FOCUSED FEASIBILITY STUDY REPORT

KLIEGMAN BROS. SITE

OPERABLE UNIT NO. 1

SITE #2-41-031

QUEENS, NEW YORK

Prepared for:

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

DIVISION OF ENVIRONMENTAL REMEDIATION

WORK ASSIGNMENT D003825-37.2

Prepared by:

URS CORPORATION

77 GOODELL STREET

BUFFALO, NEW YORK 14203

JULY 2005

TABLE OF CONTENTS

Page No.

TABLES
(Following Text)

FIGURES
(Following Tables)

APPENDICES

1.0 INTRODUCTION

1.1 Scope

This Focused Feasibility Study (FFS) presents the evaluation of alternatives for the remediation of Operable Unit No. 1 (OU1) at the Kliegman Bros. Site (Site No. 2-41-031) in Queens County, New York. This work is being performed for the New York State Department of Environmental Conservation (NYSDEC) under Task 5 of Work Assignment D003825-37.

1.2 Site Description and History

The Kleigman Brothers Site is located at 76-01 77th Avenue in Queens County, New York (Figure 1-1). The site is bordered to the north by the Long Island Railroad. Residences border the site to the east, west and south. This site has an area approximately 37,000 square feet, of which 26,000 is occupied by a building (Figure 1-2). A basement exists under the western portion of the building.

The site was formerly owned by Kliegman Bros. Inc. This site was used as a warehouse and distribution center for laundry and dry-cleaning supplies from the 1950s through the 1990s. The site contained two 6,000 gallon above ground storage tanks (ASTs) which were used to store tetrachloroethene (PCE) (Figure 1-3). The tanks have since been removed from the property. Although these tanks are the presumed source of contamination, it is unknown if, and when, product was released or, whether contamination was due to a singly catastrophic release or a chronic leak problem. Kliegman Bros. ceased operation in 1999. The site was purchased in 2000 and is currently being used as a warehouse for an imported food distributor. Known contamination at the site is unrelated to operations since 2000.

1.3 Previous Investigations

Soil and/or soil gas sampling has been performed at the site on at least six different occasions from 1997 through 2002. The initial investigations were performed by Tradewinds

Environmental Restoration, Inc. and Advanced Cleanup Technologies (ACT) in 1997 and 1998, respectively. These investigations comprised soil gas collection and analysis in the area between the building and the railroad, where the PCE storage tanks were located. Additional soil gas sampling was performed by EEA, Inc. (for a prospective site owner) and URS (for NYSDEC) in 2000. All of these investigations revealed the presence of PCE, often at high concentrations. A fifth investigation was performed by Enviroscience Consultants, Inc. in 2001 as part of a VCP agreement with NYSDEC, and included soils and groundwater sampling as part of a Focused Remedial Investigation/Interim Remedial Measures/(FRI/IRM). The objective of the FRI/IRM was to delineate on-site soil contamination sufficiently to enable design of a soil vapor extraction system or systems to remediate on-site soil. As part of the study, Enviroscience Consultants, Inc. advanced nine borings, SVE-1 through SVE-5 and EB-1 through EB-4. Enviroscience also collected 26 soil samples from beneath the subfloor of the building, approximately 0-12 inches below the concrete floor/soil interface.

Between October 2000 and August 2001, the New York State Department of Health (NYSOH) conducted ambient air sampling in 17 residences east, west, and south of the facility. NYSDOH sampled on five occasions, although individual residences were sampled only one to three times each. Vapors were detected in 16 of the 17 residences tested.

In September 2002, the site owner discontinued his participation in the VCP and thus responsibility for addressing on-site subsurface contamination reverted to NYSDEC. Because of documented ongoing PCE vapor exposures to adjacent residences, NYSDEC tasked URS to implement a soil vapor extraction (SVE) system as an interim remedial measure (IRM). The IRM is discussed in Section 1.6.

1.4 Site Model

On-site contamination consists of vadose zone (above the water table) soil contamination and groundwater contamination. Within the vadose zone, perched water was detected in the eastern area of the site. The perched water accumulates on a clay layer that is about 12 feet below ground surface in this eastern region of the site (Figure 1-3). The groundwater table is about 65-70 feet below ground surface at the site.

Groundwater contamination has migrated offsite as shown by the RI. VOCs, particularly PCE, have been detected above groundwater criteria in all directions around the site. VOCs have also migrated offsite in soil gas. The source of the soil gas contamination is mainly contamination in vadose zone soil.

