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Mr Schmied.

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JUL 1982
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PHASE I

PROPOSED HYDROGEOLOGICAL FIELD WORK
AND
BENCH SCALE TESTING
DEALING WITH
MERCURY CONTAMINATION

TAYLOR INSTRUMENT CO.
DIVISION OF SYBRON CORPORATION
ROCHESTER, NEW YORK 14601

JUNE 1982

LOZIER
ARCHITECTS/ENGINEERS

LOZIER
ARCHITECTS/ENGINEERS
600 PERINTON HILLS
FAIRPORT, NEW YORK 14450

LETTER OF TRANSMITTAL

DATE 7/22/82
JOB NO. 1656-00D
ATTENTION
RE: Taylor Instrument Co.

TO Mr. Paul Schmied
NYSDEC
6274 E. Avon/Lima Rd.
Avon, New York 14414

GENTLEMEN:

WE ARE SENDING YOU ☐ Attached ☐ Under separate cover via ______ the following items:

☐ Shop drawings ☐ Prints ☐ Plans ☐ Samples ☐ Specifications

☐ Copy of letter ☐ Change order ☐ ______

COPIES	DATE	No	DESCRIPTION

THESE ARE TRANSMITTED as checked below:

☐ For approval ☐ Approved as submitted ☐ Resubmit ______ copies for approval

☐ For your use ☐ Approved as noted ☐ Submit ______ copies for distribution

☒ As requested ☐ Returned for corrections ☐ Return ______ correct prints

☐ For review and comment ☐ ______

☐ FOR BIDS DUE ______ 19 ______ ☐ PRINTS RETURNED AFTER LOAN TO US

REMARKS Per your request of 7/21/82 and approval of 7/22/82 from Nixon, Hargrave, Devans & Doyle, enclosed is a copy of the June 1982 Taylor Instrument Co. report.

TO Cheryl Blue

AT Taylor [illegible]

SUBJECT Draft Hazardous Waste Disposal Site Report: Taylor

DATE 1-9-85

Pursuant to our telephone conversation on January 7 1985 I have enclosed a copy of the draft of HWDSR for Taylor. If you have any other questions, please give me a call.

DUPLICATE

SIGNED Debbie Jackson - Solid & Haz. Waste

DATE

SIGNED

REDIFORM® 4S 469

POLY PAK (50 SETS) 4P 469

SEND PARTS 1 AND 3 INTACT -
PART 3 WILL BE RETURNED WITH REPLY.

DETACH AND FILE FOR FOLLOW-UP

Red comments by R. Young

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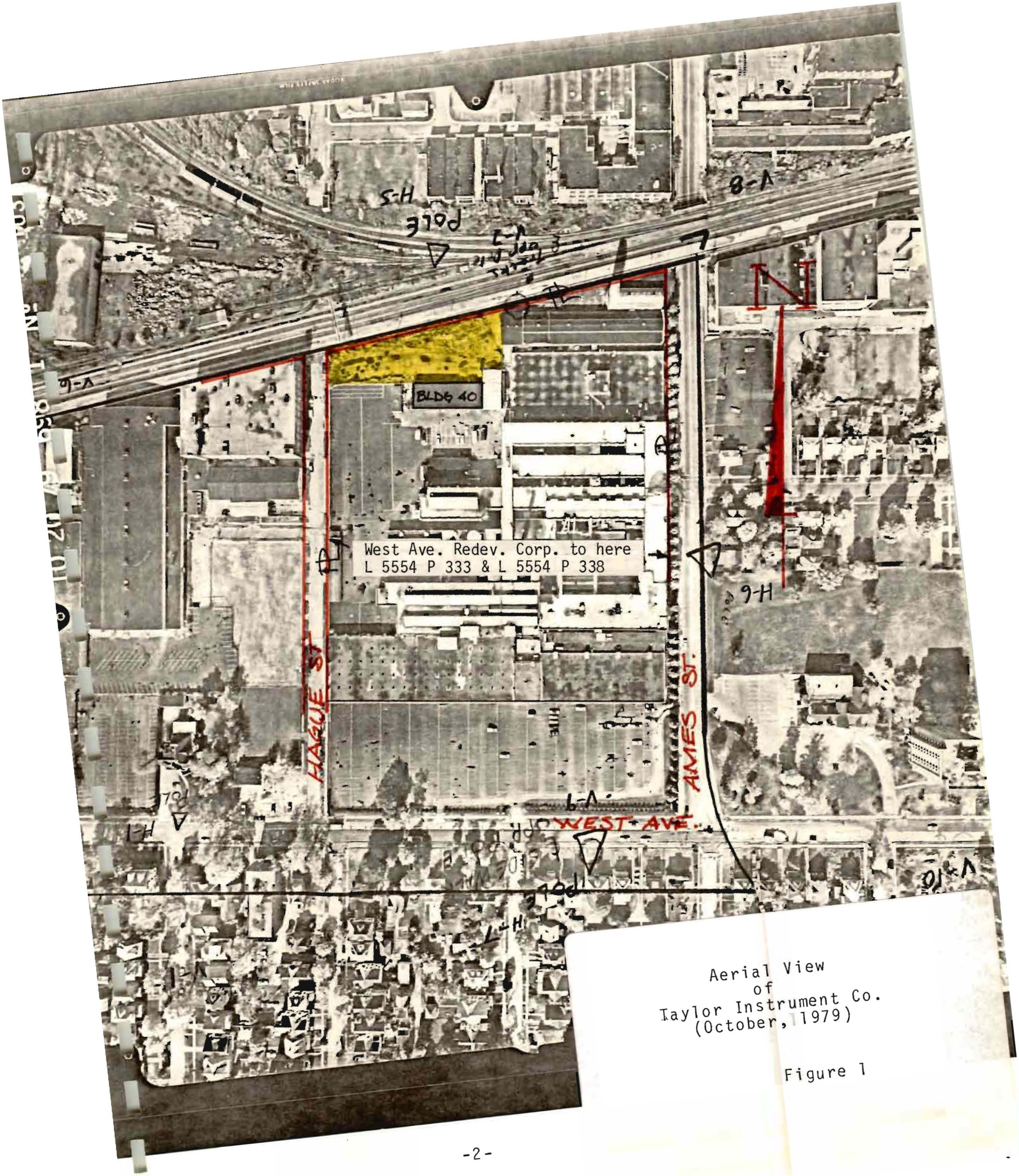
INTRODUCTION

I. INTRODUCTION

This is the third Lozier Architects/Engineers ("Lozier") Engineering Report dealing with the mercury contamination at the Taylor Instrument Company Ames Street site ("Taylor"). Taylor is a division of Sybron Corporation and has a manufacturing facility located in Rochester, New York at 95 Ames Street. The history of the discovery of mercury contamination at the Ames Street site has been dealt with in the two (2) preceeding Engineering Reports. This report will discuss the proposed hydrogeological field work and bench scale testing associated with the first phase of the proposed remedial action plan to be implemented at the Taylor site. This report is the next step in the schedule presented in Chapter IV (Program Implementation and Scheduling) of the March 1982 Lozier Engineering report.

At present only a portion of the grounds at the Ames Street facility is known to be contaminated with elemental (or metallic) mercury. That contaminated area is shown in yellow on Figure 1. One of the goals for Phase I is to delineate the boundaries of any mercury excursions across the site. Consequently, the general thrust of this report will deal with the proposed methodology for assembling soil and water data from the entire Ames Street site in order to firmly establish the extent and concentration of any mercury contamination within the groundwater and soil matrix.

The original hydrogeological field work performed in the fall of 1981 consisted of drilling four (4) P.V.C. monitoring wells and



Aerial View
of
Taylor Instrument Co.
(October, 1979)

Figure 1

sixteen (16) split spoon soil boring holes. The results of that work and the associated laboratory tests were presented in the two (2) previous Lozier Engineering Reports. Appendix A of this report contains a graphic presentation of the location and orientation of that field work within the area of known contamination at the Ames Street site.

Appendix A of this report gives a detailed discussion of the hydrogeological field work proposed during Phase I of this project. In that appendix the overall program is discussed and the reasons for the various elements of the program is explained. Prior to implementing the hydrogeological field work described in Appendix A, the New York State Department of Environmental Conservation (NYSDEC) will visit the Taylor Ames Street site.

Chemical fixation was recommended in the March 1982 Lozier report as the method which would not only remedy the mercury contamination at the Taylor site, but also minimize the environmental concerns associated with any remedial action. Research on the principles of chemical fixation has posed a number of feasible implementation methods. This fact is reflected in the proposed bench scale testing program discussed in Appendix B of this report. As a part of the program outlined in that appendix, chemical fixation will be tested for its feasibility at the Ames Street site using a spray application technique in addition to the mixing technique which was advanced in the March 1982 Lozier Engineering Report.

All of the work proposed in this first phase of the remedial action plan is a result of, and follows the approval by the New York State Department of Environmental Conservation (NYSDEC) of the treatment concept outlined in the March 1982 Lozier Engineering Report. This approval can be found in the April 26, 1982 letter from Paul F. Schmied, P.E. to Mr. G. Robert Witmer, Jr.of Nixon, Hargrave, Devans and Doyle.

Once Phase I work has been performed and the data collected and analyzed another report will be prepared and submitted to NYSDEC for approval. That report will analyze the effectiveness of the Phase I work and propose either an advancement of the project using the chemical fixation approach, or an alternate remedial action plan for use at the Taylor site.

The next section of this report will deal with proposed judgement criteria for assessing the effectiveness of the bench scale testing program in reducing mercury levels. These criteria, if accepted, will then be used as guidelines to assess the validity of the chemical fixation methodology and the recommended plan of implementation.

