of the chamber was also maintained at a constant flow rate of 5 l $min^{-1}$ using a high-capacity MFC (corresponding to about 5 min of turnover time for the internal volume of the flux chamber). The traps for Hg collection were made of gold-coated sand absorbers. To achieve a tight seal between chamber and soil surfaces, the four edges of the chamber-skirt were firmly pressed into the soil by lead bricks. The blank levels of our flux chamber were routinely measured by sealing the chamber over a large, clean sheet of FEP Teflon. The measurements of field chamber blanks and bias tests between different sampling methods were performed at the Walker Branch Watershed (WBW) in Oak Ridge, TN during June 1993 through June 1994. A detailed description of the experimental site has been presented by Kim *et al.* (in press). For the quality assurance of our flux chamber measurements, ambient air samples were occasionally collected during the same period using an independent sampling system designed to measure the vertical gradients of Hg at two heights (i.e., 10 and 165 cm). The sampling and analytical procedures used in our gradient measurements are detailed in the companion paper in this volume (see *Lindberg et al.* this volume).

The total amount of vapor-phase Hg collected from each flux chamber measurement was determined using a two-stage gold trap analysis technique (Fitzgerald and Gill, 1979) by cold-vapor atomic fluorescence spectrophotometry (CVAFS). The detection limit for the system, calculated as three times the standard deviation of typical mean blank levels of the Hg-collection traps, is typically found at 1 to 2 pg of Hg. The analytical system was standardized by measuring known volumes of a Hg-saturated atmosphere via an air tight gas syringe using a system of our own design. From our measurements of replicate air samples, we routinely achieved a combined sampling plus analytical precison in the range of 1 to 3 % (expressed in terms of relative standard error, RSE). Statistical outliers from each set of samples collected at the inlet and outlet were eliminated using the statistical method of Skoog *et al.* (1992). Since total gaseous Hg collected by our sampling system is predominantly in elemental form (~98%), the concentration and flux values of Hg in this paper are operationally defined as $Hg^0$.

The rate at which $Hg^0$ exchanges through the chamber was computed using the following equation:

$$F = \frac{(C_o - C_i)}{A} \times Q$$

where F is $Hg^0$ flux in ng $m^{-2}$ $h^{-1}$, $C_i$ and $C_o$ are the $Hg^o$ concentrations in ng $m^{-3}$ at the inlet and outlet ports, A is the bottom surface area of chamber in $m^3$, and Q is the flushing flow rate through chamber in $m^3$ $h^{-1}$.

## 3. Results and discussion

Previous flux chamber studies to measure Hg fluxes over environmental surfaces indicated that the major problem associated with application of this technique was the presence of large chamber blanks which occasionally exceeded the magnitude of sample fluxes (Xiao *et al.*, 1991). To offer insights into the significance of chamber blank problems, the results of blank/soil flux measurements performed by Xiao *et al.* (1991) are summarized in Table I. To facilitate the comparison of chamber blank vs. sample fluxes, chamber blank values expressed in terms of ng $min^{-1}$ of sampling time were converted into units that are comparable to actual sample fluxes (i.e., ng $m^{-2}$ $h^{-1}$). The mean and 1 SD of chamber blank are 2.13 ± 1.20 ng $m^{-2}$ $h^{-1}$. The results shown in Table I clearly indicate that chamber blank values are in many cases larger (up to an order of magnitude) than the flux values.

Noting the significance of chamber blank problems as acknowledged by Xiao *et al.* (1991), we began a series of laboratory and field chamber blank measurements as a first step toward the evaluation of our flux chamber system. To check the extent of initial contamination on our chamber system, the flux chamber was tested as delivered (April 10, 1993) without pre-cleaning. Table II shows a summary of seven laboratory and five field blank measurements made during the initial evaluation period. The mean and 1 SD of our laboratory blank fluxes are 0.5 ± 0.3 ng $m^{-2}$ $h^{-1}$ ($n = 7$), while those of field blank fluxes are 1.0 ± 0.3 ng $m^{-2}$ $h^{-1}$ ($n=4$). Although our chamber did not go through a complicated chemical cleaning process like that of Xiao *et al.* (1988), the mean chamber blank values derived from both of our laboratory and field tests are approximately two to four times lower than those seen from studies of Xiao *et al.* (1991). From our previous flux measurements using the MBR method (Kim *et al.*, in press), we quantified the mean and 1 SD of the WBW soil emission rates to be 7.5 and 7.0 ng $m^{-2}$ $h^{-1}$ ($n=30$). Thus, a combined effect of generally low blank values from our flux chamber system and the observations of enhanced emission rates of $Hg^{o}$ from our field study site (relative to the boreal forest site studied by Xiao *et al.*: refer to Kim *et al.*, in press) suggest that more reasonable blank-to-sample ratios may be obtained from our flux chamber measurements at WBW.

TABLE I

Comparison of chamber blanks and blank-to-sample ratio from previous soil-to-air flux measurements of Xiao *et al.* (1991) using stainless steel flux chamber.

| Date | Chamber blank* (ng min$^{-1}$) | Chamber blank** (ng m$^{-2}$ h$^{-1}$) | Hg fluxes (ng m$^{-2}$ h$^{-1}$) | B/S ratio*** (%) |
|---|---|---|---|---|
| 12/17/87 | 0.0036 | 1.35 | 1.4 | 96 |
| 2/9/88 | 0.0022 | 0.83 | -1.3 | 63 |
| 2/11/88 | 0.0032 | 1.20 | -1.4 | 86 |
| 4/14/88 | 0.0099 | 3.71 | -2 | 186 |
| 4/14/88 | 0.01 | 3.75 | -1.1 | 341 |
| 4/15/88 | 0.006 | 2.25 | -0.3 | 750 |
| 5/30/88 | 0.0042 | 1.58 | 2.5 | 63 |
| 5/30/88 | 0.0037 | 1.39 | 0.5 | 278 |
| 5/24/89 | 0.011 | 4.13 | -0.8 | 516 |
| 5/24/89 | 0.008 | 3.00 | -1 | 300 |
| 6/12/89 | 0.0042 | 1.58 | 0.14 | 1125 |
| 6/12/89 | 0.0022 | 0.83 | 0.17 | 485 |
| Mean | .0057 | 2.13 | | 357 |
| 1 SD | .0032 | 1.20 | | 322 |

* Chamber blanks are presented as originally reported by Xiao *et al.* (1991).
** Chamber blank values of Xiao *et al.* are converted into flux units.
*** Blank-to-sample ratios are expressed in terms of absolute percentage.

To further test the reliability of our flux chamber system, we performed a series of bias tests in which Hg concentrations measured at the inlet and outlet of the chamber system were directly compared with those collected by an independent Hg sampling system. To collect more replicate samples for each sampling system, we modified our typical sampling procedures of each sampling system. For the chamber system, air samples were drawn from both inlet and outlet ports with the bottom of the chamber slightly open to the ambient air. Six replicate samples were collected simultaneously near the chamber inlet using our gradient sampling system for the purpose of comparison. These bias tests between two sampling techniques were performed at both laboratory and

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**TABLE II**

Results of laboratory and field blank flux measurements of $Hg^0$ using ORNL FEP flux chamber.

| Date | $Hg^0$ concentrations Mean ± 1 SE (ng $m^{-3}$) Inlet | $Hg^0$ concentrations Mean ± 1 SE (ng $m^{-3}$) Outlet | Statistical significance* ($P < x$) | Blank Flux (ng $m^{-2}$ $h^{-1}$) |
|---|---|---|---|---|
| (1) Flux chamber blanks (Laboratory measurements) | | | | |
| 6/23/93 | 17.35±0.17 | 17.78±0.02 | 0.1 | 0.7 |
| 10/27/93 | 7.69±0.04 | 7.61±0.14 | ns | -0.2 |
| 10/27/93 | 7.37±0.29 | 6.95±0.02 | 0.15 | -0.9 |
| 11/1/93 | 6.47±0.13 | 6.60±0.09 | ns | 0.3 |
| 11/1/93 | 7.36±0.22 | 7.16±0.10 | ns | -0.4 |
| 11/1/93 | 7.13±0.10 | 7.20±0.06 | ns | 0.1 |
| 11/1/93 | 7.52±0.16 | 7.02±0.03 | 0.15 | -0.7 |
| Mean ± 1 SD of chamber blank fluxes (in absolute terms) = 0.5 ± 0.3 ng $m^{-2}$ $h^{-1}$ | | | | |
| (2) Flux chamber blanks (Field measurements) | | | | |
| 3/11/93 | 3.21±0.14 | 3.68±0.15 | 0.05 | 1.4 |
| 11/2/93 | 2.75±0.23 | 3.20±0.36 | ns | 1.0 |
| 11/2/93 | 2.36±0.10 | 2.62±0.15 | 0.15 | 0.6 |
| 11/12/93 | 4.17±0.09 | 4.61±0.07 | 0.05 | 1.0 |
| Mean ± 1 SD of chamber blank fluxes (in absolute terms) = 1.0 ± 0.3 ng $m^{-2}$ $h^{-1}$ | | | | |

* denotes the probability that two variables are not significantly different

field site. Results from three laboratory bias tests showed that differences between two sampling methods were not statistically significant. (During these tests, $Hg^o$ concentrations in lab air generally ranged from 15 to 23 ng $m^{-3}$.) In contrast to these observations, statistical analysis on our field bias test results showed discernible differences between the two methods (Table III). The initial tests performed on June 15, 1994 (Table III) show that the concentrations of $Hg^o$ collected by the chamber system are measurably larger than those measured by the reference sampling system and suggest that the extent of disagreement may decrease with time (probably due to enhanced system flushing with extended operation). The differences between laboratory and field bias tests suggest that our flux chamber system can be more easily subject to contamination under clean conditions ($Hg^{o}$ concentration from background field site ~1.5 ng $m^{-3}$) than under high $Hg^{o}$ levels associated with the laboratory air. In an effort to eliminate the possible contamination of the chamber system, we detached, acid-washed, and oven-dried all Teflon connectors attached to the body of the flux chamber. The effect of acid-washing was quite dramatic as seen from our June 21 tests (Table III). The bias between chamber/gradient system decreased from 40 to 90% (before washing) to approximately ± 5 % (after washing). Similarly, the results of our statistical analysis also show the effect of acid-washing such that differences between two methods become less significant between before and after acid-washing ($P < 0.05$ to $P < 0.10$).

TABLE III

Results of field bias tests between flux chamber and an independent gradient sampling system on June 1994

| Date | Time (EST) | Mean $Hg^{o}$ (ng $m^{-3}$) | Method | N | SE | RSE (%) | Sig ($P < x$) |
|---|---|---|---|---|---|---|---|
| | | (1) Before acid-washing | | | | | |
| 6/15/94 | 0949/1119 | 2.41 | G* | 6 | 0.08 | 3.1 | 0.05 |
| 6/15/94 | 0949/1119 | 4.57 | FC** | 6 | 0.11 | 2.3 | |
| 6/15/94 | 1128/1256 | 2.19 | G | 6 | 0.03 | 1.6 | 0.05 |
| 6/15/94 | 1128/1256 | 2.96 | FC | 6 | 0.06 | 2.1 | |
| | | (2) After acid-washing | | | | | |
| 6/21/94 | 1055/1240 | 5.49 | G | 4 | 0.18 | 3.3 | 0.10 |
| 6/21/94 | 1055/1240 | 5.83 | FC | 5 | 0.14 | 2.4 | |
| 6/21/94 | 1247/1419 | 3.50 | G | 4 | 0.11 | 3.0 | 0.10 |
| 6/21/94 | 1247/1419 | 3.33 | FC | 5 | 0.03 | 1.0 | |

* denotes gradient sampling system.