Two operable units have been defined to address contamination at the site and offsite contamination attributable to the site. Operable Unit No. 1 (OU1) is the onsite operable unit and Operable Unit No. 2 (OU2) is the offsite operable unit. This FFS addresses OU1 which includes: vadose zone soil, that is, soil above the water table and the perched water area located on the eastern portion of the site within the vadose zone. Operable Unit No. 2, which is not addressed by this FFS, comprises offsite contamination – primarily groundwater. Onsite and offsite groundwater will be addressed exclusively in the OU2 Feasibility Study as it is not feasible to address groundwater independently of the larger offsite groundwater plume.

1.5 Extent of Contamination

Nine borings were installed in the north yard (north parking lot) at the site by Enviroscience Consultants, Inc. in 2001 (Figure 1-3). Soil analytical results showed elevated levels of benzene, toluene, ethylbenzene, xylene (BTEX), tetrachloroethene (PCE), and 1,2-dichloroethene (DCE) (Table 1-1). PCE was detected most frequently, and at the highest concentrations. Several detections of PCE were above the Recommended Soil Cleanup Objective (RSCO) value of 1,400 micrograms per kilogram presented in the NYSDEC Technical Administrative Guidance Memorandum (TAGM) #4046. The borings showed a clay layer with perched water in the eastern portion of the north yard. PCE was detected above the clay layer at concentrations above the RSCO value in the eastern portion of the north yard; however, samples were not collected below the clay layer.

Enviroscience also collected 26 soil samples from below the building (Figure 1-4). Results indicated that concentrations of PCE generally exceeded the RSCO only in shallow (less than one foot below the floor) samples (Table 1-2). However, deep samples were not collected at most locations.

URS performed an extensive onsite soil gas survey in 2002. Soil gas results from onsite and offsite laboratory analysis are summarized in Figure 1-5. As shown, high concentrations of PCE were detected at all locations on site.

Although soil sampling results seem to indicate that the VOCs are limited to shallow depths in some areas of the site (under the building), there is not enough soil data to confirm this. Soil gas data indicates that contamination is likely widespread and extends throughout the depth of the vadose zone. For example, significant quantities of VOCs have been removed by the deep (screened from 30 to 65 feet bgs) well during the IRM and high PID readings were recorded at depth in some borings. For the FS, it is assumed that the entire vadose zone onsite is contaminated by VOCs – mainly PCE. The estimated area of the site is 37,000 square feet and the depth to the water table is approximately 70 feet. On this basis, the volume of contaminated soil in the vadose zone is approximately 96,000 cubic yards.

1.6 Current Interim Remedial Measure (IRM)

URS completed construction of a Soil Vapor Extraction (SVE) system at the Kliegman Bros. Site as an IRM in 2004. The system utilizes three extraction wells (SVE-1, SVE-6S and SVE-6D) as shown on Figure 1-6. SVE-1 is a one-inch diameter well screened from 5 to 25 feet below ground surface (bgs). Wells SVE-6S and 6D are two-inch diameter wells screened from 5 to 25 feet bgs (6S) and 30 to 65 feet bgs (6D). SVE-6S and SVE-6D are separate wells installed at the same location. Other wells (SVE-2 through 5), originally installed by Enviroscience as SVE wells, were not used for the IRM. The three wells are connected through a subsurface trench to the SVE system consisting of a moisture separator, an extraction blower, and vapor phase carbon vessels. The extraction blower is an approximately 250 standard cubic feet per minute (SCFM), 5 horsepower regenerative blower, and the two carbon vessels each contain 1,000 pounds of carbon. Operation of the system began on August 23, 2004. Between August 23, 2004 and March 29, 2005 (the date of the last report) the SVE system removed approximately 29,700 pounds of PCE from the vadose zone.

2.0 EVALUATION OF REMEDIAL ALTERNATIVES

2.1 Remedial Action Objectives

Remedial Action Objectives (RAOs), which are goals for protection of human health and the environment, are identified on medium-specific basis. The RAOs in this FFS address OU1 which includes the vadose zone soils and perched water area within the vadose zone (see Section 1.4).

PCE concentrations in the soil in the vadose zone exceed the RSCO presented in NYSDEC's TAGM #4046. The RAOs address three potential pathways of exposure which include the following: 1) direct human contact with soil contamination; 2) migration of VOCs in soil gas to nearby residences; and 3) migration of VOCs from soil to groundwater.