JUDGEMENT CRITERIA

It is not possible at this point to predict the amount of mercury at the Ames Street site which will be chemically fixed by either of the proposed treatment schemes. Before the bench scale tests are begun, it is important for all parties involved in the process to agree upon the general criteria which will be used to judge the success of these tests. Conversely, these criteria should not be inflexible since the bench test results might indicate that chemical fixation is a viable remedial measure but that modifications in the proposed technique are necessary.

It should be emphasized that the judgement criteria discussed below are related only to how the final results of the bench scale tests will be evaluated. Taylor realizes that throughout the bench scale and hydrogeological tests many decision-making points will occur. For example, since the literature indicates that organic mercury may not be amenable to chemical fixation, once the initial soil analysis indicates the proportion of the onsite mercury which is in the organic form, a decision will have to be made as to whether or not chemical fixation still appears to be a viable remedial technique.

Some of these decision-making points will be absolute "stop" or "proceed as planned" points while others will be utilized to select among available options. Since each decision and, in fact, each decision-making point will be influenced by all the data collected and decisions made up to that point, it is impossible (in this report) to identify all the decisions which will have to be made. Therefore only the final decision-making point (for Phase I) is discussed below. Once NYSDEC has approved this report, Taylor and its consultants will begin to identify the interim decision-making points. For the reasons discussed above this identification process, at least for Phase I, will only cease when the hydrogeological and bench scale tests have been completed and the criteria discussed below applied. The final Phase I report, which will contain the proposed details of Phase II of the remedial measures, will include a discussion of how this decision-making process was applied. If, at any time during Phase I, a decision must be made on whether to stop or delay the remedial process, DEC will be contacted immediately.

The bench tests performed in the laboratory will examine the capability of the chemical fixation technique to lock the mercury in place and reduce or eliminate the generation of a mercury contaminated leachate. In order to establish criteria by which the results of the bench scale tests can be assessed, it is important to examine first the ultimate objectives of the remedial project at the Ames Street site. In the opinion of Taylor, the ultimate objective of this remedial process should be the prevention of mercury contamination of the groundwater. Thus, Taylor believes that the most conservative criteria against which the success of the bench tests, and ultimately the actual remedial measures, could be measured is the State's groundwater standard for mercury. Since there is no known use of the groundwater by residents, industry or commercial interests in the vicinity of the

Ames Street site, Taylor believes that if, after fixation, the laboratory leachate meets OR is less than the State's groundwater effluent standard for mercury (0.004 mg/l, see 6 NYCRR § 703.6(a)) then the bench scale tests can be deemed a complete success. If the final mercury concentration in the laboratory leachate exceeds 0.004 mg/l, but still exhibits a significant decrease in mercury content, then Taylor believes that the bench scale tests should be deemed partially successful. The bench scale tests are structured so as to determine the viability of the chemical fixation methodology. It is anticipated that the employment of the method in the field will involve a direct scale up of the laboratory procedures with the possible addition of a safety factor to cover unexpected field adjustments.

Since there is no ready-made benchmark which can be used to judge whether the reduction in mercury in the leachate following chemical fixation is "significant," Taylor suggests that if the mercury concentration within the laboratory leachate after fixation has been reduced by 50 percent or more, then the reduction can be considered significant and thus the fixation technique can be deemed a partial success.

Similarly, Taylor believes that if the laboratory leachate fails to meet the 0.004 mg/l criterion but if the "EP Toxicity-mercury"[1] concentration is reduced by 75 percent or more through chemical fixation, then the chemical fixation technique can still be deemed a partial success.

If the EP Toxicity-mercury concentration is reduced between 50 and 75 percent, then Taylor believes that this data will have to be considered together with the laboratory leachate mercury data discussed above. Based on that review, a decision will be made on whether or not to deem the bench-scale tests a success.

Should the bench scale tests be only partially successful in removing the mercury content of the laboratory leachate, further on-site collection or treatment of the leachate might have to be incorporated into the final remedial procedures. If leachate collection appears to be necessary, discussions with the Monroe County Department of Wastewater Management ("Department") will be undertaken to determine the maximum concentration of mercury the Department would allow to be discharged to its collection system.

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[1] That is the mercury concentration within leachate which was generated using the EP Toxicity test procedures (40 CFR § 261, Ap. II). In the proposed bench scale study the EP Toxicity test procedure is used to simulate conditions which are much more rigorous than natural conditions, (see Appendix B).

Taylor proposes that the preceeding criteria be utilized in assessing the results of the bench scale tests. Accordingly, the preceeding proposed judgement criteria are summarized in the following table:

JUDGEMENT CRITERIA

A. Laboratory Leachate [Hg] (i = initial, F = after fixation)

		$[Hg]_F$	Judgement
1.	$[Hg]_F$	≤ 0.004 mg/l	complete success
2.	$[Hg]_F$	> 0.004 mg/l	
	and		
	$[Hg]_F$	$\leq 0.50\ [Hg]_i$	partial success
3.	$[Hg]_F$	> 0.004 mg/l	
	and		
	$[Hg]_F$	$> 0.50\ [Hg]_i$	Go to Step B

B. EP Toxicity-mercury

	$[Hg]_F$	Judgement
1.	$[Hg]_F \leq 0.25\ [Hg]_i$	partial success
2.	$0.25\ [Hg]_i < [Hg]_F \leq 0.50\ [Hg]_i$	discussions focusing on results of laboratory leachate analyses needed
3.	$[Hg]_F > 0.50\ [Hg]_i$	discussions on future directions needed

APPENDIX "A"

PROPOSED

TAYLOR SITE INVESTIGATION

PHASE 1

HYDROGEOLOGICAL INVESTIGATIONS

1.0 OBJECTIVES

1.1 To determine the overall presence, extent and concentration of mercury contamination within the soil matrix of the Taylor Instrument Company ("Taylor") Ames Street site.

1.2 To determine the overall presence, extent and concentration of mercury contamination within the groundwater at the Taylor site.

1.3 To assist geotechnically and to evaluate the geotechnical merits of any proposed site remediation alternative.

2.0 SCOPE OF WORK

2.1 General -

The general scope of geotechnical field work as proposed by Thomsen Associates ("Thomsen") was outlined in Lozier Architects/Engineers ("Lozier") Engineering Report dated March, 1982. Since that time, an additional site inspection by Lozier and Thomsen personnel has led to some adjustments in the originally proposed hydrogeological program. Consequently, the field program has been revised accordingly.

2.2 Basic Site Conditions and Assumptions

2.2.1 Initial site investigations indicated contamination to be confined to a narrow band of hot spots along the northern portion of the property between Building No. 40 and the railroad tracks. The originally proposed Phase 1 hydrogeological investigations were intended to focus the majority of the field work on that area.

2.2.2 The revised program is designed to address the entire Taylor site. The intent is to spread the sampling and monitoring program across most of the site. During Phase 1 detailed investigation will be limited to the material overlaying rock.

2.2.3 The technical assumptions underlying Phase I of the field work are based on the limited information to date. The following assumptions will either be substantiated or refuted during Phase I.

a) An estimated depth to bedrock of 20 to 30 feet.

b) A possible perched groundwater condition on top of dense glacial till.

2.3 General Phase 1 Description

Phase 1 consists of the following major elements (to be discussed in detail later in this proposal):

a) Four (4) soil borings terminated above bedrock, converted to monitoring wells.

b) 1 additional boring will be cored into bedrock and converted to a sampling piezometer. This penetration will only be advanced to that depth required for the performance of the packer tests and the installation of the piezometer.

c) Two (2) combined piezometer/lysimeter clusters

d) Nine (9) - 6 foot deep split-spoon sampled holes.

e) Two (2) - 3 to 4 foot deep backhoe trenches.

The Phase I field work will yield a total of eleven (11) water sampling locations and sixteen (16) soil sampling locations, in addition to the soil samples withdrawn from the trenches (see Figure 1). Those portions of the Phase I work which call for "continuous soil sampling" shall be understood to mean soil samples drawn approximately every two and one-half (2 1/2) feet.

There were an additional four (4) P.V.C. monitoring wells and sixteen (16) split spoon soil sample holes installed in the known contaminated area at the Taylor site in the fall of 1981 (see Figures 2 and 3).

2.4 Detailed Investigations -

2.4.1 General - The general intent of the hydrogeological portion of the field investigation program of Phase 1 is to determine the extent of any groundwater contamination by mercury and to determine the rate and direction of groundwater flow and correlative concentrations of contaminant. This analysis requires establishment of both vertical and horizontal groundwater gradients and the associated soil permeabilities. Preliminary investigations indicate that the most severe vertical migration of contaminants appears to be in the vicinity of boring positions 0-0 and E-180, (see Figure 4). Thus, further investigations into the potential for vertical migration will be concentrated in that general area.

2.4.2 Rock Surface Investigations -

a) One 6-inch diameter steel well casing will be driven to rock and will be left permanently in place at or near a location shown on the attached site plan. After the casing has been cleaned out, the rock will be cored only to that depth necessary to determine the integrity and nature of underlying bedrock. All possible preparations and field care will be exercised to prevent any penetration through the rock layer.? Upon completion of coring, approximately three (3) pressure-packer (permeability) tests will be performed to determine the permeability of the rock layer in comparison to the permeability of the overlying glacial till deposits. A porous-tube piezometer will then be placed in the core hole and the casing above the piezometer sealed off utilizing a bentonite slurry throughout the entire backfilled section of the casing. This will prevent any potential for cross-contamination from the upper elevations into the underlying bedrock.

b) It is intended that this monitor serve as the only rock monitor during Phase 1, since groundwater appears to be perched on or within the glacial till. Extensive investigations of bedrock groundwater quality would involve

Incorrect assumption see memo of R Young 1/7/86 extensive and costly deep well installations. Only after completion of Phase 1 can the merit of further rock investigations be satisfactorily evaluated.