** denotes flux chamber system.

Despite the potential problems of creating artificial environmental conditions, flux chamber techniques may still be favored over other flux measurement techniques due

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## Education

| | | | |
|---|---|---|---|
| Duke University | **B.S.** | 1969 | Chemistry |
| Florida State University | **M.S.** | 1973 | Chemical Oceanography |
| Florida State University | **Ph.D.** | 1979 | Geochemistry |

## Professional Experience

| | |
|---|---|
| 1971-1974 | **Graduate Fellow**, Florida State University Department of Oceanography, Tallahassee. |
| 1974-1980 | **Research Associate**, Oak Ridge National Laboratory, Oak Ridge, TN. |
| 1980-1986 | **Research Staff Member**, Oak Ridge National Laboratory, Oak Ridge, TN. |
| 1987 | **Visiting Professor,** Institute of Bioclimatology, University of Göttingen, Göttingen, Germany. |
| 1994 | **Visiting Scientist**, Swedish Environmental Research Institute, Göteborg, Sweden. |
| 1995 | **Visiting Professor**, University of Lund, Lund, Sweden. |
| 1996-1997 | **Visiting Scientist**, Institute of Hydrophysics, GKSS Laboratory, Geestacht, Germany |
| 1995-*present* | **Adjunct Professor**, School of Public Health, University of Michigan, Ann Arbor, MI (1996-), and Graduate Program in Ecology, The University of Tennessee, Knoxville, TN |
| 1987-*present* | **Senior Research Staff Member**, and former Group Leader for Atmospheric and Biogeochemical Cycling (1987-1996), Environmental Sciences, Division, Oak Ridge National Laboratory, Oak Ridge, TN. |

## Honors and Awards

Fellow, American Association for the Advancement of Science, 1992
Ernest Orlando Lawrence Award Nomination, 1990
Alexander von Humboldt Foundation Fellowship Award, 1986-1987
Martin Marietta Corporation Technical Achievement Awards, 1985 and 1986
Oak Ridge National Laboratory Environmental Sciences Achievement Award, 1984
American Men and Woman of Science, Who's Who in Science and Technology
Oak Ridge National Laboratory Significant Event Awards: 1983, 1985, 1992
National Defense Education Act Fellowship, 1971-1974

## Professional Activities

Associate Editor, Environmental Reviews, National Research Council of Canada
Editorial Board, Science of the Total Environment, International Journal
Co-Chairman, International Conference on Mercury as A Global Pollutant, 1995-1996
Director for Atmospheric Research, Integrated Forest Study, 1986-1990
Chairman, United States National Atmospheric Deposition Program, 1988-1989
Conference Chairman (1986-87) and Member of Conference Honorary Committee (since 1983) for the International Conference on Heavy Metals in the Environment

# SIGNIFICANT CAREER ACCOMPLISHMENTS RELATED TO MERCURY RESEARCH

Dr. Lindberg is internationally recognized for his record of accomplishments in the environmental fields of atmosphere-surface exchange, trace metal geochemistry, and biogeochemical cycling. His research has earned him numerous awards, fellowships, and invited visiting professorships in this country and abroad.

## · Interactions between Mercury and Natural Organic Matter (1972–74)

Early in his career, Dr. Lindberg discovered the importance of mercury binding with dissolved organic matter in water and in sediments. His observation was essential in understanding the ways in which mercury, a highly toxic and pervasive contaminant in food chains and the environment, can be mobilized. His publications on this subject include an important article which has been cited in the literature more than 65 times to date. Following this work, he was invited to an international symposium to present the first summary of the geochemistry of mercury in the estuarine environment.

## · Environmental Volatilization of Mercury (1975–82)

Dr. Lindberg joined the Environmental Sciences Division at ORNL in 1974 and assumed primary responsibility for the mercury studies supported by the National Science Foundation (NSF) program: Research Applied to National Needs. In this capacity, he devised revolutionary ways to quantify the passive emission of mercury from industrial solid waste sites, a previously unrecognized pathway for release to the environment. He published this research in the British journal *Nature* and elsewhere. The NSF project was a unique, pioneering effort for both NSF and ORNL. From the time of his arrival, Dr. Lindberg made significant contributions to the project, bringing in new ideas on the atmospheric emission of mercury from wastes produced in the chemical and mining industries in the United States and Europe. He designed, carried out, and published research that proffered the first measurements of mercury volatilization from solid wastes stored at a chloralkali facility in the United States and from wastes stored at the world's largest cinnabar mine, in Almaden, Spain. On the basis of his early pioneering work, Dr. Lindberg has been invited in more recent years to consult with researchers in diverse European countries on the issue of mercury emissions.

## · Global Mercury Cycling (1990–present)

In 1990, after 10 years of research on acid rain, Dr. Lindberg returned to studies of the atmospheric behavior of mercury, and since then he has developed a world-class reputation as an expert on the physical and chemical factors that control the cycling of this toxic element in the environment. He discovered that dry deposition of gaseous mercury species to environmental surfaces is a major part of the cycling. Furthermore, he discovered that unanticipated pathways for emission of mercury from environmental media, such as vegetation, are of great importance in remobilizing the metal; this last point is in direct opposition to the conventional belief that environmental media act as sinks, rather than sources, for mercury. Again, innovative techniques for measuring minute amounts of mercury with extreme precision—a precision previously unavailable to researchers—have been developed by Dr. Lindberg and his group. His productivity in publishing articles on this new work is impressive, with more than 20 open literature papers published since 1994.

Dr. Lindberg has become one of the world's foremost authorities on air-surface exchange and speciation of tropospheric mercury. He has brought exciting new methods to bear on the issue of global mercury cycling, developing the first micrometeorological gradient method to directly measure atmospheric fluxes of mercury. He provided the first direct evidence of reactive, water-soluble mercury compounds in the vapor phase in ambient air, and the first direct in-air method to quantify Hg emission from environmental surfaces. These findings have led to exciting new discoveries of unanticipated pathways of mercury emission from the natural environment, discoveries that challenge established doctrine about mercury behavior and explain long-standing discrepancies in the results of other mercury research. Groups in Sweden, Russia, Canada, Germany, and the United States have sought out Dr. Lindberg for technology transfer of his many new methods. His new work has already earned him dozens of invitations to participate on committees and panels, speak at conferences, and participate in funded sabbaticals, including invitations to:

(1) chair the 1996 International Mercury Conference in Hamburg;
(2) join the organizing committees for four international conferences in this country, Canada, Sweden, Germany, and Russia;
(3) participate on the Expert Panel on Atmospheric Mercury;
(4) present keynote addresses at two international meetings in Europe and Asia;
(5) develop an international atmospheric mercury project for the International Global Atmospheric Chemistry Program;
(6) chair international review teams for federal agencies in Sweden and Germany;
(7) present over 25 seminars at universities and academic institutes in the United States and Europe; and
(8) spend funded sabbaticals as a visiting scientist at the Swedish Environmental Research Institute, the Lund University, the Meteorological Institute of Stockholm, and the Geestacht National Physics Research Center (GKSS) in Germany.

Publications

Six books edited, and over 160 papers, book chapters, and reports published, including over 75 in refereed journals, in the fields of atmosphere/surface exchange, trace metal chemistry, and biogeochemical cycling. Invited lecturer and plenary speaker on atmospheric deposition and canopy interactions at over 25 institutes and conferences outside of North America.

Funded Proposals, Contracts, and Grants:

**1970-1979**

1975-1976, "Trace Element Emissions from Coal Fired Power Plants" (with AW Andren). US Dept. of Energy (DOE) ($50,000).

1975-1976, "Geochemical Cycling of Hg in a River-Reservoir System" (with RR Turner). NSF-RANN ($90,000).

1978, "Mercury Emissions from Mine Spoils" (with D Jackson). NSF-RANN ($75,000).

1977-1980, "Trace Element Deposition, Stream Chemistry, and Cycling in Forest Watersheds" (with RR Turner). US DOE ($1,000,000).

**1980-1989**

1981-1982, "Dry Deposition to Petri Dish and Foliar Surfaces" (with CI Davidson). US Environmental Protection Agency (EPA) ($30,000).

1981-1983, "Acid Deposition/Forest Canopy Interactions: Mechanisms of Sulfur and Nitrogen Deposition to Forests." Electric Power Research Institute (EPRI) ($675,000).

1981-1984, "Atmosphere/Canopy Interactions: Wet Deposition and Rain Chemistry." US DOE ($900,000).

1985-1989, "Integrated Forest Study (IFS) of the Effects of Atmospheric Deposition on Forest Nutrient Cycles" (with DW Johnson). EPRI ($11,600,000).

1985-1990, "Atmosphere/Canopy Interactions: Development of Surface Analysis Methods for Dry Deposition." US DOE ($1,020,000).

1987, "Deposition and Atmospheric Chemistry of Nitrogen Compounds" (with G. Gravenhorst). West German Federal Ministry for Technology and Alexander von Humboldt Foundation ($45,000).

1989, "Atmospheric Deposition and Red Spruce Nutrition in the Great Smoky Mountains National Park" (with DW Johnson and H Van Miegroet). USDA Forest Service ($225,000).

**1990-1999**

1990, "A Soft Ionization Mass Spectrometer for the Simultaneous, Real-time Analysis of Biogenic Non-methane Hydrocarbons in the Forest Canopy Airspace" (with M Payne, W Chen, and P Hansen). ORNL Seed Money Committee ($100,000).

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1990-1991, "Development of Methods for Network Sampling of Air Toxics in Precipitation" (with S. Vermette. USGS ($70,000).

1991-1994, "Atmosphere/Canopy Interactions: Surface Analysis of Dry Deposition in Complex Terrain". US DOE ($600,000).

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1994-1995, "Aerosols at the Sea/Land Interface". Swedish NFR (NSF) (30,000Kr).

1996, "Emission of Mercury over Great Waters". USEPA ($18,000).

1996-1997, "Emission of Mercury from soils in the Elbe River Floodplain". German BMFT (15,000DM).

1996-1999, "Mercury Emissions from Wetlands in the Florida Everglades". South Florida Water Management District ($400,000).
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1996-1999, "Natural Mercury Emissions from Soils (NaMES)". EPRI ($250,000).
1997-1999, "Natural Mercury Emissions in the Lake Superior Watershed". Univ. of Michigan ($250,000).
1998-1999, "Speciation of Reactive Gaseous Mercury in Ambient Air." Florida DEP/USEPA ($0,000; pending).

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Invited Presentations

"Mercury air/surface exchange in the Everglades Nutrient Removal Project site." Presentation to Annual Review Florida Mercury Programs, Madison, WI, May, 1997.