The RAOs for soil are as follows:

- Reduce, control, or eliminate to the extent practicable, soil contamination present on site in the vadose zone.
- Reduce, control, or eliminate to the extent practicable, future direct contact with contaminated soil.
- Reduce, control, or eliminate, to the extent practicable, migration of VOCs in soil gas off site.
- Reduce, control, or eliminate, to the extent practicable, the impact of soil in the vadose zone on groundwater quality.

2.2 Evaluation of Technologies

The EPA and NYSDEC have compiled data from past remediations to identify preferred technologies for certain site conditions. These technologies are often referred to as presumptive remedies. They are considered presumptive remedies because they have been consistently successful in remediating other sites.

The most appropriate preferred technologies for VOCs in vadose zone soil, such as found at the Kliegman Bros. site, include soil vapor extraction (SVE), ex-situ thermal desorption, and excavation/disposal. Ex-situ thermal desorption and excavation/disposal are more appropriate when there are significant quantities of Non-Aqueous Phase Liquid (NAPL) present in the soil and/or when all or most of the soil is impermeable to air, rendering SVE infeasible. NAPL and impermeable soil do not exist at the site. In addition, an in-use building covers most of the site. Excavation under the building required for ex-situ thermal desorption and excavation/disposal are infeasible with this building in place.

Soil Vapor Extraction (SVE) is the best technology for the Kliegman Bros. site remediation. It has already successfully been employed at the site to remove more than 29,000 pounds of contamination (see Section 1.6), and the other preferred technologies are infeasible because of the onsite building.

2.3 Alternatives Identified for Detailed Analysis

2.3.1 Alternative 1 – No Further Action

This alternative would leave the site in its present condition. Operation of the IRM would cease, equipment would be removed, and wells would be abandoned. The No Further Action alternative was established by the National Contingency Plan and is used as a baseline to evaluate other alternatives. This alternative is included to fulfill the procedural requirements of 6NYCRR Part 375.

2.3.2 Alternative 2 – Soil Vapor Extraction (SVE)

Under this alternative, the existing IRM (see Section 1.6) would remain in-place and continue to operate. In addition, new components would be added to the remediation including the following:

1. Vapor Extraction Wells: Three new well pairs would be installed in the northern yard (parking lot) near the existing building (Figure 2-1). The wells would be spaced about 80 feet apart based on an 80-foot radius of influence determined during the IRM. This spacing and radius of influence provides coverage for the entire OU1 area. Two-inch diameter wells would be installed. A shallow and deep well would be installed at each of the three locations.

2. SVE System: A new SVE treatment system would be installed for the additional extraction wells. The new SVE system would be designed to handle about three times the amount of extracted soil gas as the current IRM. The system would include a moisture separator, an approximately 750 SCFM blower, and two 2,000 pound carbon vessels. Extraction wells would be connected to the SVE system by underground pipe.

2.3.3 Alternative 3 – Enhanced Soil Vapor Extraction (ESVE)

A conventional SVE system, such as Alternative 2, will not completely address the zone of perched water in the eastern portion of the site. Alternative 3 includes Alternative 2 (the existing IRM and additional SVE components) plus an additional extraction system to address the perched water zone.

The additional extraction system would operate independently of the SVE system. Its purpose is to both lower the water level in the perched water zone, thus exposing the contaminated soil to venting, and to provide soil vapor extraction from the desaturated zone. The system would extract both water and soil gas by means of dual-phase extraction wells.

Analysis indicated that the feasibility of implementing this method strongly depends on the unknown factors of recharge and hydraulic conductivity of the perched zone. If the ratio of these two parameters were low, the spacing between extraction wells would be approximately 30 feet. For high ratios, the required spacing could be as low as two feet, resulting in hundreds or thousands of wells and a prohibitively large system. Therefore, for the purpose of this description, as well as the cost estimate, it is assumed that the aquifer parameters are favorable. The system of wells spaced every 25 feet is assumed. A pilot test would need to be performed to confirm this spacing if this alternative were selected for remediation. (See Appendix A).

Forty-eight dual phase extraction wells would be installed (see Figure 2-2). The wells would be 2-inch diameter, PVC, penetrating to the bottom of the clay layer where the perched zone occurs. Wells would be equipped with a 1-foot long screen. Each well would contain a drop tube, whose opening would be placed immediately above the bottom of the screen. Drop tubes would be connected to a header pipe, terminating in a building housing a high-vacuum blower.

An additional dual phase extraction system would also be installed. The design capacity of this system is 100 cfm of air flow and 1 gpm of water flow (See Appendix A). The system would include a high-vacuum blower, a moisture separator and a carbon vessels to treat air and water.