2.4.3 Vertical Groundwater and Contaminant Movement-

a) The potential for the vertical groundwater and contaminant migration will be evaluated by the installation of a piezometer/lysimeter cluster installed adjacent to existing monitor E-180. First an initial continuously sampled soil boring will be advanced to bedrock. Then the bottom one foot of the hole will be sealed with bentonite. Next, a porous-tube piezometer will be installed and packed with sand above the base seal. The last step in the piezometer installation is to seal above it with bentonite (around 18 feet in depth). A second piezometer will then be installed the same as the preceeding at a depth of approximately 12 feet. The remainder of the borehole will be sealed using bentonite slurry methods and the piezometer installation completed with a lockable protective casing and cap.

b) Two unsampled auger boring holes will then be installed within a five foot radius of the piezometer cluster. A pressure-suction lysimeter will be installed within each of these holes. The depths of these pressure-suction lysimeters will be determined by the prevailing groundwater depth. Each of these will be packed and sealed off within the vadose zone and completed in a manner similar to the piezometer clusters.

c) The second piezometer/lysimeter cluster will be located generally as shown on Figure 1. This additional cluster, in conjunction with the former cluster, will provide data on vertical gradients in the area. The location of this second cluster will be determined during field operations.

d) These piezometer/lysimeter clusters, as well as the rock piezometer installation, will provide a basis for measuring changes in the vertical hydraulic gradient as well as providing for vertical water quality sampling points. Soil samples obtained from the deep piezometer hole may also be utilized for chemical analysis.

2.4.4 Horizontal Groundwater and Contaminant Movement

a) Four 2-inch diameter PVC monitors will be installed at various locations indicated on the site plan. Due to the low permeability of the glacial till, larger diameter monitors would make accurate water level readings, sampling, and purging difficult.

b) The location of these four (4) new monitoring points, in conjunction with the existing four (4) wells, will establish overall horizontal hydraulic gradients and general groundwater flow vectors across the site. It is anticipated that building foundation footings and utility trenches may result in localized variations in the upper groundwater flow patterns. Additional monitors may be necessary during possible future phases.

c) The four (4) new monitors will be installed by auger boring methods with continuous split-spoon sampling in order to provide for soil analysis and general stratigraphic correlation across the site. Selected soil samples will also be available for chemical analysis. Each monitor will consist of a sandpacked five-foot slotted PVC screen, with the remainder of the hole backfilled with bentonite slurry to prevent cross-contamination. Each monitor will be completed with lockable protective pipe and cap, grouted in at the ground surface.

d) After the water level within the monitors has stabilized, slug tests will be performed within each monitor to establish horizontal permeabilities within the zone of saturation.

2.4.5 Extent of Soil Contamination -

a) Broad Site Analysis - In addition to the soil samples obtained from the monitoring wells and piezometer/lysimeter cluster installations, nine additional locations will be selected at the Taylor site for soil sampling. These locations will be sampled to approximately six (6) feet. Due to the logistics of locating drilling equipment between buildings, it is anticipated that a tripod mounted driven spoon sampling device (no augering) will be used. This is the easiest method to obtain soil samples for chemical analyses. All samples obtained will be logged and retained. The sampling holes will then be filled with bentonite slurry to prevent cross-contamination. It is possible that a Phase 2 soil sampling grid may be necessary, depending on the results of the analysis performed on the soil from these sampling points.

b) Northern Site Analysis - The proposed method for delineating the three-dimensional extent of the soil contamination in this area is the installation of shallow excavation trenches across the north portion of the site. The trenches will be logged by a geologist and selected soil samples, in both the horizontal and vertical planes will be obtained for chemical analyses. All material excavated during trenching will be immediately replaced in the trench after the soil samples have been taken.

3.0 SAFETY PRECAUTIONS AND METHODOLOGY

3.1 Cross-Contamination

3.1.1 The design of the rock piezometer with the casing left in place is intended to prevent cross-contamination between shallow and deep aquifer horizons

3.1.2 All other monitors, lysimeters, piezometers and bore holes will be backfilled with a bentonite/cement slurry to prevent future cross-contamination.

3.1.3 All equipment shall be steam cleaned throughout the course of the site work to prevent cross-contamination.

3.2 Soil Sample Contamination

3.2.1 Sampling devices and equipment will be cleaned between each sample utilizing a steam cleaning apparatus.

3.2.2 All soil samples will be placed in plastic jars. All procedures for sample collection, identification and storage shall be the same as those used during the site work of Fall 1981.

3.2.3 All equipment will be steam cleaned before it is used on the site and before it leaves the site.

3.3 Personnel Safety

3.3.1 All field personnel will be provided with protective clothing (boots, gloves, and coveralls) and breathing masks as required. The need for breathing masks will be determined after air measurements are performed in the field using Bacharach mercury test equipment supplied by Taylor.

3.3.2 A technician will be assigned to the drill crew to assist the driller and his assistant with the drilling equipment, the preparation of the monitoring instrumentation, the care and handling of the safety equipment, the cleaning of the field equipment and the acquisition of the required samples.

3.3.3 All field work will be under the full-time direction of a geologist or geotechnical engineer.

3.4 Procedures and Regulations

Applicable regulations of the Environmental Protection Agency (E.P.A.) and the New York State Department of Environmental Conservation (N.Y.S.D.E.C.) shall be followed. Specifically the following standards and methods will be employed during the Phase I field work.

A. Piezometers, lysimeters and monitoring wells will be installed in conformance to the EPA guidelines contained in the "Procedures Manual for Groundwater Monitoring at Solid Waste Disposal Sites", (E.P.A. Manual SW-611 December 1980).

B. Laboratory analyses to determine the soil characteristics of all soil samples will follow A.S.T.M. methods D421 and D422.

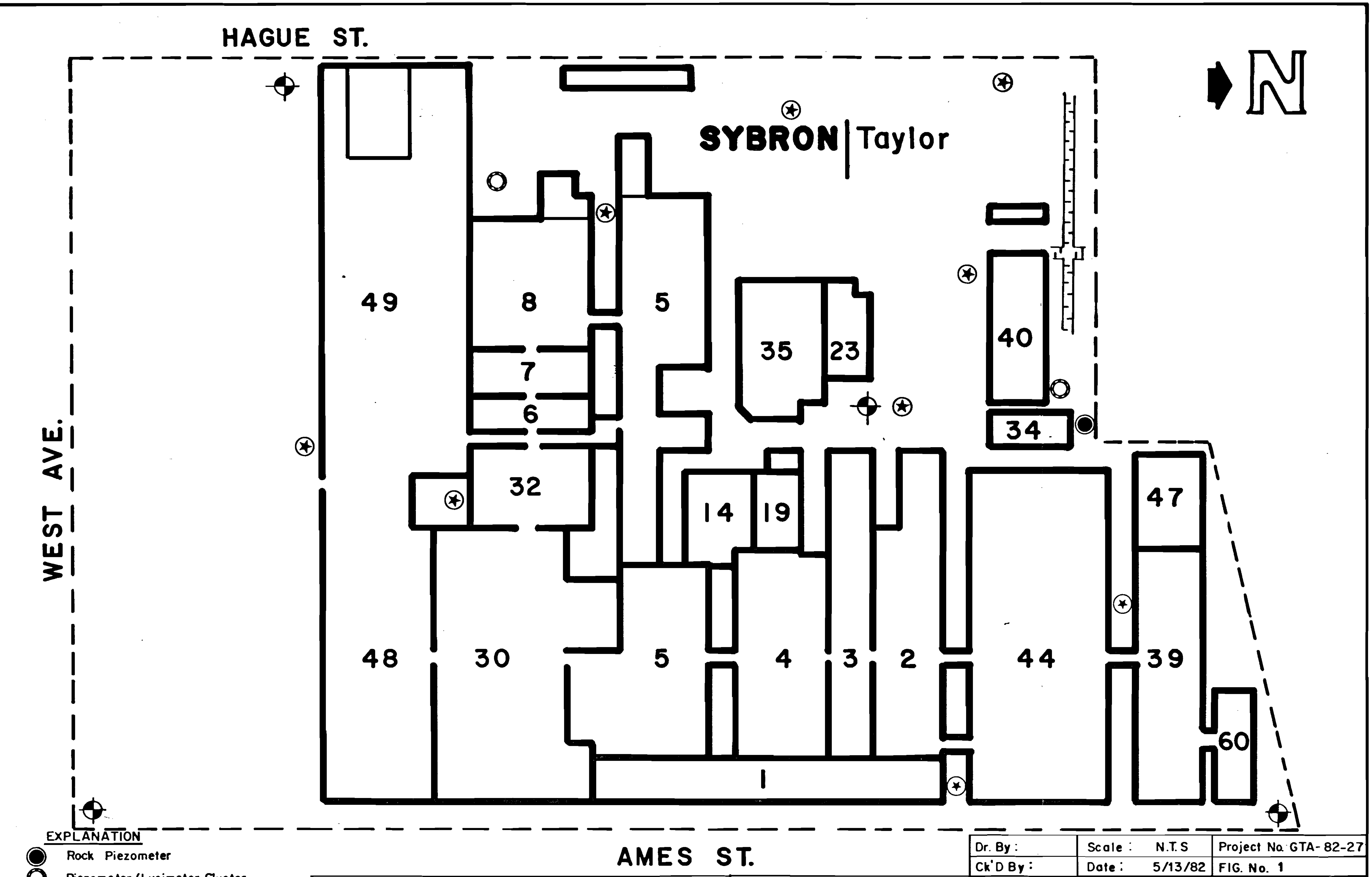
C. Soil samples taken from all the augered holes shall be withdrawn using A.S.T.M. method D1586.