"The re-emission of mercury from natural surfaces: A critical link in the global mercury cycle." Invited presentation at Mercury Elimination and Reduction Symposium, Toronto, May, 1997.

"Multiple talks on the application of Tekran automated analyzers to mercury studies." Invited presentations at First Tekran Workshop, Toronto, May, 1997.

"The Role of a Center for the Environment on a University Campus." Invited seminar, Cornell University, March, 1997.

"Processes of mercury emission from terrestrial and wetland ecosystems." Invited seminar, Dept. of Soil, Crop, and Atmospheric Sciences, Cornell University, March, 1997.

"Thoughts on the re-emission of mercury from coal combustion solid wastes." Invited presentation at the Clean Air Advisory Board workshop on mercury emission controls (given in absentia by D. Porcella), Chicago, January, 1997.

"Micrometeorological measurements of mercury evasion over a subtropical wetland and a boreal forest lake." Invited presentation, Environmental Toxics Seminar, Cornell University, Nov., 1996.

"The application of surface analysis methods to quantification of coarse particle dry deposition of phosphorus in the Florida Everglades, Invited presentation, Nutrient Loading Working Group, South Florida Water Management District, West Palm Beach, November, 1996.

"The influence of solar radiation on mercury emission from soils and waters." Invited presentation at the University of Nevada- Reno, Sept., 1996.

"The biogeochemical cycle of mercury in forests." Invited presentation at the Desert Research Institute, Reno, NV, Sept., 1996.

"The mobility of mercury in contaminated and background soils: Is emission the dominant pathway over subsurface transport?" Invited presentation at the USEPA/DOE Workshop on Mercury Speciation, Denver, CO, Sept., 1996.

"The E-MASE project: Mercury evasion in the Florida Everglades Nutrient Removal project", and "Recent developments in the EPRI MASE project." Invited presentations at the All-Florida Investigators Workshop, Orlando, FL, April, 1996.

"Strategies for development of a mercury wet deposition network in Central and South America", invited presentation at the Americas-MDN Workshop, Montreal, Canada, Feb., 1996.

"An overview of the global cycling of atmospheric mercury", Invited presentation to the NAFTA Commission for Environmental Cooperation, North American Working Group on the Sound Management of Chemicals, Montreal, Canada, Feb., 1996.

"Emissions of mercury from natural surfaces in the environment." Invited seminar, Departmental Colloquium, Department of Geology, Florida State University, Tallahassee, November, 1995.

"Atmospheric speciation and air/surface exchange of mercury vapor." Invited seminar, Atmospheric Environment Service, Environment Canada, Toronto, Canada, October, 1995.

"The role of air/surface exchange in the biogeochemical cycle of mercury." Invited presentation at the Atmospheric Sciences Department, University of Michigan, Ann Arbor, September, 1995.

"Dry and wet deposition mechanisms for mercury." Invited presentation at the Canadian Mercury Network Symposium, Toronto, Canada, September, 1995.

"Forests and the global biogeochemical cycling of mercury." Invited plenary paper at the NATO Advanced Science Institute Expert Workshop on Regional and Global Mercury Cycles, Novosibersk, Siberia, July, 1995.

"Methods to measure the lake surface evasion of Hg." Invited seminar at the South Florida Water Management District, West Palm Beach, March, 1995.

"Air/surface exchange and atmospheric speciation of Hg." Invited seminar at Frontier Geosciences, Seattle, February, 1995.

"Evasion of Hg at Lake Gardsjön, Sweden: The EPRI G-MASE Project." Invited seminar at the Swedish Environmental Research Institute, Goteborg, Sweden, February, 1995.

"A review of recent research on mercury at Oak Ridge National Laboratory." Invited plenary lecture at the International Review of Mercury Research at GKSS, Geesthacht Physics Research Center (GKSS), Hamburg, Germany, May, 1994.

"The role of surface re-emission in the global Hg cycle", Invited seminar in the Meteorological Institute of Stockholm University Seminar Series, Stockholm, Sweden, May, 1994.

"Development of micrometeorological methods to quantify air/surface exchange of mercury over forest soils and canopies." Invited seminar at the Department of Inorganic Chemistry at Chalmer's Technical University, Goteborg, Sweden, May, 1994.

"Micrometeorological and chamber measurements of the air/surface exchange of mercury." Invited seminar at the Air Toxics Lab, School of Public Health, University of Michigan, Ann Arbor, MI, Jan. 1994.

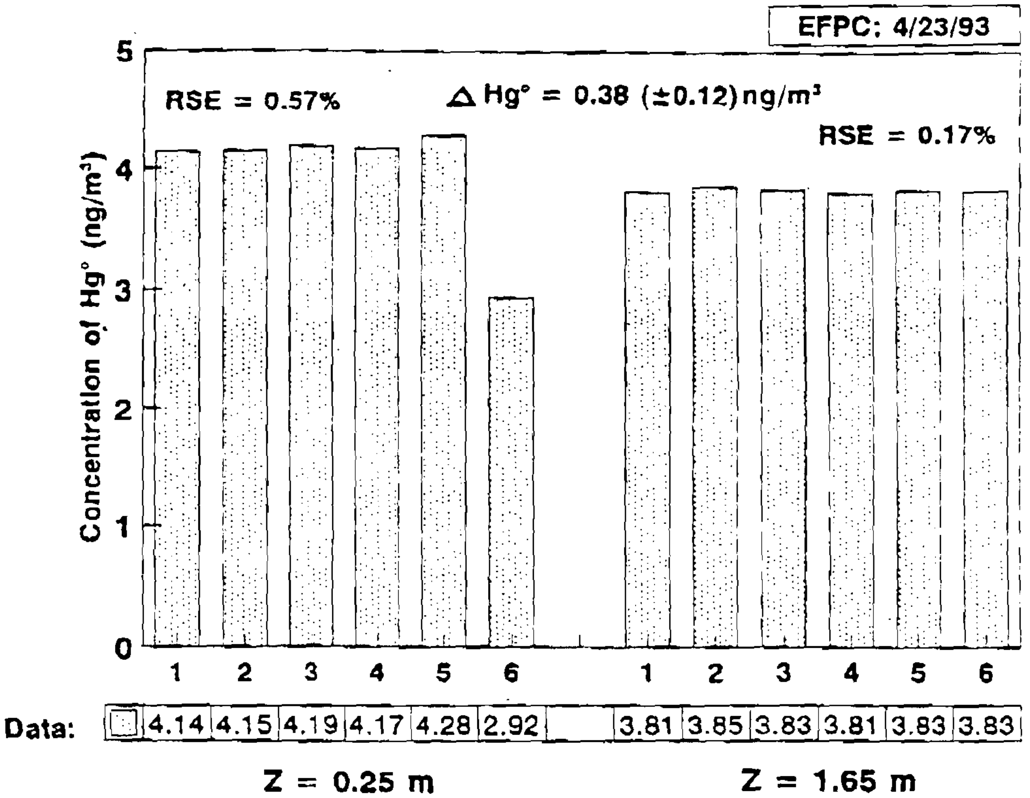

**FIGURE 2. Airborne Hg concentration data collected with the ORNL six-port mass flow controlled sampler at two heights above Hg-contaminated soils on April 23, 1993, showing the precision of the replicate samples (as RSE) and the resulting concentration gradient and its 90% CI. Sample 6 at 0.25 m height (concentration of 2.92) was identified as a statistical outlier and deleted.**

using peak-area integration) and was found to be comparable to using aqueous standards in a recent international intercalibration (*29*). The absolute detection limit for $Hg^0$ (three times the instrumental noise) is ~0.2 pg (*26*), and the working limit in our lab based on gold trap blanks is ~1–2 pg (compared to typical sample signals of 50–200 pg). All handling and analysis of gold traps in our laboratory was done in class 100 laminar flow clean air benches (particulate Hg <0.001 ng/m$^3$, $Hg^0$ ~10–20 ng/m$^3$).

Gradient methods require precise measurements of atmospheric concentrations to quantify small differences with minimal uncertainty. The limitation on precise $Hg^0$ determination lies largely with sample collection and handling. Previous measurements of $Hg^0$ concentration gradients utilized a single sampler at each height (*10, 17*), as often done in studies of other trace gases (e.g., refs 30 and 31). This approach is inadequate to differentiate between actual concentration differences and analytical or sampling artifacts (*32*). To reduce the uncertainty of the computed Hg gradients, a portable sampling system was built to collect six replicate air samples using a manifold connecting six mass flow controllers to a small vacuum pump. We have published the design of this system, and tests showing that biases between adjacent systems were small (~0.01–0.03 ng Hg/m$^3$) and insignificant (*20*). Data outliers ($n$ = 15 out of ~300 total analyses) were detected using the $Q$ and $T_n$ tests for small sample sizes (*33*).

Figure 2 illustrates the original $Hg^0$ concentration data for measurements at two heights on April 23, illustrating the precision of our approach and the consistency of the gradient from independent replicate samples. This precision is possible in part because of clean handling and analysis methods. The mean of three gold trap field blanks analyzed on April 23 was <1% of the sample signal (1.5 pg compared to samples of ~260 pg). We have achieved consistently high precision results (<~3%, generally 0.5–1.5% relative standard errors) at both contaminated and background sites (*21, 22*).

**Modified Bowen Ratio Method.** The modified Bowen ratio (MBR) method is widely used for inferring fluxes of trace gases from concentration gradients (e.g., refs 32 and 34). The typical application of the technique requires direct measurements of the vertical turbulent fluxes of sensible ($F_s$) and latent heat ($F_l$) using eddy correlation with fast-response instrumentation (e.g., see ref 35). Vertical gradients of temperature ($\Delta\theta = d\theta/dz$) are simultaneously measured along with the vertical concentration gradients of the trace gas of interest ($\Delta\chi$). The average flux of the gas is then determined as

$$F_z = F_s \frac{\Delta\chi}{\Delta\theta} \tag{1}$$

The application of the MBR approach used here addresses a potential problem with one assumption of gradient methods, that the transport characteristics for heat and scalars are similar. Instead, we used direct measurements of gradients and fluxes of trace gases such as water vapor and $CO_2$ to derive turbulent mixing coefficients for $Hg^0$ (*36*). Bartell et al. (*37*) discuss several advantages of this approach. In our study, $Hg^0$ gradients were measured concurrently with fluxes and vertical gradients of $CO_2$ and $H_2O$ vapor over the same height interval using infrared gas analyzers and eddy correlation with fast-response instrumentation as described in Baldocchi and Meyers (*38*). The air–surface exchange rates of $Hg^0$ were then inferred from the following relationship:

$$F_{Hg} = K_W \Delta Hg \tag{2}$$

where ($F_{Hg}$) is the flux of mercury, ($\Delta Hg = dHg/dz$) is the vertical concentration gradient of $Hg^0$, and ($K_W$) is the turbulent transfer coefficient that was calculated from the ratio of the $H_2O$ vapor flux and its gradient:

$$K_W = \frac{F_{H_2O}}{\Delta H_2O} \tag{3}$$

where $\Delta H_2O = dH_2O/dz$ (or substitute $CO_2$ for $H_2O$). Heat fluxes were also measured and used to assure an acceptable energy balance for the site under the conditions of the measurements. The heat flux corrections to the water vapor flux measurements (*39*) were applied and were less than 10% of the measured water flux.