3.0 DETAILED ANALYSIS OF THE ALTERNATIVES

This section includes a detailed analysis of the three alternatives in accordance with the criteria for evaluating alternatives established in 6NYCRR Part 375.

3.1 Alternative 1 – No Further Action

Alternative 1 is described in Section 2.3.1.

3.1.1 Overall Protection of Human Health and the Environment

This alternative is not protective of human health and the environment. It does not meet the remedial action objectives for OU1. It does not comply with SCGs related to soil remediation and is not effective in the long term.

3.1.2 Compliance with SCGs

On-site soil would contain VOCs at concentrations above the RSCOs presented in NYSDEC's TAGM #4046 – the SCG governing the site remediation. Consequently, Alternative 1 does not comply with SCGs.

3.1.3 Short-Term Impacts and Effectiveness

Since no further remedial action is occurring, there are no increased short-term risks caused by implementation of this remedial action.

3.1.4 Long-Term Effectiveness and Permanence

Potential risk caused by contaminated soil remaining in place is not addressed under this alternative. There are no controls to manage contaminants, thereby allowing continued migration from soil to groundwater and migration of soil gas with unacceptable levels of VOCs beyond site boundaries.

3.1.5 Reduction of Toxicity, Mobility, and Volume

Reduction of toxicity, mobility, or volume would occur very slowly, through natural attenuation. However, the time frame associated with reductions by natural processes is not acceptable.

3.1.6 Implementability

There are no technical or administrative actions required. This alternative is easily implemented.

3.1.7 Cost

There are no capital or operation and maintenance (O&M) costs associated with this alternative.

3.2 Alternative 2 – Soil Vapor Extraction (SVE)

Alternative 2 is described in Section 2.3.2.

3.2.1 Overall Protection of Human Health and the Environment

The SVE alternative is protective of human health and the environment. It meets all the remedial action objectives for OU1. It reduces or eliminates all exposure pathways including direct contact with soil, VOC migration in soil gas, and migration of VOCs from the vadose zone into groundwater.

3.2.2 Compliance with SCGs

After remediation is complete, on-site soil VOC concentrations are expected to be reduced to the RSCOs presented in NYSDEC's TAGM #4046 – the SCG governing the site remediation. However, it is possible that some of the soil in the perched water zone would not be remediated to SCGs. Compliance will be verified by confirmatory soil sampling.

The SVE alternative will produce air emissions during operation which are subject to 6NYCRR200, 201, and 212 and New York DAR-1, Guidelines for Control of Toxic Ambient Contaminants, which are action-specific SCGs. Air emissions shall be treated with carbon to comply with these action-specific SCGs.

3.2.3 Short-Term Impacts and Effectiveness

Since the SVE alternative includes little intrusive activity, short-term impacts will be minimal during construction. There are some potential impacts to workers and the community from VOCs during drilling; however, these impacts should be easily controlled by a properly administered health and safety program. During SVE operation, air emissions will be treated by carbon, thereby, essentially eliminating any risk to the community. It is expected that construction can be completed in 2 to 3 months. Remediation of soil by SVE typically is accomplished within 2 to 10 years depending on site conditions. For this FS, it is estimated that the operating phase will cease and remediation will be complete after five years.

3.2.4 Long-Term Effectiveness and Permanence

SVE is a permanent remedy for OU1 soil. Little residual contamination is expected to remain after remediation is complete. Residuals could remain in the perched water layer above clay which will be less effected by SVE than the remainder of the vadose zone and residuals could remain in the clay layer which will only be remediated by natural attenuation. The adequacy of remediation will be determined by confirmatory soil sampling. Once soil sampling results are satisfactory, no further monitoring or controls will be required for OU1 soil.

3.2.5 Reduction of Toxicity, Mobility and Volume

By removing VOCs from soil, the toxicity and volume of contaminated soil would be reduced. Since removal of VOCs would reduce offsite migration via soil gas and impacts on groundwater, the mobility of VOCs would also be significantly reduced.

3.2.6 Implementability

The equipment and material needed to install the SVE system are commercially available from many vendors. SVE is a proven and reliable technology which has led it to be designated as a presumptive remedy for VOCs in soil. Following completion of soil remediation, no further monitoring or maintenance of the soil would be required. The location of the extraction wells in the north yard (parking lot) and not in the onsite building will simplify construction and render this alternative easier to construct, operate and maintain. Access to the onsite building is limited for drilling – particularly in the western section which has a basement.