D. United States Bureau of Reclamation Procedures for Packer Tests will be used for the pressure packer tests mentioned under 2.4.2.

Beyond this all methods and procedures proposed herein are designed to

A. Provide optimum results while minimizing the risks of cross-contamination, and

B. Provide the most up to date and accurate means of acquiring geotechnically sound data.



EXPLANATION

- ● Rock Piezometer
- ○ Piezometer/Lysimeter Cluster
- ⊕ Groundwater Monitor
- ⊛ Soil Sampling Point
- Investigation Trench

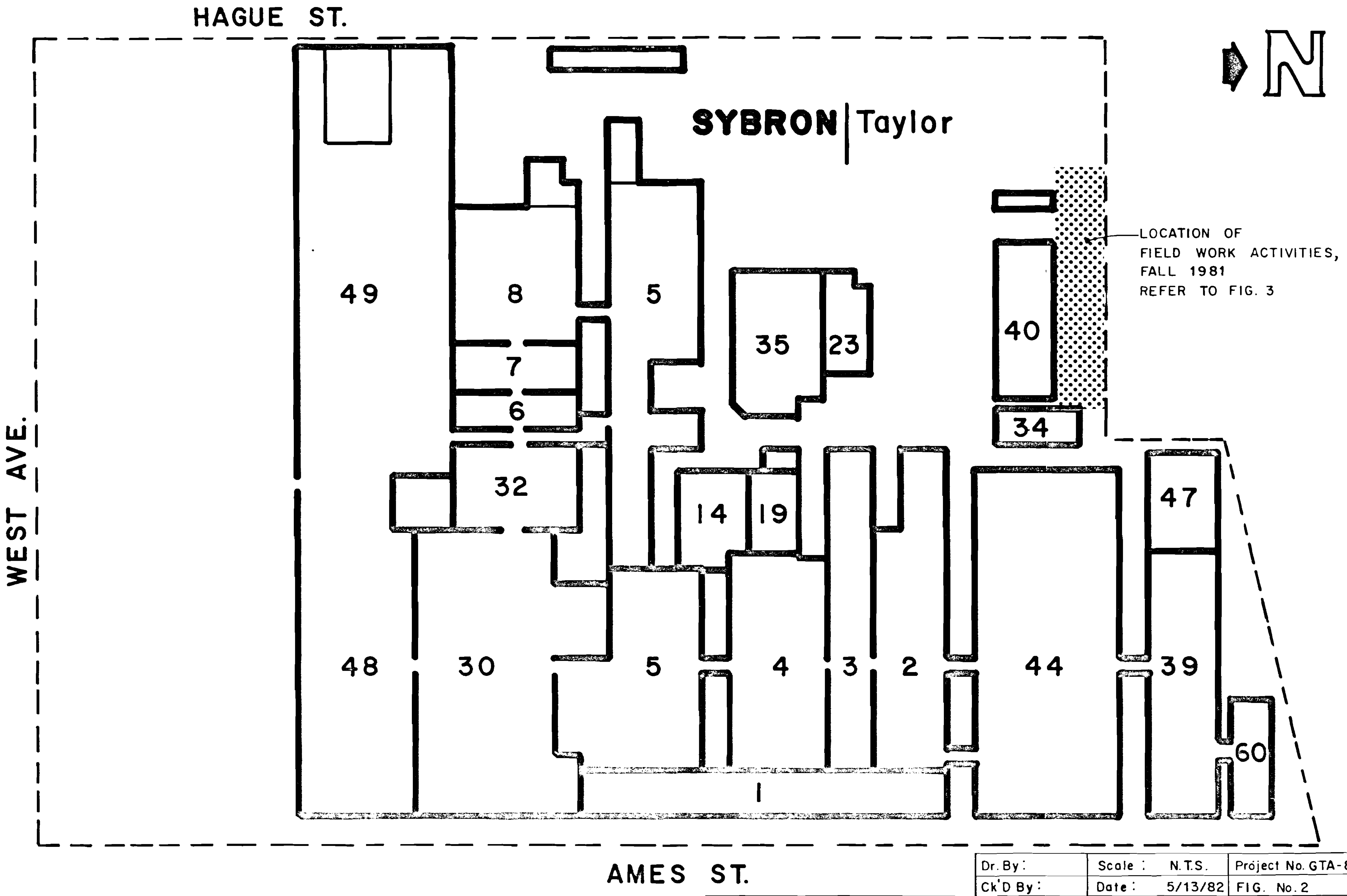
Dr. By :	Scale :	N.T.S	Project No. GTA-82-27
Ck'D By :	Date :	5/13/82	FIG. No. 1