Most applications of MBR have been used above crops and forests. Within the trunk space of a forest in the absence of local sources or sinks, flux–gradient relationships are not an appropriate framework to characterize turbulent transport (*40*). However, soils beneath forest canopies are important sources and sinks for some trace gases (*38, 41, 42*), and the flux–gradient framework necessary for the MBR approach is useful near the soil surface. For example, several studies beneath plant canopies have shown pollutant concentrations that roll off sharply close to the ground (*43–45*). Since both fluxes and gradients (which are commensurate with the fluxes) can be measured above the forest floor, the MBR technique should be applicable. Tests of this approach over soils under the closed forest canopy at nearby Walker Branch Watershed have been quite successful (*38*).

During the spring, the wet soils at EFPC generally yielded insignificant fluxes of $CO_2$, and we computed all mixing coefficients for this study from our water vapor data. In a subsequent study, we found good agreement between values of $K_w$ and $K_{CO_2}$ over upland forest soils (*21*). The concentration gradients were computed from measurements at 0.25 and 1.65 m above the surface (an intermediate height was sampled twice for QA purposes). Eddy fluxes of heat and $H_2O$ vapor and routine meteorological data (wind speed, wind direction, air temperature, relative humidity, and solar radiation) were measured continuously at 1.65 m, and soil temperature was recorded at the surface, 2 cm, and 6 cm (*38*). The gradients and fluxes of $H_2O$ vapor were averaged over 30-min intervals, which provided an important degree of noise reduction (*36*), and the mixing coefficients were computed over these 30-min averaging periods. Mixing coefficients corresponding to each Hg gradient (which were measured over intervals of ~1–3 h to achieve the necessary analytical precision) were computed from the means of the corresponding water vapor gradients and fluxes. Since all concentration gradients in this study were measured over the same height interval, we will express the gradients throughout this paper in terms of the absolute concentration differences measured (i.e., $C_{0.25m} - C_{1.65m}$, in units of $ng/m^3$, understood to be $ng/m^3$ per 1.40 m height interval).

## Results and Discussion

We measured $Hg^0$ gradients over soils during 26 experiments from March 29 to May 13 and from Oct 8 to 15, 1993 (Table 1). The $Hg^0$ concentrations over the contaminated soils were generally above background, averaging 3.48 $ng/m^3$ (range 1.70–11.50). By comparison, the concentrations of $Hg^0$ at the Walker Branch Watershed research site 2.5 km southwest of EFPC were near continental background during this period (mean 2.15, range 1.52–3.68 $ng/m^3$; *21*). We detected significant ($p < 0.05$) concentration gradients in $Hg^0$ during all measurements at EFPC, with consistently higher concentrations at 25 cm height than at 165 cm, indicating net emissions of $Hg^0$. The measured concentration gradients ranged from 0.12 to 5.60 $ng/m^3$ and averaged nearly 1 $ng/m^3$. The computed $Hg^0$ emission rates from the surrounding soils ranged from 7.0 to 232.6 $ng\ m^{-2}\ h^{-1}$ (Figure 3) and were somewhat higher during the spring than during the fall. Both the gradients and the fluxes at EFPC exceed those measured over background soils at Walker Branch Watershed by about an order of magnitude (*21*). Confidence intervals computed for the gradients from the replicate concentration data suggest the overall sampling plus analytical uncertainties are generally 10–20% (Table 1).

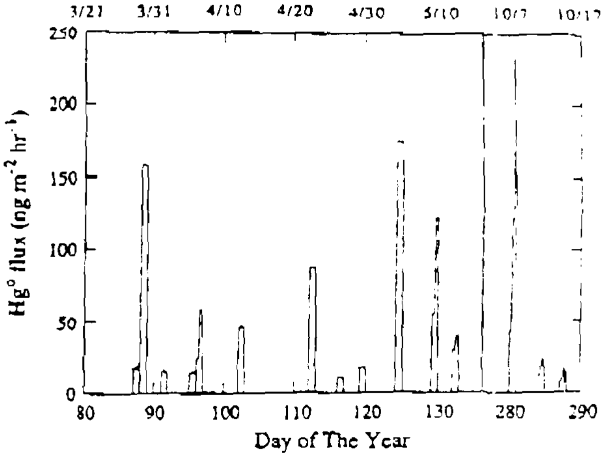

**FIGURE 3.** Temporal trend in fluxes of $Hg^0$ measured over contaminated soils during the spring and fall of 1993.

**Tests of Gradient Data.** One objective of this study was to test our ability to measure actual concentration gradients of $Hg^0$ in air, as opposed to artifacts of sampling and analytical procedures. Although our methods provide sufficient precision to detect small gradients with reasonable uncertainty, we need to demonstrate that the gradients provide a meaningful signal of the source strength of the soils within the measurement area. Principles of gaseous turbulent exchange and Hg chemistry suggest three simple tests which would help to validate our data: (a) the level of contamination of EFPC soils with elemental Hg suggests that these soils would consistently act as a source of $Hg^0$ to the atmosphere due to volatilization (metallic Hg exhibits a vapor pressure of 0.0012 mm at 20 °C). The measured $Hg^0$ gradients between 0.25 and 1.65 m were consistent with this expectation under a variety of conditions (Table 1); (b) trace gas concentrations measured near a known source are predictably influenced by atmospheric turbulence such that concentration gradients should decrease with increasing turbulence due to mixing. Figure 4 illustrates that our $Hg^0$ and water vapor data fit the expected relationship; and (c) on two separate occasions we measured $Hg^0$ at three levels and found concentrations which uniformly decreased with height, consistent with turbulent diffusion (Figure 5).

# APPENDIX A-2

# NIOSH ANALYTICAL METHOD 6009 FOR MERCURY

# MERCURY 6009

Hg MW: 200.59 CAS: 7439-97-6 RTECS: OV4550000

**METHOD: 6009, Issue 2** **EVALUATION: PARTIAL**

**Issue 1: 15 May 1989**
**Issue 2: 15 August 1994**

| | |
|---|---|
| OSHA : | C 0.1 mg/m$^3$ (skin) |
| NIOSH: | 0.05 mg/m$^3$ (skin) |
| ACGIH: | 0.025 mg/m$^3$ (skin) |

PROPERTIES: liquid; d 13.55 g/mL @ 20 °C; BP 356 °C; HP −39 °C; VP 0.16 Pa (0.0012 mm Hg; 13.2 mg/m$^3$) @ 20 °C; Vapor Density (air = 1) 7.0

SYNONYMS: quicksilver

## SAMPLING

| | |
|---|---|
| SAMPLER: | SOLID SORBENT TUBE<br>(Hopcalite in single section, 200 mg) |
| FLOW RATE: | 0.15 to 0.25 L/min |
| VOL-MIN: | 2 L @ 0.5 mg/m$^3$ |
| -MAX: | 100 L |
| SHIPMENT: | routine |
| SAMPLE STABILITY: | 30 days @ 25 °C [1] |
| FIELD BLANKS: | 2 to 10 field blanks per set |
| MEDIA BLANKS: | at least 3 per set |

## ACCURACY

| | |
|---|---|
| RANGE STUDIED: | 0.002 to 0.8 mg/m$^3$ [2]<br>(10-L samples) |
| BIAS: | not significant |
| OVERALL PRECISION ($\hat{S}_{rT}$): | not determined |
| ACCURACY: | not determined |

## MEASUREMENT

| | |
|---|---|
| TECHNIQUE: | ATOMIC ABSORPTION, COLD VAPOR |
| ANALYTE: | elemental mercury |
| DESORPTION: | conc. $HNO_3$/HCl @ 25 °C,<br>dilute to 50 mL |
| WAVELENGTH: | 253.7 nm |
| CALIBRATION: | standard solutions of $Hg^{2+}$ in 1% $HNO_3$ |
| RANGE: | 0.1 to 1.2 µg per sample |
| ESTIMATED LOD: | 0.03 µg per sample |
| PRECISION ($\hat{S}_r$): | 0.042 @ 0.9 to 3 µg per sample [4] |

**APPLICABILITY:** The working range us 0.01 to 0.5 mg/m$^3$ for a 10-L air sample. The sorbent material irreversibly collects elemental mercury. A prefilter can be used to exclude particulate mercury species from the sample. The prefilter can be analyzed by similar methodology. The method has been used in numerous field surveys [3].

**INTERFERENCES:** Inorganic and organic mercury compounds may cause a positive interference. Oxidizing gases, including chlorine, do not interfere.

**OTHER METHODS:** This replaces method 6000 and its predecessors, which required a specialized desorption apparatus [4,5,6]. This method is based on the method of Rathje and Marcero [7] and is similar to the OSHA method ID 145H [2].

**REAGENTS:**

1. Water, organics-free, deionized.
2. Hydrochloric acid (HCl), conc.
3. Nitric acid ($HNO_3$), conc.
4. Mercuric oxide, reagent grade, dry.
5. Calibration stock solution, $Hg^{2+}$, 1000 $\mu$g/mL. Commercially available or dissolve 1.0798 g of dry mercuric oxide (HgO) in 50 mL of 1:1 hydrochloric acid, then dilute to 1 L with deionized water.
6. Intermediate mercury standard, 1 $\mu$g/mL. Place 0.1 mL 1000 $\mu$g/mL stock into a 100 mL volumetric containing 10 mL deionized water and 1 mL hydrochloric acid. Dilute to volume with deionized water. Prepare fresh daily.
7. Stannous chloride, reagent grade, 10% in 1:1 HCl. Dissolve 20 g stannous chloride in 100 mL conc. HCl. Slowly add this solution to 100 mL deionized water and mix well. Prepare fresh daily.
8. Nitric acid, 1% (w/v). Dilute 14 mL conc. $HNO_3$ to 1 L with deionized water.

**EQUIPMENT:**

1. Sampler: glass tube, 7 cm long, 6-mm OD, 4-mm ID, flame sealed ends with plastic caps, containing one section of 200 mg Hopcalite held in place by glass wool plugs (SKC, Inc., Cat. #226-17-1A, or equivalent).
   NOTE: A 37-mm, cellulose ester membrane filter in a cassette preceding the sorbent may be used if particulate mercury is to be determined separately.
2. Personal sampling pump, 0.15 to 0.25 L/min, with flexible connecting tubing.
3. Atomic absorption spectrophotometer with cold vapor generation system (see Appendix) or cold vapor mercury analysis system.*
4. Strip chart recorder, or integrator.
5. Flasks, volumetric, 50-mL, and 100-mL.
6. Pipet, 5-mL, 20-mL, others as needed.
7. Micropipet, 10- to 1000-$\mu$L.
8. Bottles, biological oxygen demand (BOD), 300-mL.

* See SPECIAL PRECAUTIONS

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**SPECIAL PRECAUTIONS:** Mercury is readily absorbed by inhalation and contact with the skin. Operate the mercury system in a hood, or bubble vented mercury through a mercury scrubber.

---

**SAMPLING:**

1. Calibrate each personal sampling pump with a representative sampler in line.
2. Break ends of sampler immediately prior to sampling. Attach sampler to pump with flexible tubing.
3. Sample at an accurately known rate of 0.15 to 0.25 L/min for a total sample size between 2 and 100 L.
   NOTE: Include a minimum of three unopened sampling tubes from the same lot as the samples for use as media blanks.
4. Cap sampler and pack securely for shipment.