3.2.7 Cost

The cost analysis for Alternative 2 is presented in Appendix B. The capital cost for the SVE alternative is estimated at $350,000 and the estimated O&M cost is $132,000 per year. It is assumed the SVE system will operate for 5 years after construction in order to complete remediation. Under this assumption, the total present worth cost for O&M is $570,000 (based on a 5% discount rate). The total cost (capital and O&M cost) is estimated at $920,000.

It should be noted that the most costly component for O&M is carbon for emissions control. The cost for this component, however, is the most difficult to estimate. The annual O&M cost in this FS includes an estimated carbon usage rate of 25,000 pounds per year. For the existing IRM, 42,000 pounds of carbon was used during the first seven months of operation. However, the carbon usage rate has been reduced to 2,000 pounds per month for months six and seven as vapor concentrations decreased. For the additional SVE wells, the quantity of soil gas extracted is expected to be greater than for the IRM although VOC concentrations may be lower. Based on this data, an average carbon usage rate of 25,000 pounds per year over a five year operation period is a reasonable midrange estimate of carbon use. Actual carbon use could vary significantly from this estimate, however.

3.3 Alternative 3 – Enhanced Soil Vapor Extraction (ESVE)

Alternative 3 is described in Section. 2.3.3.

3.3.1 Overall Protection of Human Health and the Environment

The ESVE alternative is protective of human health and the environment. It meets the remedial action objectives for OU1. It reduces or eliminates exposure pathways including direct contact with soil, VOC migration in soil gas, and migration of VOCs from the vadose zone into groundwater.

3.3.2 Compliance with SCGs

After remediation is complete, on-site soil is expected to reduce VOC concentrations to the RSCOs presented in NYSDEC's TAGM #4046 – The SCGs governing site remediation. Compliance will be verified by confirmatory sampling.

Alternative 3 will produce air emissions during operations which are subjected to 6NYCRR 200, 201, 212 and New York DAR-1, Guidelines for Control of Toxic Ambient Contaminants, which are action-specific SCGs. Air emissions shall be treated with carbon to comply with these action-specific SCGs.

The perched water treatment system will have a water discharge. This water would either be discharged to surface waters (storm sewers) or the local publicly owned treatment works (POTW). If discharged to surface waters, it would be subject to New York State regulations for SPDES discharges. If water is discharged to the POTW, coordination with the local municipality would be required. Since the water discharge would be treated, these requirements would be met.

3.3.3 Short-Term Impacts and Effectiveness

This alternative includes significant intrusive activity during construction. It is estimated that 48 extraction wells will need to be installed to remediate the perched water zone. There are some potential impacts to workers and the community from VOCs during drilling. A properly administered health and safety program should significantly reduce these risks. It is expected that construction will be completed in 1 year. Remediation of soil by SVE typically is accomplished within 2 to 10 years depending on site conditions. For this FS, it is estimated that the operating phase will cease and remediation will be complete after five years.

3.3.4 Long-Term Effectiveness and Permanence

SVE is a permanent remedy for OU1 soil. Little residual is expected to remain after remediation. This alternative will at least partially remediate the perched water zone; however, the clay layer will not be remediated. The contamination in clay could continue to impact the perched water zone even after remediation is completed. In addition, this alternative includes a dual phase extraction system that would need to be tested in the field. The effectiveness of the dual phase system has not been demonstrated and is uncertain. The adequacy of remediation will be determined by confirmatory soil sampling. Once soil sampling results are satisfactory, no further monitoring or controls will be required for OU1 soil.

3.3.5 Reduction of Toxicity, Mobility and Volume

By removing VOCs from soil, the toxicity and volume of contaminated soil would be reduced. Since removal of VOCs would reduce the offsite migration via soil gas and impacts on groundwater, the mobility of VOCs would also be significantly reduced.

3.3.6 Implementability

The equipment and material to install an SVE system are commercially available from many vendors. SVE is a proven and reliable technology which has led to it being designated as a presumptive remedy for VOCs in soil. However, the extraction system included to address the perched water zone will be very difficult to implement. Wells will have to be installed in the onsite building which is in use. Significant coordination with the site owner would be required. Installation will be particularly difficult in the western section of the building which has a basement. The building will make both the construction and the maintenance of the extraction system difficult.