TAYLOR INSTRUMENT COMPANY SITE
PROPOSED
PHASE 1 HYDROGEOLOGIC INVESTIGATION PLAN

LOZIER
ARCHITECTS/ENGINEERS

THOMSEN
ASSOCIATES

CONSULTING GEOTECHNICAL
ENGINEERS & GEOLOGISTS

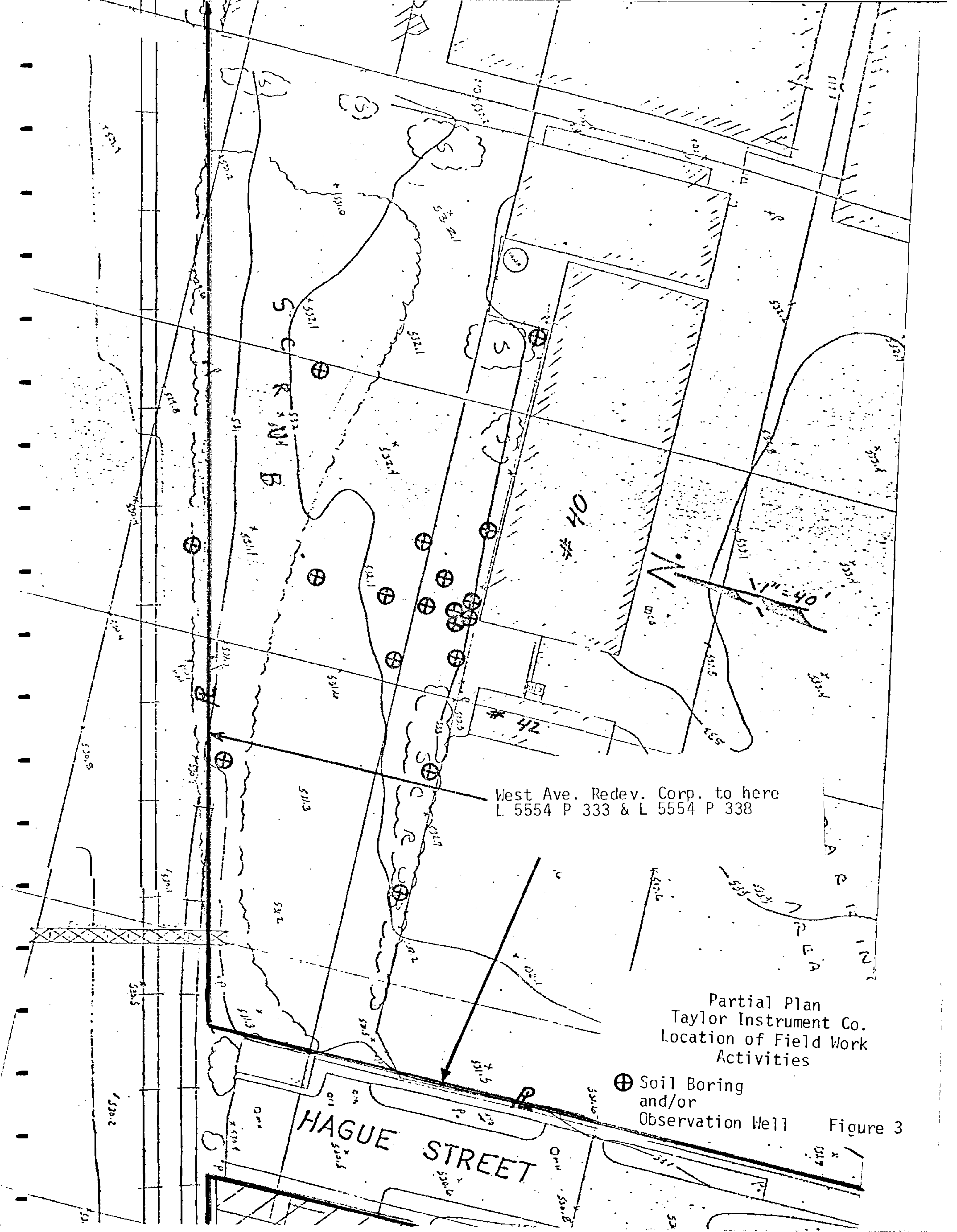


LOCATION OF FIELD WORK ACTIVITIES, FALL 1981 REFER TO FIG. 3

Dr. By:	Scale: N.T.S.	Project No. GTA-82-27
Ck'D By:	Date: 5/13/82	FIG. No. 2

TAYLOR INSTRUMENT COMPANY SITE

LOZIER
ARCHITECTS/ENGINEERS

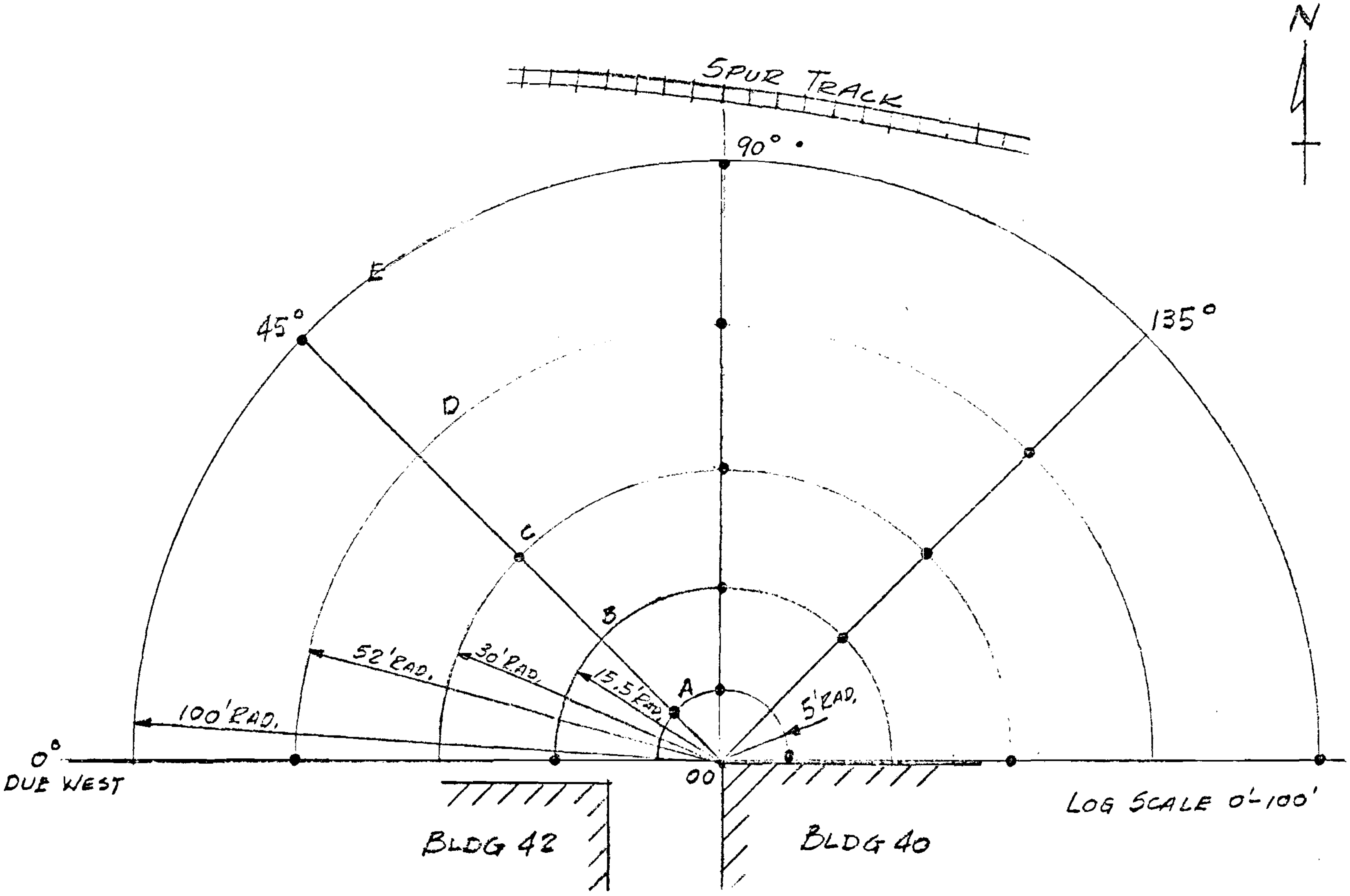


West Ave. Redev. Corp. to here
L 5554 P 333 & L 5554 P 338

Partial Plan
Taylor Instrument Co.
Location of Field Work
Activities

⊕ Soil Boring
and/or
Observation Well

Figure 3



TAYLOR INSTRUMENT CO.
SAMPLING GRID PATTERN
FIGURE # 4

APPENDIX "B"

LOZIER
CAMO
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23 N. MAIN STREET • FAIRPORT, NEW YORK 14450 • 716-425-2210

ON-SITE CHEMICAL FIXATION
OF
MERCURY CONTAMINATED SOIL

BENCH SCALE STUDY

TAYLOR INSTRUMENT CO.
A Division of Sybron Corp.
Rochester, New York 14601

DATE: June 14, 1982

LOZIER
CAMO
LABORATORIES
23 N. MAIN STREET • FAIRPORT, NEW YORK 14450 • 716-425-2210

TAYLOR INSTRUMENT CO.
BENCH SCALE STUDY

June 14, 1982

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TAYLOR INSTRUMENT CO.
BENCH SCALE STUDY

June 14, 1982

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Appendices

I. PURPOSE OF THE STUDY

The engineering and analytical program for site clean-up as proposed by Lozier Architects/Engineers for Taylor Instrument Co. includes an outline for chemical fixation of the mercury on site. The basis of the theory involves sequestering (or fixing) the mercury within the soil by chemical means. If this is successful, there would be little or no available mercury that could go into solution and migrate from the contaminated areas to the groundwater. Any mercury not chemically fixed that might migrate to the groundwater could be collected in a leachate collection system and treated if necessary before disposal.

The chemical fixation approach, as outlined by Lozier, includes three (3) steps for Phase I. The first step involves a visual inspection of the Taylor site. The second step includes hydrogeological field tests and associated laboratory analyses. The object of these tests is to characterize the soil and groundwater. The third step of Phase I deals with bench testing of representative soil samples to judge the applicability of the proposed chemical fixation methodology.

This report outlines the bench scale study proposed to determine the feasibility of mercury sequestration with iron sulfide minerals.

II. INTRODUCTION

The bench scale study outlined in this report will determine if iron pyrite (iron sulfide, FeS_2) can be used at the Taylor Instrument Co. Ames St. facility ("Taylor") in Rochester, New York, to sequester the mercury contaminating the soil at this site and to prevent migration of the mercury to the groundwater.

Much of the analytical research which underlies this treatment method is supported by the work of Dr. William Fyfe, Department of Geology at the University of Western Ontario in Canada. Dr. Fyfe's paper "Mercury Removal from Water by Iron Sulfide Minerals. An Electron Spectroscopy for Chemical Analysis (ESCA) Study", is enclosed (see Appendix 1 of this report). Dr. Fyfe's work showed a 95% reduction in Hg° and Hg^{+2} in solution through the use of iron sulfide.

The laboratory testing will be composed of a number of separate investigations.

1) Contaminated and uncontaminated soil samples obtained from Taylor will be tested to determine the different forms of mercury present in the soil matrix and their respective quantities.

2) A mixing technique employing the chemistry of fixation will be set up and tested as shown in Figure 1. Once the iron pyrite has been mixed with the soil samples, the mixture will be transferred to test columns (see Figure 2).

3) Next, to duplicate the effect of low pH rain on the soil/pyrite mixtures the test columns will be subjected to pH adjusted deionized water. The resulting leachate will be tested for mercury content.

4) The possibility of sequestering mercury through the formation of iron pyrite within the soil matrix utilizing a spray technique will also be tested. Contaminated and uncontaminated

soil samples will be placed in test columns as shown in Figure 2. The test columns will be subjected to solutions of ferrous chloride ($FeCl_2$) and sodium bisulfite ($NaHSO_3$). These solutions will be prepared using potable water from Taylor.

5) The leachate generated from spraying the test columns with pH adjusted deionized water will be analyzed for mercury content.

Detailed discussions on the preceeding is found in Sections III and IV of this report.

III. BENCH SCALE STUDY - PRELIMINARY ANALYSIS

A) Contaminated soil from each hot spot (to date three (3) have been identified) will be sampled at various depths and composited. Each of the composite samples would be split into two (2) portions; one portion would be analyzed for total mercury (2), organic mercury (3), and EP Toxicity - mercury (4). These analyses will establish base data points. The difference in mercury concentration between the total mercury and the organic mercury analyses will indicate the concentration of mercury that is inorganic. The composited soil from the most contaminated hot spot will be selected for all further mixing procedures and test column use. If the iron sulfide mixing method is successful for the most contaminated soil, it should be applicable to lower levels of contamination.

B) Groundwater Analysis - The groundwater will be characterized with respect to organic and inorganic constituents to determine the quality of the groundwater prior to any treatment processes. These analyses will include: pH, cadmium, cyanide, nitrate (as N), chloride, iron, hexavalent chromium, nickel, sulfate, copper, mercury, zinc, trichloroethylene, and methyl chloroform.

why?

C) Soil Analysis - Those parameters for which the results of the groundwater analyses were positive will also be tested for during the analysis of the soil samples. In addition redox potential and percolation tests will be performed.

IV. BENCH SCALE STUDY - METHODOLOGY 1 (MIXING TECHNIQUE)

A. One half of the second portion of the split contaminated soil samples (see section III-A above) will be physically mixed with various amounts of iron sulfide. The amounts of iron sulfide used will range from 1% to 10% (weight/weight basis) in the soil. These percentages were suggested by the author of the reference paper contained in Appendix 1 of this report.

The iron sulfide/soil mixtures will be hand mixed in beakers in the laboratory. The end result of this preparation will be the array of samples as shown in Figure 1. This physical mixing procedure will parallel a possible on-site excavation and mixing of the soil and iron sulfide.

Control Mix #1 will be a method blank, and will indicate the effect of the mixing on the resultant leachate mercury levels without the addition of iron sulfide.

Test Mixes #1 through #4 will have varied amounts of iron sulfide mixed with 100 g soil aliquots. The addition will result in mixtures with 1, 2, 5, and 10 percent of iron sulfide (by weight) in the soil.