**SAMPLE PREPARATION:**

5. Place the Hopcalite sorbent and the front glass wool plug from each sampler in separate 50-mL volumetric flasks.
6. Add 2.5 mL conc. $HNO_3$ followed by 2.5 mL conc. HCl.
   NOTE: The mercury must be in the oxidized state to avoid loss. For this reason, the nitric acid must be added first.
7. Allow the sample to stand for 1 h or until the black Hopcalite sorbent is dissolved. The solution will turn dark brown and may contain undissolved material.
8. Carefully dilute to 50 mL with deionized water. (Final solution is blue to blue-green).
9. Using a volumetric pipet, transfer 20 mL of the sample to a BOD bottle containing 80 mL of deionized water. If the amount of mercury in the sample is expected to exceed the standards, a smaller aliquot may be taken, and the volume of acid adjusted accordingly. The final volume in

the BOD bottle must be 100 mL. To prevent possible loss of mercury during transfer, place the pipet tip below the surface of the liquid in the BOD bottle.

## CALIBRATION AND QUALITY CONTROL:

10. Prepare a minimum of two series (six levels each) of working standards covering the range 0.01 to 0.5 µg Hg per aliquot by adding known amounts of the intermediate standard to BOD bottles containing enough 1% nitric acid to bring the final volume to 100 mL.
11. Analyze the working standards together with the samples and blanks (steps 13 through 16). Analyze full set of standards at the beginning of the run, and a second set at the end of the run. Additional standards may be run intermediately during the analysis to confirm instrument response.
12. Prepare calibration graph (peak height vs. solution concentration, µg/sample).

## MEASUREMENT:

13. Zero the spectrophotometer by removing the bubbler from the BOD bottle, allowing the baseline on the recorder to stabilize.
14. Place the bubbler in a BOD bottle containing 0.5 µg mercury in 100 mL 1% nitric acid. Adjust the spectrophotometer so that it will give a 75% to full-scale deflection of the recorder.
15. Vent the mercury vapor from the system.
16. Analyze standards, samples and blanks (including media blanks).
    a. Remove the bubbler from the BOD bottle.
    b. Rinse the bubbler with deionized water.
    c. Allow the recorder tracing to establish a stable baseline.
    d. Remove the stopper from the BOD bottle containing the next sample to be analyzed. Gently swirl the BOD bottle.
    e. Quickly add 5 mL 10% stannous chloride solution.
    f. Quickly place the bubbler into the BOD bottle.
    g. Allow the spectrophotometer to attain maximum absorbance.
    h. Vent the mercury vapor from the system.
    i. Place the bubbler into an empty BOD bottle. Continue venting the mercury until a stable baseline is obtained.
    j. Close the mercury vent.

## CALCULATIONS:

17. Calculate the amount of mercury in the sample aliquot (W, µg) from the calibration graph.
18. Calculate the concentration C ($mg/m^3$), of mercury in the air volume sampled, V (L):

$$C = \frac{W \cdot \frac{V_s}{V_a} - B}{V}.$$

Where: Vs = original sample volume (step 8; normally 50 mL)
Va = aliquot volume (step 9; normally 20 mL)
B = average amount of mercury present in the media blanks

## EVALUATION OF METHOD:

Rathje and Marcero originally used Hopcalite (MSA, Inc.) as the sorbent material [7]. Later, Hopcalite was shown superior to other methods for the determination of mercury vapor [8]. Atmospheres of mercury vapor for the study were dynamically generated in the range 0.05 to 0.2 mg/m$^3$ and an adsorbent tube loading of 1 to 7 µg was used. The Hydrar material sometimes used is similar to Hopcalite. No significant difference in the laboratory analysis of mercury collected on the two sorbent materials was observed [9]. OSHA also validated a method for mercury using Hydrar [2]. An average 99% recovery, with $\bar{S}_r$ = 0.042, was seen for 18 samples with known amounts (0.9 to 3 µg) of mercury added (as $Hg(NO_3)_2$) [10]. No change in recovery was seen for samples stored up to 3 weeks at room temperature or up to 3 months at −15 °C; longer storage times were not investigated [10].

## REFERENCES:

[1] Evaluation of Mercury Solid Sorbent Passive Dosimeter, Backup Data Report. Inorganic Section, OSHA Analytical Laboratory, Salt Lake City, Utah, 1985.

[2] Mercury in Workplace Atmospheres (Hydrar Tubes). Method ID 145H, Inorganic Section, OSHA Analytical Laboratory, Salt Lake City, UT, 1987.

[3] NIOSH/MRSB. Reports for analytical Sequence Nos. 5854, 5900, 6219, and 6311, NIOSH (Unpublished, 1987-1988).

[4] NIOSH Manual of Analytical Methods, 3rd. ed., Method 6000. (1984).

[5] NIOSH Manual of Analytical Methods. 2nd. ed., V. 4, S199, U.S. Dept. of Health. Education, and Welfare Publ. (NIOSH) 79-141 (1979).

[6] Ibid., V. 5, P&CAM 175, Publ. (NIOSH) 79-141 (1979).

[7] Rathje, A.O., Marcero, D.H. Improved hopcalite procedure for the determination of mercury in air by flameless atomic absorption, Am. Ind. Hyg. Assoc. J. 37, 311-314 (1976).

[8] McCammon, C.S., Edwards, S.L., Hull, R.D., Woodfin, W.J., A comparison of four personal sampling methods for the determination of mercury vapor, Am. Ind. Hyg. Assoc. J., 41, 528-531 (1980).

[9] Internal Methods Development Research, DataChem Laboratories, Inc., Salt Lake City, UT (1982).

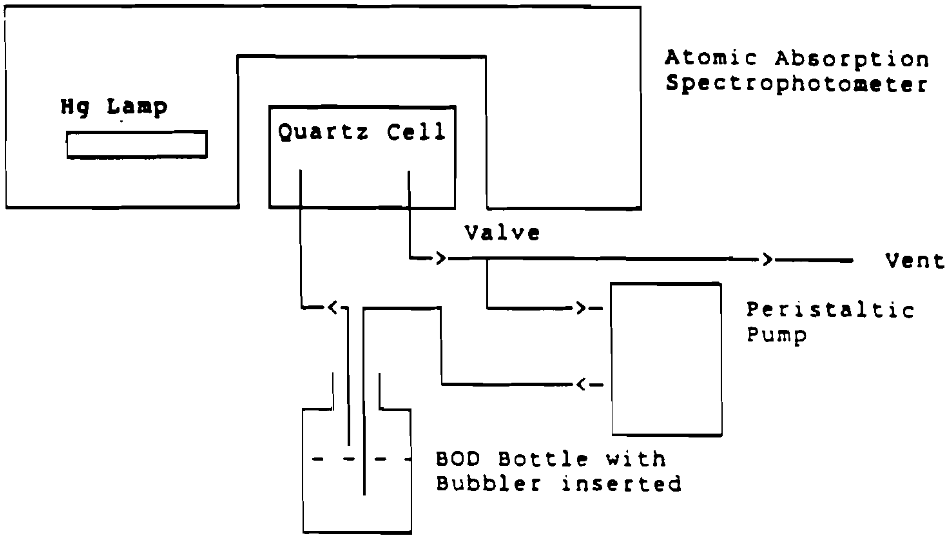
[10] Eller, P.M., NIOSH, unpublished data (1987-88).

## METHOD WRITTEN BY:

Keith R. Nicholson and Michael R. Steele, DataChem Laboratories, Inc., Salt Lake City, Utah, under NIOSH contract No. 200-87-2533.

## APPENDIX: COLD VAPOR MERCURY ANALYSIS SYSTEM

1. The valve should direct the vented vapors to a hood or to a mercury scrubber system.
2. When the valve is opened to "Vent" the peristaltic pump should draw room air. Place a Hopcalite tube in the air intake to eliminate any mercury that may be present.
3. Adjust the peristaltic pump to a flow that will create a steady stream of bubbles in the BOD bottle, but not so great that solution droplets enter the tubing to the quartz cell.
4. If water vapor condenses in the quartz cell, heat the cell slightly above room temperature by wrapping it with a heating coil and attaching a variable transformer.
5. The bubbler consists of a glass tube with a bulb at the bottom, slightly above the bottom of the BOD bottle. The bulb contains several perforations to allow air to escape into the solution (in a stream of small bubbles). A second tube is provided to allow the exit of the vapor. The open end of the second tube is well above the surface of the liquid in the bottle. The two tubes are fixed into a stoppering device (preferably ground glass) which fits into the top of the bottle. A coarse glass frit can be used in place of the bulb on the first tube. However, it is more difficult to prevent contamination when a frit is used.
6. Replace the flexible tubing (Tygon or equivalent) used to connect the bubbler, cell, and pump periodically to prevent contamination from adsorbed mercury.



# APPENDIX A-3

# SOIL GAS VENDOR TECHNOLOGY - QUADDRELL SERVICES, INC.

**Quadrel Services, Inc.**

1896 Urbana Pike, Suite 20, Clarksburg, MD 20871 • (301) 874-5510 fax: (301) 874-5567

February 19, 1997

Mr. Jeff Knight
ABB Environmental Services, Inc.
1400 Center Point Blvd., Suite 158
Knoxville, TN 37932

Subject: **EMFLUX® Soil-Gas Survey Cost Proposal**

Dear Jeff:

We appreciate the opportunity to respond to your request for a cost proposal involving the use of the EMFLUX® Soil-Gas Detection System to obtain data for a risk assessment at a Brownfield site in New York State.

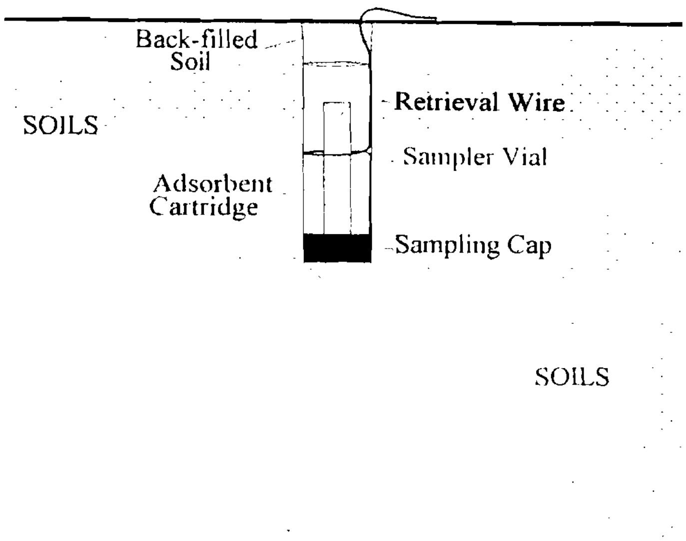
Currently EMFLUX® is listed in the EPA VendorFACTS Database of Innovative Site Characterization Technologies. The technology has a demonstrated and field-tested ability to detect VOCs and SVOCs with an unusually high degree of accuracy. In its formal evaluation at the EPA Las Vegas test site, EMFLUX® obtained a correlation coefficient of 0.91; and in field work during the seven years the system has been commercial it has met or exceeded a 90% correspondence to ground truth in all cases in which follow-on data has been provided.