3.3.7 Cost

The cost analysis for Alternative 3 is presented in Appendix B. Costs for Alternative 3 are derived by adding the costs for Alternative 2 (the SVE system) and the costs for the additional dual phase extraction system. The capital cost for the ESVE alternative is estimated at $820,000, and the estimated O&M cost is $207,000 per year. It is assumed the ESVE system will operate for 5 years after construction in order to complete remediation. Under this assumption, the present worth cost for O&M is $900,000 (based on a 5% discount rate). The total cost (capital and O&M cost) is estimated at $1,720,000.

As with Alternative 2, carbon usage for air emissions is difficult to estimate. The estimated usage of 28,300 lbs/yr is a reasonable midrange estimate for carbon use.

Since a pilot test has not been performed, the well spacing required for water extraction is uncertain. A significantly greater number of wells could be required for actual remediation (see Appendix A). The cost of this alternative could be 50% greater or more depending on the results of the pilot test.

4.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

4.1 Overall Protection of Human Health and the Environment

The No Further Action alternative would not be protective of human health and the environment. The SVE alternative (Alternative 2) and the ESVE alternative (Alternative 3) would actively remediate soil in OU1 and would be protective of human health and the environment.

4.2 Compliance with SCGs

The No Further Action alternative would not meet SCGs since it would leave contaminated soil on site with concentrations above the RSCO values established by NYSDEC's TAGM #4046. SVE and ESVE are expected to reduce concentrations of VOCs below the RSCO values in OU1 soil. It is possible that soil in the perched water zone just above the clay layer would not meet SCGs with either SVE or ESVE; however, ESVE is expected to better remediate this zone. For both SVE (Alternative 2) and ESVE (Alternative 3) compliance would be verified by confirmatory soil sampling.

4.3 Short-Term Impacts and Effectiveness

The No Further Action alternative would cause no short-term impacts since no is intrusive work would take place.

For the SVE alternative (Alternative 2), there is a small amount of intrusive activity; however, potential impacts can be adequately controlled by a properly administered health and safety program. SVE also includes air emissions control (carbon adsorption units) to protect the community from air emissions. Proper monitoring and maintenance of the emissions control system will minimize any potential impacts.

For the ESVE alternative (Alternative 3), there is significantly more instrusive work than for Alternative 2. Consequently, potential short-term impacts are greater. Particularly, construction in the onsite building increases risks to workers in the building during construction.

4.4 Long-Term Effectiveness and Permanence

The No Further Action alternative would allow contaminated soil to remain in place and would not reduce or control offsite migration of VOCs in soil gas or the continued migration of VOCs from the vadose zone soil into the groundwater.

For SVE (Alternative 2) and ESVE (Alternative 3), VOCs are expected to be reduced to below TAGM #4046 RSCOs and little residual contamination is expected to remain in OU1. It is a possibility that contamination could remain in the perched water zone and clay. However, contamination in clay is of less concern because it is less of a threat to migrate into groundwater or produce significant soil gas that could migrate off site. Alternative 3 will likely better address the perched zone and clay. However, the effectiveness of Alternative 3 to remediate the perched zone, and consequently its advantage over Alternative 2, is uncertain because it has not been tested in the field.

4.5 Reduction of Toxicity, Mobility and Volume (TMV)

With the No Further Action alternative, reduction in toxicity, mobility, and volume of contamination would occur very slowly over time through natural attenuation; however, the time frame for attenuation would be unacceptable with regard to protecting human health and the environment. SVE (Alternative 2) and ESVE (Alternative 3) quickly and effectively reduce toxicity, mobility, and volume of VOC contamination by removing VOCs from soil. Alternative 3 is slightly better at reducing TMV because it more effectively addresses the perched water zone. However, because much of the contamination in the perched zone is in clay, and can only be slowly remediated, Alternative 3 will probably only be marginally more effective in reducing TMV.

4.6 Implementability

The No Further Action alternative is easy to implement since no construction is necessary. SVE, (Alternative 2) although more difficult to implement than No Action, would be relatively easy to implement. SVE is a well understood and often used technology, and has already been successfully employed at the site to address some of the soil contamination (see Section 1.6). ESVE (Alternative 3) would be the most difficult alternative to implement. It involves construction of numerous extraction wells – many of them in the onsite building which is currently being used. Construction would be particularly difficult in the western section of the building where there is a basement. Implementation of Alternative 3 would likely disrupt operations for the current owner and would decrease the Contractor's productivity during construction.

4.7 Cost

There is no cost associated with the No Further Action alternative. The estimated total cost for implementing the SVE alternative (Alternative 2) is $920,000. The estimated total cost for implementing the ESVE (Alternative 3) is $1,720,000. As discussed in Section 3.3.7, the cost for Alternative 3 is more uncertain than for Alternative 2. The cost of Alternative 3 could be significantly higher if field testing shows more extraction wells are required than estimated for the FFS.