Control Mix #2 will be utilized to indicate what maximum pH and iron concentration changes may be expected in the groundwater from the application of the iron sulfide with contaminated soil. Research indicates that there is a possibility that acidic conditions may be generated by the oxidation of S_2 to SO_4 and, subsequently, to H_2SO_4. This reaction may decrease the groundwater pH(5). Also, the iron concentrations will serve as an indicator as to whether or not the treatment might cause the State Groundwater effluent standards for iron to be exceeded in groundwaters of the surrounding area. If pH decrease appears to be a potential problem, the application of $CaCO_3$ (lime) on the surface of the site (allowing rain water to carry this neutralizing agent down through the soil) will be considered.

B) Six (6) test columns (see Figure 2) will then be constructed using the contents of the beakers in Figure 1. To each test column will be added pH adjusted deionized water with a pH similar to that of the rainwater in the Rochester area. The application rate will be at the perk rate determined for this soil in vivo. The addition of the artificial rainwater will cause a leachate to be generated within each test column. This leachate ("leachate #1") will be collected as it flows from the base of the columns. Each sample of leachate #1 will be tested for total mercury and organic mercury. After a sufficient volume of leachate has been generated, the test column contents will be analyzed for EP Toxicity-mercury.

The reduction of total and organic mercury in the treated soil leachate versus the untreated soil leachate will indicate to what extent the iron sulfide has reacted with the mercury in the soil. This leachate will represent the liquid that, after iron sulfide treatment, could reach the groundwater on site. The EP Toxicity test procedures are being conducted only in that they are more rigorous than the elements which nature would normally present. Since HgS_2 is basically water insoluble, it should not be extracted by the EP Toxicity test methodology, and thus the EP Toxicity-mercury data on the reacted test mixtures (as compared to the unreacted control mixture) will indicate whether the mercury has been sequestered.

C) An iron sulfide curtain could be installed in a trench excavated in the direction of groundwater flow to capture any transported mercury already in the groundwater or which may go into solution in the future. A bench test to simulate this condition will be developed by passing leachate #1 (see Figure 2) through an iron sulfide column.

If DEC approves this concept, then all six (6) samples of leachate #1 (from each of the six (6) test columns) will be passed through another series of test columns containing coarse iron sulfide (See Figure 2). The effluent from this column would represent the actual discharge to a final collection system or to the ambient groundwater if the iron sulfide curtain were installed. Total mercury and organic mercury analysis of this final treated leachate ("leachate #2") will be performed.

V. BENCH SCALE METHODOLOGY 2 (SPRAYING TECHNIQUE)

A) An alternate proposal for creating the reaction of iron sulfide with mercury is now being studied. This approach would simplify the on-site work, lessen the exposure of remedial workers to mercury and lessen the expense of the remedial process.

Under this potential treatment scheme, the entire contaminated area would be sprayed with a ferrous chloride ($FeCl_2$) solution until the vadose zone is saturated. A second spraying of a sodium-bisulfite ($NaHSO_3$) solution would then be done, which would also saturate the vadose zone.

In theory, this two-staged spraying would create a reaction of ferrous chloride and sodium-bisulfite to form iron sulfide within the soil matrices. The chemical reaction would be:

$$FeCl_2 + NaHSO_3 \longrightarrow FeS_2 + \text{various salts} + \text{water}$$

The iron sulfide generated would then be available to react with any available mercury present to create mercuric sulfide. The chemical reaction would be:

$$Hg^{+2} + S^{-2} \rightleftharpoons HgS \text{ (insoluble)}$$

A bench scale test to study this will be set up by putting the remainder of the second portion of the most contaminated soil in a test column and by spraying the column with ferrous chloride solution followed by sodium-bisulfite solution. Various molar concentrations of each chemical would be applied to determine the best usage concentrations. The leachate generated by the test columns would be tested for total mercury, organic mercury, and iron as outlined in Sections III and IV, above.

If this approach indicates that the technique is successful in sequestering the mercury, the test column leachate #1 could also be passed through a series of test columns of coarse iron sulfide to simulate leachate passing through an iron sulfide curtain.

See Figure 3 for the proposed test column set up.

VI. QUALITY CONTROL

A) System Control:

The control mixtures for methodology 1 (mixing technique) and the control test columns for methodology 2 (spraying techniques) will be utilized as control blanks and method blanks.

B) Analytical Equipment:

The atomic absorption spectrophotomer used for the total mercury analysis will be a Perkin-Elmer 460 with a Perkin-Elmer mercury analyzer kit (cold vapor technique). The organic mercury Analysis will utilize a Perkin-Elmer Sigma One gas chromatograph with a flame ionization detector in concert with a Perkin-Elmer Sigma 10 Data Station. Calibration of both instruments will be separately documented and will consist of a 3-5 point calibration curve. The calibration will be performed each day of the analysis.

C) Precision and Accuracy Data:

All leachate samples will be analyzed in duplicate. Thirty-three percent (one out of every three) of all leachate samples will be spiked with known mercury concentrations and recovery data generated for both total mercury and organic mercury.

All EP Toxicity analyses will be performed in triplicate due to the heterogeneous nature of the soil samples.

D) Report:

All Quality Control data will be reported.

VI. RESULTS AND DISCUSSION

The initial characterization of the soil for organic and inorganic mercury will be the first evaluation point. Originally the source of contamination was elemental mercury, and it is believed that a great majority of the total mercury now present in the soil is inorganic Hg^0 or Hg^{+2}. If this is not the case and a large portion of the mercury exists as organic mercury then the phase I bench studies may have to be revised.

The second evaluation point will consist of a review of the mixing procedures and the spraying techniques. Either or both of these treatment methods may indicate approximate amounts of treatment chemical(s) that can be applied on-site for the successful sequestration of mercury.

The ultimate success or failure of the bench scale tests will be judged in accordance with the judgement criteria proposed in the main body of this Phase I report, as modified (if necessary) in accordance with DEC comments. Any such modification of these criterion must be made prior to the beginning of actual bench scale testing.

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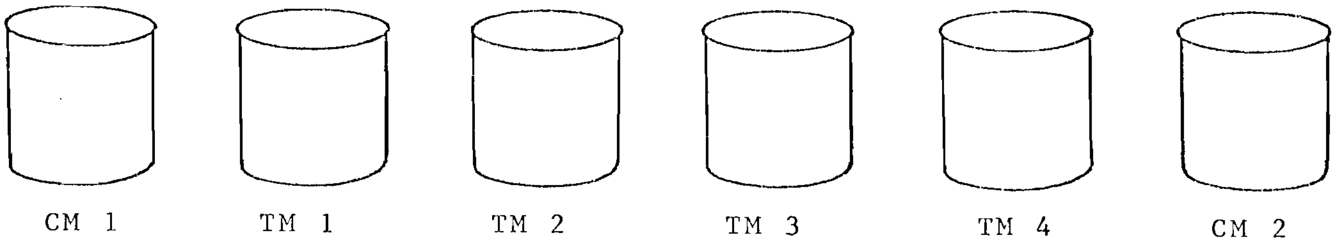
FIGURE 1 - METHODOLOGY 1

TEST MIXING PROCEDURE FOR THE MOST CONTAMINATED SOIL



CM 1 - Control mix 1: 100 g soil-contaminated, no iron sulfide

TM 1 - Test mix 1: 100 g soil-contaminated, 1 g iron sulfide

TM 2 - Test mix 2: 100 g soil-contaminated, 2 g iron sulfide

TM 3 - Test mix 3: 100 g soil-contaminated, 5 g iron sulfide

TM 4 - Test mix 4: 100 g soil-contaminated, 10 g iron sulfide

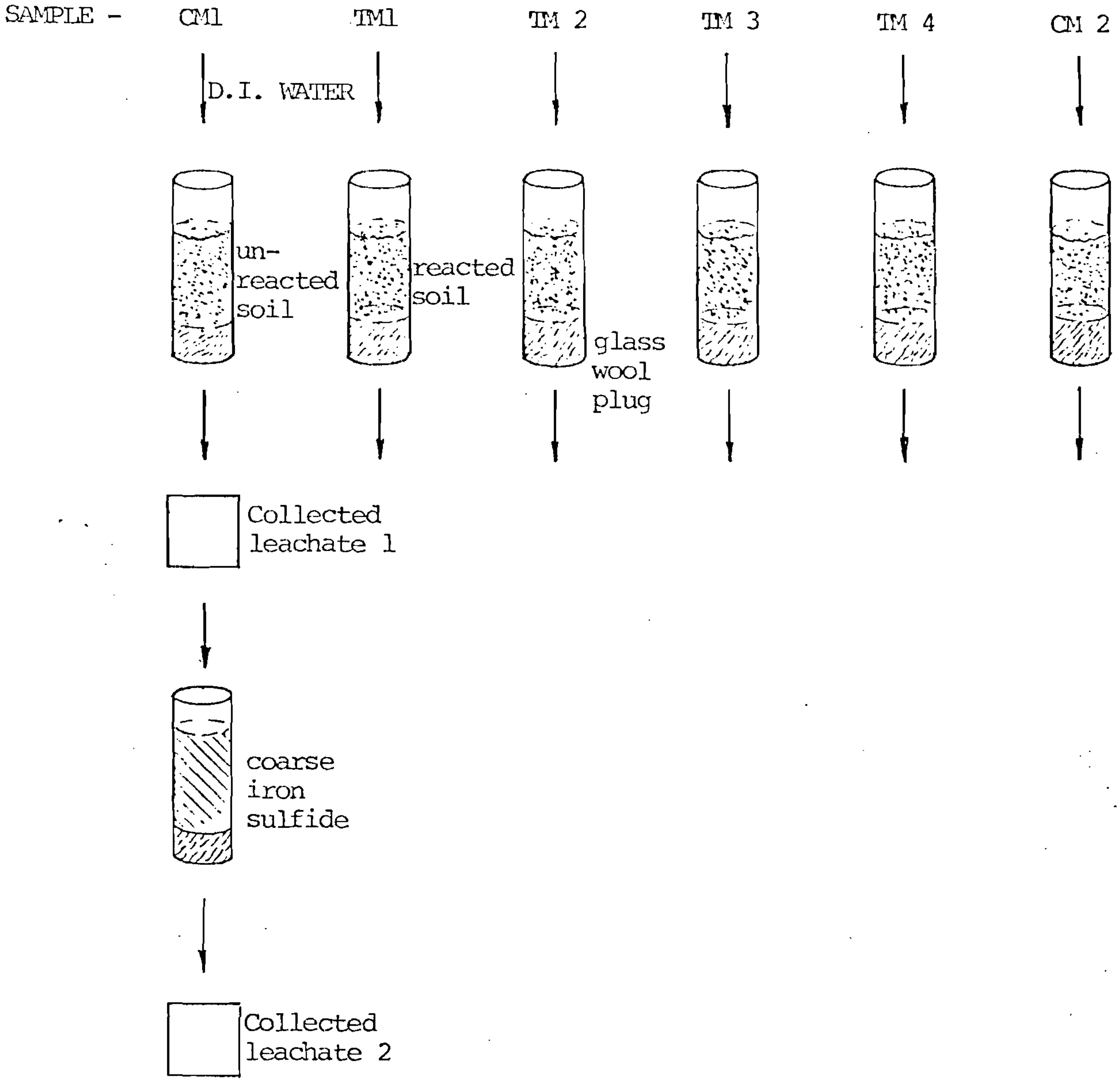
CM 2 - Control mix 2: 100 g soil-uncontaminated, 5 g iron sulfide