EMFLUX® field applications are straightforward. There are two types of Collectors. The surface-placed Collector is placed at grade, while the subsurface Collector is placed in the ground to a minimum depth of three inches (see enclosures). Deployment and retrieval of either collector type requires usually less than two minutes (exclusive of time required to drill and repatch holes in artificial caps), and are left in place for just three days. Each small, easily carried EMFLUX® Field Kit contains everything needed for a Survey of 25 points or fewer (except for a hammer and, when sampling through artificial surfaces, drilling equipment). For sample points involving artificial caps, Quadrel also supplies sanitized metal sleeves for the subsurface Collectors.

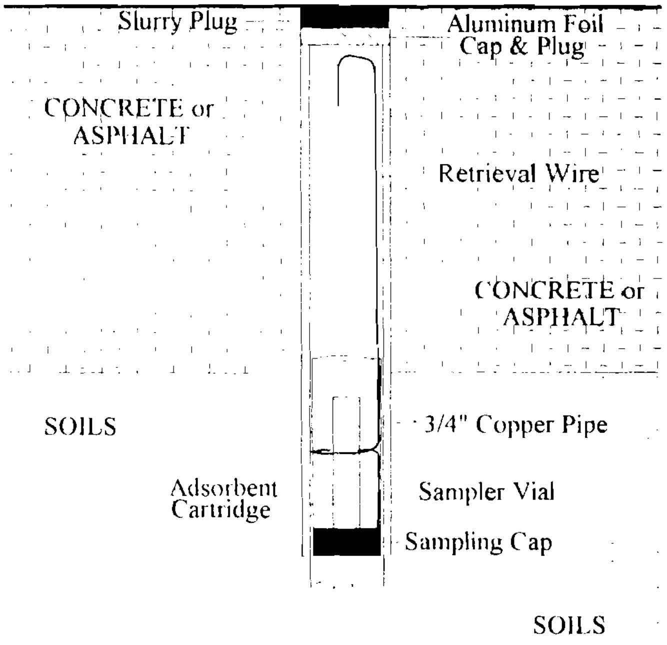
To protect the levels of sensitivity and accuracy attained in the field, Quadrel thermally desorbs EMFLUX® sample cartridges and analyzes them by means of gas chromatography and quadrupole mass spectrometry (TD-GC/MS) or gas chromatography (TD-GC) and various detectors (*e.g.*, PID, FID, DELCD), in the process employing standard and modified EPA Methods, as well as extensive laboratory QA/QC procedures. GC/MS analysis is performed at our CLP, USACE/MRD, and NavyCLEAN certified contract laboratory.

# EMFLUX® COLLECTOR

## DEPLOYMENT THROUGH SOILS



## DEPLOYMENT THROUGH AN ASPHALT/CONCRETE CAP



## Enclosure

# The Quadrel Predictive Timing Model
# and
# The EMFLUX® Soil-Gas Detection System

Quadrel offers a unique technology in the field of soil-gas investigation, a passive non-invasive method most readily distinguished by superior levels of accuracy and sensitivity. EMFLUX® data correctly identifies specific contaminants and accurately represents changes in subsurface contaminant concentrations in excess of 90% of the time. The reason for this is that EMFLUX® takes advantage of and corrects for major changes in the vertical velocity of gases migrating through the earth's crust. Such changes, generated by gravitational phenomena known as "earth tides," reach three-to-five orders of magnitude and can occur very rapidly, thereby introducing significant errors in measurement of soil-gas concentrations and/or emission rates.

Quadrel's Predictive Timing Model for earth tides permits field deployment of EMFLUX® Collectors during 72-hour periods of maximum emission -- when the largest quantities of gas are moving per unit of time -- and thus greatly enhances sensitivity. In addition, by sampling simultaneously during the survey exposure period, the company ensures that all Collectors are exposed to the same fluctuations in soil-gas velocity and that, as a result, it is possible to compensate arithmetically for these variations in a uniform and consistent manner. By so compensating, EMFLUX® can eliminate major extraneous errors introduced by earth-tidal effects.

Every soil-gas method except EMFLUX® takes samples without regard to timing, and therefore without regard to favorable or unfavorable periods of gas emission. And active soil-gas systems in particular take sequential -- not simultaneous -- samples of fixed duration and are hence vulnerable to the full range of error ultimately deriving from earth tides (which, incidentally, far outweigh such influences as barometric pressure, temperature and other meteorologic factors). What this means in practical terms is that other systems can provide lower detection sensitivity, higher percentages of false negatives, and less reliable portrayal of subsurface contaminant patterns. Additionally, EMFLUX® offers direct detection of SVOC contamination (*e.g.*, diesels, jet fuels, weathered gas, coal tars, etc.) even in highly moist soils or through tight clays.

# FIELD PROCEDURES FOR EMFLUX® SOIL-GAS SURVEYS

The following field procedures are routinely used during EMFLUX® Soil-Gas Surveys. Modifications can be and are incorporated from time to time in response to individual project requirements. In all instances, Quadrel adheres to EPA-approved Quality Assurance and Quality Control practices.

A. Field personnel carry EMFLUX® system components and support equipment to the site and deploy the EMFLUX® Collectors in a prearranged survey pattern. Although EMFLUX® Collectors require only one person for emplacement and retrieval, the specific number of field personnel required depends upon the scope and schedule of the project. Each Collector emplacement generally takes less than two minutes.

B. For those sample locations covered with soils or vegetation, a field technician clears vegetation and debris exposing the ground surface. Using a hammer and a ¾-inch-diameter pointed metal stake, the technician creates a hole approximately three inches deep. For those locations covered with an asphalt or concrete cap, the field technician drills a 1-1/2 inch diameter hole through the cap to the soils beneath and inserts the ¾ inch i.d. copper pipe sleeve (provided), into which the Collector is placed.

C. The technician then removes the solid plastic cap from an EMFLUX® Collector (a glass vial containing an adsorbent cartridge with a length of wire attached to the vial for retrieval) and replaces it with a Sampling Cap (a plastic cap with a hole covered by screen meshing). The technician inserts the Collector, with the Sampling Cap end facing down, into the hole (**see attached figure**). The Collector is then covered with either local soils for uncapped locations or, for capped locations, aluminum foil and a concrete patch. The Collector's location, time and date of emplacement, and other relevant information are recorded on the Field Deployment Form.

D. As a quality-control check during emplacement and retrieval, the technician takes periodic ambient-air control samples and records the date, time, and location of each. (One or more trip blanks are also included as part of the quality-control procedures).

E. Once all EMFLUX® Collectors have been deployed, field personnel schedule Collector recovery (approximately 72 hours after emplacement) and depart, taking all no-longer-needed equipment and materials with them.

F. Field personnel retrieve the Collectors at the end of the 72-hour exposure period. At each location, a field technician withdraws the Collector from its hole and wipes the outside of the vial clean using gauze cloth; following removal of the Sampling Cap, the wire is removed with wire cutters and the threads of the vial are cleaned. A solid plastic cap is screwed onto the vial and the sample location number is written on the label. The technician then records sample-point location, date, time, etc. on the Field Deployment Form.

G. Sampling holes are refilled with soil, sand, or other suitable material. If Collectors have been installed through asphalt or concrete, the hole if filled to grade with a plug of asphalt cold patch or cement.

H. Following retrieval, field personnel ship or carry the EMFLUX® Collectors to analytical laboratories under contract to Quadrel Services. The remaining equipment is returned to Quadrel's preparation facility.

**Quadrel Services, Inc.**

1896 Urbana Pike, Suite 20, Clarksburg, MD 20871 • (301) 874-5510 fax: (301) 874-5567

April 2, 1997

ABB Environmental Services, Inc.

Attn: Jeff Knight and Eric Sandin

Thanks again for your interest in the use of the EMFLUX® Soil-Gas Detection System to define TCE and mercury vapor concentrations in soils. For your project requirements, it is recommended that GC/MS instrumentation be used for the TCE analysis to assure the best in data quality. A modified EPA Method 8260 will be used. The soil-gas concentrations can be effectively calculated regardless of what depths the samples are taken.

A contact who has used the EMFLUX® System for a somewhat similar Brownfields project in New York is Dennis Conley with Haley and Aldrich. He can be reached at 716-327-5534.

The mercury samples are deployed in the same fashion as the VOC Collectors. To protect the levels of sensitivity and accuracy attained in the field, the mercury sample sorbent is digested using nitric acid and hydrochloric acid, reduced to elemental mercury using stannous chloride, and analyzed with a cold vapor-atomic adsorption spectrophotometer. The method detection limit is 100 nanograms. The standard cost per sample is $145.

Again with regard to mercury, Quadrel is currently offering the system on a site-specific demonstration basis.

Sincerely,

Paul Henning

Paul Henning
Vice President

## LABORATORY PROCEDURES
## FOR EMFLUX® ADSORBENT CARTRIDGES

After exposure, EMFLUX® cartridges are analyzed using U.S. EPA Method 8260 as described in the Solid Waste Manual (SW-846), a purge-and-trap capillary gas chromatographic/mass spectrometric method, modified to accommodate high- temperature thermal desorption of the adsorbent cartridges. This procedure is summarized as follows:

A. The adsorbent cartridges are thermally desorbed at 300°C for 11 minutes in a 40 mL/min helium flow, through 5 mL of reagent water spiked with 250 ng of internal standards and surrogates held in the sparging vessel. Any analytes in the helium stream are adsorbed onto a standard three-component trap (Tenax, silica gel, coconut charcoal).

B. Following cryofocusing, the three-component trap is thermally desorbed at 220°C onto a Supelco VOCOL 105 m, 0.5 mm ID, 3.00 micron filament thickness capillary column, per the U.S. EPA CLP Statement of Work (SOW) for the method.

C. Following the SOW, the GC/MS is scanned between 35 and 260 Atomic Mass Units (AMU) at one second per scan.

D. BFB tuning criteria and initial calibration are per the EPA CLP 2/88 guidelines, with an 18-hour tune window. A laboratory blank is analyzed after the daily standard to determine that the system is contaminant-free.

E. The instrumentation used for these analyses includes:

- Finnigan Model OWA 1050 Gas Chromatograph/Mass Spectrometer;
- Tekmar Model 6016 Aero Trap Autosampler;
- Tekmar Model LSC 2000 Liquid Sample Concentrator; and
- Tekmar Model ALS 2016 Autosampler.