5.0 RECOMMENDED REMEDIAL ALTERNATIVE

The No Further Action alternative (Alternative 1) was rejected because this alternative is not protective of human health and the environment, does not satisfy SCGs, and does not satisfy the RAOs. It would leave contaminated soil in place which would act as a continuing source of contamination for both soil gas and groundwater migrating offsite.

Both Alternative 2 (SVE) and Alternative 3 (ESVE) are effective alternatives. Alternative 3 is slightly more effective because it better addresses the perched water zone. However, Alternative 3 has the following drawbacks:

- It includes a dual phase extraction system that would need to be tested in the field. The effectiveness of the dual phase system has not been demonstrated and is uncertain.

- It increases risks to workers and the community during construction because there is much more intrusive work.

- It will be very difficult to implement because much of the construction will occur inside the onsite building which is in use. Significant coordination with the site owner shall be required which could cause delays in construction, make maintenance more difficult, and increase costs.

- It is much more costly than Alternative 2. The estimated cost for Alternative 3 is about twice that for Alternative 2. However, the cost for Alternative 3 is based on a rather favorable assumption for well spacing. A pilot test of dual phase extraction system could show a significantly greater number of extraction wells will be required. If more wells are required, the cost for Alternative 3 could be three times or more greater than for Alternative 2.

Much of the contamination addressed by Alternative 3 is in clay which means the dual phase system included in Alternative 3 would probably only remove a small amount of PCE compared to SVE. In addition, because much of the contamination is in clay, it is less of a threat to migrate into groundwater or produce significant soil gas that could migrate off site. On the basis of the above, the SVE alternative (Alternative 2) is recommended.

TABLES

TABLE 1-1
Soil Chemical Analytical Results
Former Kliegman Bros. Site
76-01 77th Avenue, Glendale, Queens

Sample Location	EB-1		EB-2		EB-3		EB-4		NYSDEC Recommended Soil Cleanup Objectives
Depth (in feet below grade)	20-25	28-30	12-14	20-22	3-4	6-7	5-6	11-12	
Volatile Organic Compounds ***(in micrograms per kilogram)***									
Benzene	ND	ND	140J	ND	ND	ND	43J	ND	60
n-Butylbenzene	ND	ND	ND	ND	ND	ND	150J	ND	18,000
sec-Butylbenzene	ND	ND	620J	220J	ND	ND	ND	ND	25,000
Carbon Tetrachloride	ND	ND	ND	ND	1J	ND	ND	ND	600
Chloroform	ND	ND	93J	ND	7J	5J	**750J**	6J	300
Chloromethane	ND	ND	ND	ND	ND	ND	ND	ND	-
1,2-Dichloroethylene (DCE)	ND	ND	ND	ND	ND	ND	ND	ND	250
1,4-Dichlorobenzene	ND	ND	310J	ND	ND	ND	ND	ND	8,500
Ethylbenzene	ND	ND	200J	23J	ND	ND	20J	ND	5,500
p-Isopropyltoluene	ND	ND	ND	ND	ND	ND	29J	ND	11,000
Methylene Chloride	44B	41B	**17,000B**	**8,700B**	82B	69B	**10,000B**	70B	100
Naphthalene	ND	ND	190J	ND	ND	ND	ND	ND	13,000
n-Propylbenzene	ND	ND	290J	59J	ND	ND	140J	ND	14,000
Tetrachloroethylene (PCE)	55	40	**85,000**	**430,000E**	1,400	38	**1,400,000**	**2,100**	1,400
Toluene	ND	ND	800J	600J	2J	3J	490J	2J	1,500
Trichloroethylene (TCE)	ND	ND	400J	480J	ND	1J	180J	ND	700
1,2,4-Trimethylbenzene	ND	ND	730J	260J	ND	1J	1,400	ND	13,000
1,3,5-Trimethylbenzene	ND	ND	530J	160J	4J	5	**4,200**	4J	3,300
Vinyl Chloride (VC)	ND	ND	ND	ND	ND	ND	35J	ND	200
Xylenes (total)	ND	ND	200J	128J	ND	ND	600J	ND	1,200

Notes:
Only detected analytes are reported.
ND =Not detected.
B =Analyte detected in associated blank.
E =Quantitation is estimated. Concentration is greater than calibration range.
J =Quantitation is estimated. Concentration is less than calibration range.
DCE =Concentrations and NYSDEC Objective are reported for cis-DCE.
- =No NYSDEC Objective available.
Bold values indicate an exceedence of the NYSDEC Recommended Soil Cleanup Objectives (TAGM 4046).