Test Conditions:

Mixing Time - 30 minutes
Temperature - ambient
Equipment - six paddle stirrers

FIGURE 2 - METHODOLOGY 1

TEST COLUMN SET-UP FOR LEACHATE GENERATION

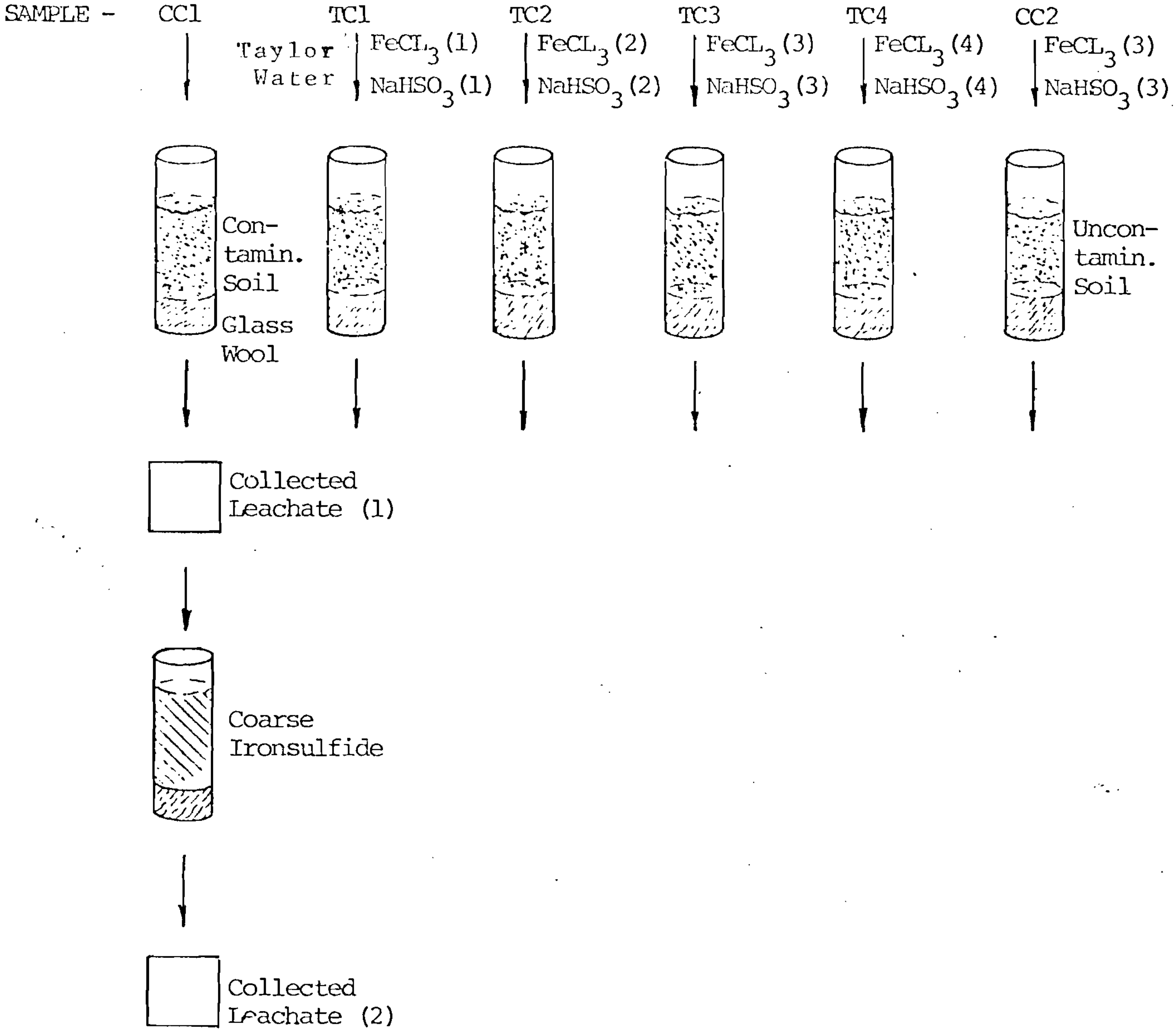


Test Conditions:

Column - glass
Size - To be determined
Temperature - ambient

FIGURE 3 - METHODOLOGY 2 (Spraying Technique)

TEST COLUMN SET-UP FOR LEACHATE GENERATION



SAMPLE IDENTIFICATION:

CC1 - control column 1: 100 g - contamin. soil, no $FeCL_3$ or $NaHSO_3$, instead D.I. Water
TC1 - test column 1: 100 g - contamin. soil, $FeCL_3$(1) and $NaHSO_3$(1), (1) = 0.01 M
TC2 - test column 2: 100 g - contamin. soil, $FeCL_3$(2) and $NaHSO_3$(2), (2) = 0.02 M
TC3 - test column 3: 100 g - contamin. soil, $FeCL_3$(3) and $NaHSO_3$(3), (3) = 0.05 M
TC4 - test column 4: 100 g - contamin. soil, $FeCL_3$(4) and $NaHSO_3$(4), (4) = 0.10 M
CC2 - control column 2: 100 g - uncontamin. soil, $FeCL_3$(3) and $NaHSO_3$(3), (3) = 0.05 M

TEST CONDITIONS: Column - Glass, Temperature - Ambient

Mercury Removal from Water by Iron Sulfide Minerals. An Electron Spectroscopy for Chemical Analysis (ESCA) Study

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■ Using ESCA (electron spectroscopy for chemical analysis) and atomic absorption spectroscopy as analytical techniques, we show that naturally occurring sulfides are excellent adsorbers for aqueous solutions of Hg^{2+} and Hg^0. The Hg concentration in chlor-alkali effluent can be decreased dramatically to less than 100 ppt.

Mercury pollution of natural waters by man's activities (*1–3*) has created severe problems in many countries of the world. It has been estimated that the land-derived flux of mercury to the oceans is four times the preman level (*4*). In addition, an increased use of coal and geothermal steam for electrical generation will, without further abatement measures, increase mercury (and other heavy metal) contamination of the atmosphere and hydrosphere. Of particular recent ecological concern has been the mercury pollution from industrial plants and their associated dump sites (*2*).

Although mercury losses from these plants have been reduced greatly in the last decade (*5,6*), economical and efficient methods must be devised to decrease further losses to the environment. Because the solid-solution adsorption reaction is known to control many heavy ion concentrations in the environment, we looked for a common economical mineral to adsorb Hg from such industrial waste. Pyrrhotite (FeS) and pyrite (FeS_2) ores seemed ideal candidates for a number of reasons. Mercuric ions have a large affinity for sulfide, as evidenced by the solubility product for HgS and a preliminary adsorption study on heated pyrite (*7*). Iron sulfides are common and economical minerals to mine throughout the world and are usually quite accessible in localities where mercury contamination is dominant. For example, most massive sulfide mining operations (Pb, Zn, Cu) separate and discard huge amounts (thousands of tons) of iron sulfides yearly. Iron sulfide and its oxidation products should pose little pollution threat if dumped into contaminated waterways. If mercury exchanges for surface lattices sites, the displaced iron and/or sulfur is precipitated by natural processes.

Three separate sets of adsorption experiments have been carried out. In the first two experiments, 0.1 to 1.0 g of powdered (<200 mesh) pure Sudbury pyrrhotite or pyrite was stirred in deionized distilled water in polypropylene or borosilicate beakers for approximately 2 h to obtain equilibrium. The pH was adjusted to between 4 and 9. Solutions of $HgCl_2$ were added to the stirred FeS to give initial Hg concentrations between 1 and 200 ppm in a first study and 20 and 100 ppb in a second study. In the second study, large concentrations of Cl^- were added to simulate chlor-alkali waste. At selected times, 10-mL aliquots were removed and centrifuged to remove any iron sulfide powder. The samples were then analyzed for mercury by cold vapor chemical (*8*) or graphite furnace flameless atomic absorption methods (*9*).