## Data Treatment

Table 1 provides the survey results in average soil-gas concentrations in nanograms per liter (ng/L, or parts per trillion). Laboratory values were converted to soil-gas concentrations using the following formula:

$$C = 10^3 KW/TR$$

where: C = Avg. soil-gas conc. in collector (ng/L)
K = Cartridge collection constant (1.0 sec/$cm^3$)
W = Contaminant mass (ng)
T = Collection period (sec)
R = Adsorbent recovery factor (decimal fraction)

**Note:** Quadrel's derivation of the EMFLUX® cartridge collection constant, K, involved (i) adoption of 0.05 $cm^2$/sec as a typical diffusion coefficient, D, for VOCs in free air and (ii) evaluation of experimental laboratory data to determine the ratio between collection area, A, and diffusion distance, Z. The latter relationship, based on work done to date, appears to be A/Z = 20.2 cm. Given these values, Quadrel has computed the value of the constant to be:

$$\begin{aligned} K &= 1/[D(A/Z)]\ \text{sec/cm}^3 \\ &= 1/[0.05(20.2)]\ \text{sec/cm}^3 \\ &= 1/1.01\ \text{sec/cm}^3 \\ &\approx 1.0\ \text{sec/cm}^3 \end{aligned}$$

# APPENDIX B

# TASK SPECIFIC HEALTH AND SAFETY PLAN

# Task Specific Health and Safety Plan

## Phase II VSI
## Taylor Instruments Site, Rochester, NY

This Task Specific Health and Safety Plan (HASP) has been prepared in conformance with the ABB Environmental Services, Inc. (ABB-ES) Health and Safety Program and is intended to meet the requirement of 29 CFR 1910.120. The Task Specific HASP has been prepared to supplement the Health and Safety Plan included as Appendix B to the Final Phase I Site Investigation Work Plan prepared for the Ames Street Site in February 1996.

The Phase I scope of work consisted of soil boring and groundwater sampling activities that were conducted on-site to identify concentrations of site-related chemicals in overburden soils that represent soil contact hazards or that may act as sources of contamination to groundwater. Phase II activities outlined in this Work Plan include soil gas, soil and groundwater sampling to:

- Determine the potential presence of mercury vapors in onsite surface soils;
- Determine the presence of VOCs in shallow soils on abutting properties and at select points of known onsite groundwater concentrations;
- Provide correlative data at select soil gas sampling locations;
- Determine shallow onsite bedrock water quality and provide overburden groundwater data both on- and offsite to correlate with soil gas results; and,
- Characterize sewer water and sediment levels of mercury to assess the source of mercury impact to sewers.

The site investigation tasks which will be conducted to address both mercury and VOC contamination are briefly discussed in the following sections. Table 1 identifies chemicals of concern identified in site soil and groundwater during the Phase I VSI and their exposure limits.

### Mercury Contamination Investigations

Several activities are planned to assess the presence of mercury vapor in on-site near surface soils and estimate the potential for mercury releases to buildings and open air areas. Samples will also be collected to estimate the potential for exposure to future site workers from subsurface excavations. The following sampling activities will be conducted to address mercury contamination at the site:

Soil gas point sampling. Samples will be collected form 10 locations at the site. Samples will be collected at each location from driven or drilled small-diameter boreholes. Samples will be collected at these locations by applying a vacuum to the PVC point and samples will also be analyzed instantaneously using a portable Jerome Mercury Vapor Analyzer (MVA).

The site is completely paved and potential exposure is limited to soils brought to the ground surface while boring and to soil gas vapors purged from vapor points. This task will be conducted at Level D with mercury vapor monitoring by Jerome MVA and VOC monitoring by PID. Upgrade criteria are listed in Table 2.

Soil gas trench sampling. Mercury vapor samples will be collected from a total of three excavated test trenches. Each trench will consist of a backhoe excavation at least 4 feet wide, 10 feet long, and 6 feet deep. Instantaneous samples will be collect at timed intervals after excavation using a handheld Jerome MVA. These samples will be collected from positions near the end of each trench at elevations about 2 feet above the trench floor. This sampling will be conducted by manually lowering vapor sample collection instruments into the excavated trench. No sampling personnel will enter the trenches. Samples will also be collected using an industrial hygiene-type mercury collector.

Exposure hazards include VOCs or mercury vapors from excavated soils and from emissions within the test trenches. The test trenches are not anticipated to intersect significant VOC contamination. At the time of excavation, wind direction will be noted and soils will be stockpiled adjacent to each trench in the downwind direction. Workers will approach the trench and excavated soils from upwind when performing sampling activities. Workers will not enter the test trenches. This task will be conducted at Level D with mercury vapor monitoring by Jerome MVA and VOC monitoring by PID. Upgrade criteria are listed in Table 2.

Mercury Soil Sampling. Subsurface soil samples will be collected at 5 mercury soil gas sampling locations. Sample will be collected using hydraulic-push sampling methodology. Samples will be analyzed for mercury via USEPA method 7471.

The site is completely paved and potential exposure is limited to soils brought to the ground surface while boring. This task will be conducted at Level D with mercury vapor monitoring by Jerome MVA and VOC monitoring by PID. Upgrade criteria are listed in Table 2.

## VOC Contamination Investigations

Soil Gas samples will be collected from 7 off-site locations and from 4 onsite locations to assess the presence of VOCs in vadose zone soils Samples will collected from small-diameter boreholes using hydraulic push technology. samples will be collected from several feet below ground surface. Samples will be collected by applying a vacuum to the PVC point.

In addition to the VOC soil gas program, both overburden and bedrock groundwater will be sampled for VOC compounds.

The principal hazard anticipated for these tasks is exposure to VOC vapors while purging or sampling. Levels are not anticipated to exceed Level D or modified Level D criteria. Conditions will be monitored using a PID, MVA, and Draeger tubes, as necessary. Upgrade criteria are listed in Table 2.

**Sewer Sampling**

This task involves the collection of water and sediment samples from stormwater sewers at the site and on nearby streets. Samples will be collected by grab techniques and workers will not enter the sewers.

The principal hazard expected are vapors associated with the opening of a confined space and traffic hazards of working on active streets. Upon opening each manhole, ambient air condition will be measured using an explosimeter/Oxygen meter, and PID. If work is occurring on active streets, the work area will be marked with traffic cones and a minimum of one non-sampling crewmember will direct traffic, as necessary. This task will be performed at level D with upgrade as necessary as shown on Table 2.

# TABLE 1
# CHEMICALS OF CONCERN
# TAYLOR INSTRUMENT SITE
# 95 AMES STREET
# ROCHESTER NEW YORK

| COMPOUND | EXPOSURE PEL/TWA OR TLV/TWA | LIMITS STEL/CEIL(c) (ppm) |
|---|---|---|
| | | |
| Mercury | **0.05 mg/m3 (skin)** | - |
| TCE | **50 ppm** | **200** |
| PCE | **25 ppm** | - |
| 1,1,1-TCA | **350 ppm** | **450** |
| Ethylbenzene | **100 ppm** | **125** |
| Vinyl chloride | **5 ppm** | **500 (for 5 min)** |
| Toluene | **100 ppm** | - |
| cis-DCE | **200 ppm** | - |
| trans-DCE | **200 ppm** | - |

PEL/TWA - Permissible Exposure Limit/Time Weighted Average
TLV/TWA - Threshold Limit Value/Time Weighted Average
STEL - Short Term Exposure Limit (The 15 minute time-weighted average which should not be exceeded at any time during the working day)
CEIL - The concentration which should never be exceeded during any part of the working exposure

## TABLE 2
## Contaminant Levels for Modification of Protective Equipment

Site Investigations to Address VOC Contamination

Monitor the breathing zone with the PID. If levels steadily exceed background, monitor for benzene using the 5/c benzene Draeger Tube. If benzene levels exceed 0.5 ppm, upgrade to Level C. If benzene levels are > 10 ppm, upgrade to Level B. If benzene levels are < 0.5 ppm, continue work at Level D/Modified Level D until the PID reads > 10 ppm then upgrade to Level C. If PID > 175 ppm, upgrade to Level B.

Site Investigations to Address Mercury Contamination

Monitor continuously with the Jerome Mercury Vapor Analyzer (MVA) and upgrade accordingly.

The action levels for upgrade are as follows:

Level D/Modified Level D acceptable if:

- PID reads < 10 ppm; and
- Benzene 5/c Draeger Tube reads < 0.5 ppm; or
- MVA reads <0.025 mg/m3

Level C required if:

- PID reads between 10 and 175 ppm; and/or
- MVA reads > 0.025 mg/m3; and/or
- Benzene 5/c Draeger Tube reads < 10 ppm.

Level B required if:

- PID reads > 175 ppm: or
- >2.5 mg/m3 on the MVA; and/or
- Benzene 5/c Draeger Tube reads > 10 ppm.

If the explosimeter 10%, use non-sparking tools. If the explosimeter reads 20%, stop work, eliminate all ignition sources, and evacuate the area.

# ABB Environmental Services, Inc.
## Health and Safety Plan

Site: AMES STREET SITE  Contact:
Street Address: 95 AMES STREET, ROCHESTER, NEW YORK
Proposed Date(s) of Investigation:  Job Number: 7198-29
Prepared by: PETER HALL  Date: 4/4/97
Approved by:  Date:
Proposed Activity(s): SOIL GAS SAMPLING, SOIL SAMPLING, GROUNDWATER SAMPLING
Known or Suspected Chemicals (include PELs):

HAZARD EVALUATION (Check all that apply):

| | | | | | |
|---|---|---|---|---|---|
| Overall Hazard Estimation: | ☐ Serious | ☑ Moderate | ☐ Low | ☐ Unknown | ☐ None |
| Major Exposure Route(s): | ☑ Dermal | ☑ Inhalation | ☐ Ingestion | ☐ Puncture | |
| Contaminant Location(s): | ☑ Surface<br>☐ Tank | ☐ Underground<br>☐ Other (list): | ☑ Soil | ☐ Sediment | ☑ Water |
| Health Hazard(s): | ☐ Liquid<br>☑ Volatile | ☐ Solid<br>☐ Radioactive | ☐ Sludge<br>☐ Reactive | ☐ Corrosive<br>☐ Unknown | ☐ Ignitable |
| Safety Hazard(s): | ☐ Height<br>☐ Near Water<br>☐ Lifting | ☐ Equipment<br>☐ Confined Space<br>☑ Slips/Falls | ☐ Cold Stress<br>☐ Heat Stress<br>☐ Other (list): | ☐ Noise<br>☐ Machinery | ☐ Eye<br>☐ Burns |

EQUIPMENT (check all that apply):  Initial Level of Personal Protection:

| | | | |
|---|---|---|---|
| PPE Selected: | ☐ Cartridge Respirator<br>☐ Escape Respirator<br>☑ Safety Boots/Shoes<br>☐ Chemical Resistant Boots<br>☑ Disposible Boot Covers<br>☐ Other (list): | ☑ Coveralls<br>☐ Safety Glasses<br>☐ Face Shield<br>☑ Hard Hat<br>☐ Ear Protection | Gloves<br>☐ •inner<br>☑ •outer<br>Tyveks<br>☑ •regular<br>☐ •coated |
| Monitoring Equipment: | ☐ Combustible Gas/Oxygen Meter<br>☐ Hydrogen Sulfide Meter<br>☐ Radiation Alert Meter<br>☐ Dosimeter Badge | ☐ Explosimeter<br>☑ Draeger Tubes<br>•list: BENZENE 5/C<br>☑ Other (list): JEROME MERCURY VAPOR ANALYZER (MVA) | ☐ OVA<br>☑ PID |
| Emergency Equipment: | ☑ First Aid Kit<br>☐ Other (list): | ☐ Fire Extinguisher | ☑ Eye Wash |

CONTAMINANT LEVELS FOR MODIFICATION OF PROTECTIVE EQUIPMENT:
SEE TABLE 3 - ATTACHED

DECONTAMINATION/DISPOSAL: All personnel and/or equipment leaving contaminated sites are subject to decontamination. Under no circumstances (except emergency evacuation) will personnel be allowed to leave the site prior to decontamination. The decontamination procedures to be used at the site are as follows: ALL PROTECTIVE GEAR, DECONTAMINATION FLUIDS, AND OTHER DISPOSABLE MATERIALS WILL BE DISPOSED OF AT EACH SITE. DECONTAMINATION FLUIDS IDENTIFIED TO BE CONTAMINATED WILL BE STORED IN DOT-APPROVED 55-GALLON DRUMS. CONTAMINATED DISPOSABLE MATERIALS WILL BE DOUBLE-BAGGED AND STORED AS IS, OR PLACED IN DOT-APPROVED 55-GALLON DRUMS.

EMERGENCY MEDICAL TREATMENT/FIRST AID: First aid will be rendered to any person injured on-site, as appropriate. The injured person will then be transported to a medical facility for further examination and/or treatment. An ambulance will be used to transport the injured person to the hospital unless one is not readily available or could result in excessive delay. In this case, other transport is authorized. Under no circumstances will the injured persons transport themselves to a medical facility for emergency treatment.

EMERGENCY EVACUATION: In the event of an emergency requiring evacuation, the HSO assumes the role of on-site coordinator. Evacuation responses will occur at three levels: (1) withdraw from the immediate work area (100+ feet upwind); (2) site evacuation; and (3) evacuation of surrounding area. If the residences and commercial operations require evacuation, the local agencies will be notified and assistance requested. Designated on-site personnel will initiate evacuation of the immediate off-site area without delay.

EMERGENCY TELEPHONE NUMBERS:

| | |
|---|---|
| Local Police Department | ( ) - 911 |
| Local Fire Department | ( ) - 911 |
| Local Rescue Service | ( ) - 911 |
| Primary Hospital: ST. MARY'S HOSPITAL | (716) 469-2130 |
| Secondary Hospital: STRONG MEMORIAL | (716) 275-2100 |
| Environmental Medicine Resources, Inc. (Dr. David Barnes) | (800) 229-3674 |
| National Poison Control Center | (800) 492-2414 |
| Chemical Manufacturing Association-Chemical Referral Center | (800) 262-8200 |
| Regional Health and Safety Supervisor: | ( ) - |
| Health and Safety Manager: Cindy Sundquist | (207) 775-5401 |

AUTHORIZED PERSONNEL:

GEOFF KNIGHT

ERIC SANDIN

* Current First-aid Certification

\+ Current CPR Certification

FIELD TEAM REVIEW: I have read and reviewed the health and safety information in the HASP. I understand the information and will comply with the requirements of the HASP.

Name: Date:

Name: Date:

Name: Date:

Name: Date:

Name: Date:

Name: Date:

# ROUTES TO EMERGENCY MEDICAL FACILITIES

PRIMARY HOSPITAL:

Facility Name: ST. MARY'S HOSPITAL
Address: 89 GENNESEE STREET
Telephone Number (716) - 464 - 2130

DIRECTIONS TO PRIMARY HOSPITAL (attach map):

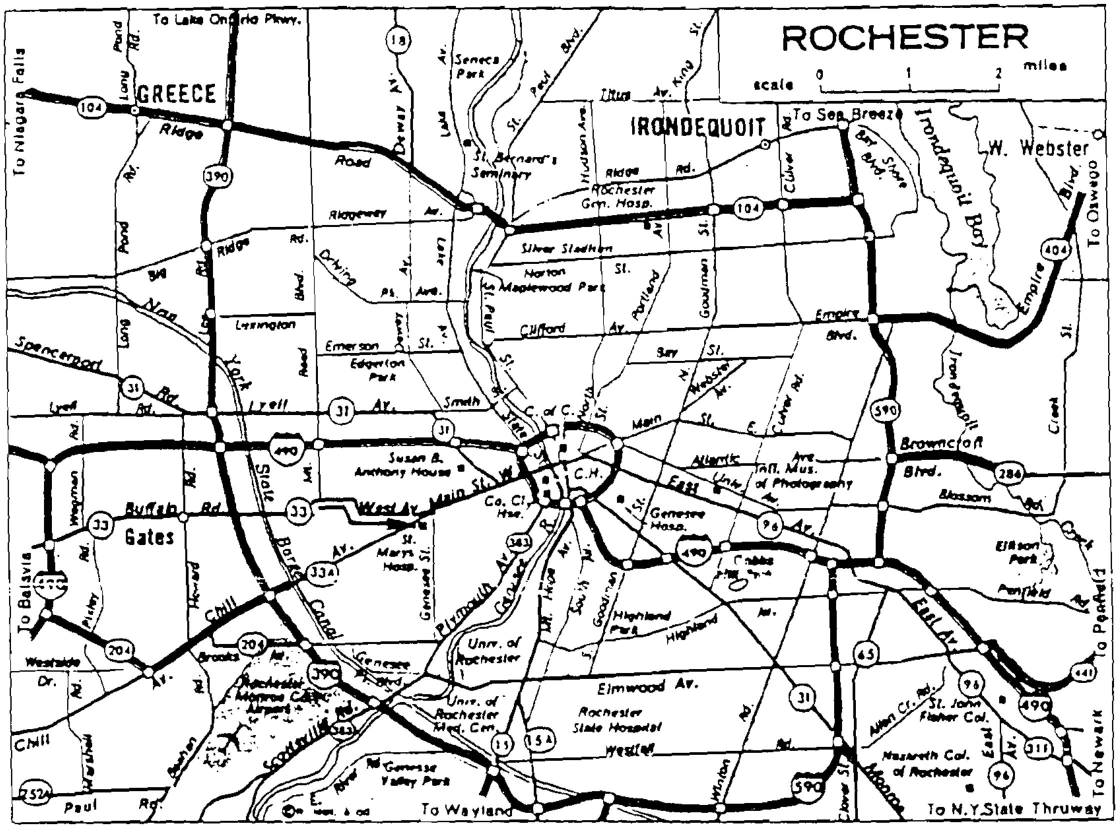
LEFT ON WEST AVENUE FROM HAGUE STREET
FOLLOW WEST AVENUE TO INTERSECTION OF WEST AVENUE AND CHILI/WEST MAIN STREET
HOSPITAL IS LOCATED ON THE SOUTH SIDE OF INTERSECTION

ALTERNATE HOSPITAL:

Facility Name: STRONG MEMORIAL HOSPITAL
Address: ELMWOOD AVENUE
Telephone Number (716) - 275 - 2100

DIRECTIONS TO ALTERNATE HOSPITAL (attach map):

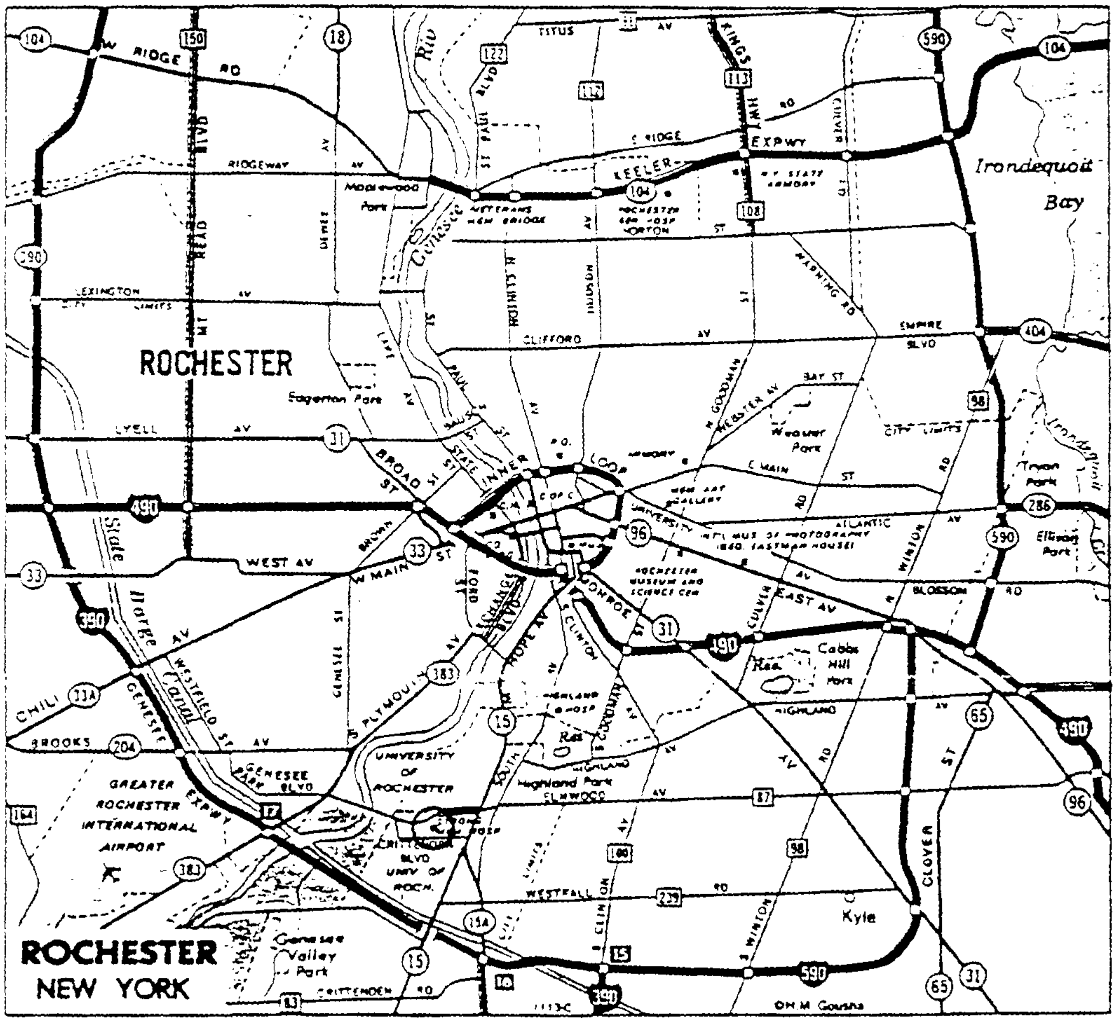
RIGHT ON WEST AVENUE FROM HAGUE STREET
FOLLOW WEST AVE. 8 BLOCKS TO THURSTON ROAD, TURN LEFT
FOLLOW THURSTON TO CHILI AVENUE, TURN RIGHT
FOLLOW CHILI TO 390 SOUTH
390 SOUTH APPROXIMATELY 3 MILES TO THE 15 NORTH (SOUTH AVENUE/MT. HOPE AVENUE)
APPROXIMATELY 1/4 MILE TO CRITTENDEN ROAD, TURN RIGHT
HOSPITAL 1/10 MILE ON RIGHT SIDE



PRIMARY
HOSPITAL ROUTE MAP
AMES STREET FACILITY
ROCHESTER, NEW YORK

ABB Environmental Services, Inc.

7198-00



SECONDARY
HOSPITAL ROUTE MAP
AMES STREET FACILITY
ROCHESTER, NEW YORK

ABB Environmental Services, Inc.