To show the great utility of the ESCA technique for studying metal sorption on solids directly, and to study further the effect of chloride ion concentration, a third set of experiments was performed. High grade pyrrhotite and pyrite ores were cut into small pieces with a 1-cm² surface and then ground and polished. Each sulfide plate was washed thoroughly in acetone and deionized distilled water and air-dried prior to ESCA (XPS) analysis for surface trace impurities of silica (SiO_2), mercury, chlorine, etc. A review of this ESCA technique has been previously published (*10–12*). The theory of ESCA and its recent applications in surface analysis have been critically reviewed by Hercules (*13–15*). These plates were then placed in 500 mL of various concentrations of mercuric chloride or elemental mercury (Hg^0) at pH 4–7. After a specific time in solution, each plate was carefully removed from its reaction solution and dipped five times in fresh deionized water to remove unadsorbed, adhering Hg ions (*10, 16*). Each plate was then air-dried and analyzed using the ESCA technique for the following elements: Hg, Cl, S, Fe, C, and O.

The data for the mercuric ion uptake in the first experiment are summarized in Figure 1. The data indicate an adsorption process, as the mercury loss from solution is proportional to the weight of powdered FeS and the initial mercury ion concentration. The Langmuir adsorption expression (*17*) was used to determine the maximum adsorption capacity (X_m, 3.55×10^{-2} mol of Hg/mol of FeS) and the adsorption constant (b, 6.05×10^4) for the FeS powder. The equilibrium results fit well to the Langmuir adsorption equation and adsorption isotherm. The good linear fit to the Langmuir equation indicates a sorption process proportional to sorbent surface area and sorbate concentration at constant pH.

Table I summarizes the Hg uptake at much lower Hg contents for both Hg^{2+} and Hg^0 with FeS and FeS_2. These results are notable for two reasons. Firstly, with the exception of Hg^0 on FeS, over 95% of the Hg is removed from solution in all cases. Secondly, the adsorption is not decreased by the chloride ion concentration. This result contrasts with previous studies involving the removal of mercury from solution by other materials where increasingly greater Cl^- content reduced the mercury adsorption from solution (*18*).

The ESCA results using both pyrrhotite and pyrite plates, at a solution pH of ~4 ($HgCl_2{}^0$ species dominant) and variable sodium chloride content (0, 100, 1000 ppm), are shown in Tables II and III. These results show that for each initial mercuric ion concentration and constant time of reaction, the sorption rate of mercury *increased* with increasing chloride concentration, especially at low initial Hg concentrations. Mercury sorption rates on iron sulfide minerals thus do not follow a simple cation hydrolysis relationship as previously suggested for oxides (*19*). The highest Hg intensities correspond to near monolayer coverage. In the ESCA studies, little chloride and no sodium ions were detectable, although the initial solution concentration of NaCl was as large as 1000 ppm. This indicates that the mercury sorption is highly specific.

A sulfide plate studied at pH ~7 (Table II) produced a much lower sorption rate with respect to the results at pH ~4. This again indicates the pH influence upon sorption rates (see also Table I). It was also found that pyrrhotite sorbed much larger weights of mercury ions than pyrite, assuming equivalent initial mercury, sodium, and chloride ion concentrations. Thus, surface lattice sites and solubility differences are important sorption reaction parameters.

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Table I. Results of Hg^{2+} and Hg^0 Adsorption by 1-g Iron Sulfide Minerals

Hg species and mineral type [a]	pH	[Hg] initial, ppb	[Cl] initial, ppm	[Hg] final, ppb	% Hg reduction in solution
A. Hg^{2+}–FeS	4.4	20	0	0.14	99.3
	6.5	20	0	0.35	98.3
	9.8	20	0	1.00	95.0
	4.6	20	100	0.12	99.4
	7.0	20	100	0.40	98.0
	9.7	20	100	0.45	97.8
	4.4	100	0	0.57	99.4
	6.5	100	0	1.5	98.5
	9.5	100	0	4.30	95.7
	4.6	100	100	0.60	99.4
	6.7	100	100	1.3	98.4
B. Hg^0–FeS	4.5	30	0	5.1	83.0
–FeS_2	4.5	30	0	0.10	99.7
C. chlor-alkali plant waste–FeS					
CA 1 [b]	5.5	2000	>1000	60	97.0
	4.4 [c]	2000	>1000	40	98.0
CA 2 [d]	6.2	5	<100	0.10	98.0
	4.4 [c]	5	<100	0.05	99.0

[a] 100 mL of solution shaken for 1 h, and then allowed to settle 1 h before analysis of the supernatant. [b] Nontreated chlor-alkali processing water. [c] pH adjusted by dropwise addition of 1 M HCl. [d] Treated chlor-alkali processing water.

Table II. ESCA Study of Mercury Adsorption on Iron Sulfides; Variation with Chloride Concentration

Init Hg concn, ppm [a]	mineral type [b]	solution pH	react. time, min [c]	Hg 4f peak area intensity (× 10^4) [d] at init chloride concn, ppm: 0	100	1000
A. Hg^{2+} reactions						
0.02	FeS	4	1440	3.6	29.4	38.7
0.10	FeS	4	5		0.42	0.47
	FeS	4	60	0.82	2.12	7.30
	FeS	4	1440	30.6	56.9	69.5
	FeS	7	1440	2.3	6.0	2.3
1.0	FeS	4	60	53.0	43.8	38.2
	FeS	4	1440	40.6	40.6	52.4
0.02	FeS_2	4	1440	1.0	7.4	9.4
0.10	FeS_2	4	1440		14.00	10.0
B. Hg^0–H_2O equilibrium reactions						
0.03	FeS	5.7	2880	2.54		
	FeS_2	5.7	5760	18.6		
	FeS_2	5.7	5760	16.0		
C. Hg^0	FeS		2880	31.3		
	FeS_2		5760	32.8		

[a] 500 mL of Hg solution used. [b] Cut pyrrhotite or pyrite ore. [c] Mineral plates dipped five times in fresh water to remove Hg solution. [d] Peak area intensity for 50 scans of Hg 4f.

Several pyrrhotite and pyrite plates reacted in elemental mercury (Hg^0) and in elemental mercury in water (Table II) were also studied by ESCA for sorption rates; pyrite appears to be a superior adsorber for Hg^0. An earlier study of Hg^0 solubility in water at 22 °C indicated an equilibrium mercury content of ~25 ppb (*20*). It is apparent that iron sulfide minerals concentrate mercury ions and atoms from extremely dilute mercury solutions, efficiently and specifically.

Process water samples (CA1 and CA2) were collected at a large chlor-alkali plant in Canada, and Hg adsorption was studied using both iron sulfide powder and plates. The adsorption results (Tables IC and III) are consistent with those using our prepared mercury solutions. The ESCA results (Table III) indicate that a significant amount of mercury in the 500-mL 5-ppb solution is removed, and the powder results (Table IC) show that this Hg content is reduced to ≤0.1 ppb. The ESCA results again indicate that the sorption rate increases with decreasing pH.

Some recent studies on mercury in fish in Quebec indicate that the natural existence of sulfide minerals, such as pyrite and pyrrhotite, may be a factor in reducing the availability of mercury to biota in otherwise sensitive areas. In contrast to

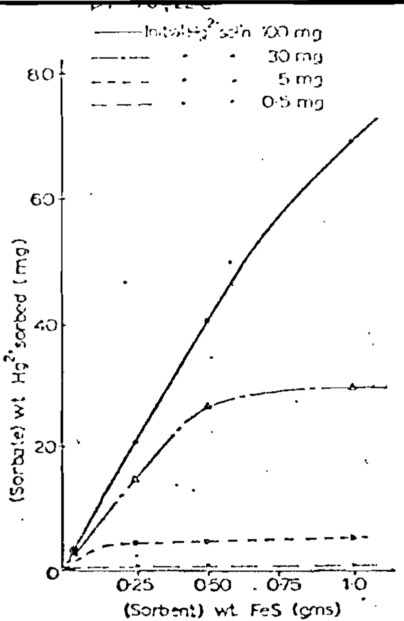

Figure 1. Mercuric ion adsorption on powdered FeS in 500 mL of solution. The time of reaction in each case is 30 min

Table III. ESCA Study of Mercury Sorption by Iron Sulfides from Chlor-Alkali Processing Waters

chlor-alkali processing solution type [a]	iron sulfide ore [b]	reaction time, h [c]	peak area intensity Hg 4f (×10^4) [d]
1. CA 1 (pH ~5.5)	FeS	1.0	1.1
		24.0	3.0
		48.0	6.9
CA 1 [e] (pH ~4.0)	FeS	4.0	nil
		24.0	4.5
		48.0	27.5
	FeS_2	24.0	7.0
2. CA 2 (pH ~6.2)	FeS	6.0	0.83
		24.0	2.10
CA 2 [e] (pH ~4.0)	FeS	4.0	27.3
		24.0	7.1
		48.0	19.3
	FeS_2	24.0	2.7

[a] As per Table II. [b] As per Table II. [c] As per Table II. [d] As per Table II. [e] pH adjusted by dropwise addition of 1 M HCl.

accepted theory, the mercury concentration in fish (*21*) was lowest in regions unaffected by point sources with the highest sediment mercury concentrations. This supposed anomaly can be explained by the presence of relatively high concentrations of sulfide minerals in the regions with the highest sediment mercury concentrations.

Our results of mercury adsorption on iron sulfides indicate the potential use in eliminating both mercuric ions and elemental mercury atoms from polluted natural waters, industrial waste, and process waters. The observed residual solution values compare to levels in ocean water (~5 ppt) and rain (~1 ppt) (*22*). A more detailed investigation involving the most efficient design of a pilot plant and related chemical parameters to best use iron sulfide ore is in progress.

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