Source: Enviroscience Consultants, Inc. – 2001
AG18222-035971-080103-HAB

TABLE 1-1 (cont.)
Soil Chemical Analytical Results
Former Kliegman Bros. Site
76-01 77th Avenue, Glendale, Queens

Sample Location	**SVE-2**			**SVE-3**			**SVE-4**			**SVE-5**			**NYSDEC Recommended Soil Cleanup Objectives**
Depth (in feet below grade)	**4-6**	**36-38**	**44-46**	**9-11**	**54-56**	**60-61**	**4-6**	**61-63**	**65-66**	**2-4**	**14-15**	**15-16**	
Volatile Organic Compounds ***(in micrograms per kilogram)***													
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**200,000**	60
n-Butylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	18,000
sec-Butylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	25,000
Carbon Tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	600
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	300
Chloromethane	590J	680J	ND	ND	ND	ND	450J	ND	ND	ND	ND	ND	-
1,2-Dichloroethylene (DCE)	ND	ND	ND	ND	ND	ND	**1,200**	ND	ND	ND	ND	ND	250
1,4-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	8,500
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**65,000**	5,500
p-Isopropyltoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	11,000
Methylene Chloride	**2,800B**	ND	**66,000B**	97B	80B	**140B**	ND	ND	ND	ND	ND	ND	100
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	13,000J	13,000
n-Propylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	14,000
Tetrachloroethylene (PCE)	**10,000**	**130,000**	**2,400,000**	22	18	68	**16,000**	18	47	110	710	**6,7000,000**	1,400
Toluene	420J	430J	**8,200J**	ND	ND	5J	100J	ND	ND	ND	ND	**39,000J**	1,500
Trichloroethylene (TCE)	ND	ND	ND	ND	ND	ND	200	ND	ND	ND	8J	ND	700
1,2,4-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**36,000J**	13,000
1,3,5-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**14,000J**	3,300
Vinyl Chloride (VC)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	200
Xylenes (total)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**191,000J**	1,200

Notes:

Only detected analytes are reported.

ND =Not detected.

B =Analyte detected in associated blank.

E =Quantitation is estimated. Concentration is greater than calibration range.

J =Quantitation is estimated. Concentration is less than calibration range.

DCE =Concentrations and NYSDEC Objective are reported for cis-DCE.

\- =No NYSDEC Objective available.

Bold values indicate an exceedence of the NYSDEC Recommended Soil Cleanup Objectives (TAGM 4046).

Source: Enviroscience Consultants, Inc. – 2001

AG18222-035971-080103-HAB

TABLE 1-2
Subfloor Soil Chemical Analytical Results
Former Kliegman Bros. Site
76-01 77th Avenue, Glendale, Queens

Sample Location	S-1	S-2	S-3	S-4			S-5	S-6		NYSDEC Recommended Soil Cleanup Objectives
Depth (in feet below grade)	**0-1**	**0-1**	**0-1**	**0-1**	**3-4**	**6-7**	**NA**	**0-1**	**3-4**	
Volatile Organic Compounds ***(in micrograms per kilogram)***										
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	60
Bromomethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
tert-Butylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
Chloromethane	ND	ND	ND	ND	ND	ND	ND	94J	ND	-
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	300
1,2-Dichloroethylene (DCE)	ND	120J	ND	ND	ND	2J	ND	ND	ND	250
Ethylbenzene	ND	ND	ND	ND	ND	ND	98	ND	ND	5,500
Isoproplybenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	5,000
p-Isopropyltoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	11,000
Methylene Chloride	ND	**2,200B**	ND	ND	ND	ND	**110B**	**2,400B**	ND	100
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	13,000
n-Propylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	14,000
Styrene	ND	ND	ND	ND	ND	ND	8J	ND	ND	-
Tetrachloroethylene (PCE)	**320,000**	**19,000**	**58,000**	**80,000**	43	690	55	**44,000**	30	1,400
Toluene	ND	140J	ND	ND	ND	ND	6J	160J	ND	1,500
Trichlorethylene (TCE)	ND	250	ND	ND	ND	4J	ND	ND	ND	700
Trichloroethane (TCA)	ND	ND	ND	ND	ND	ND	ND	ND	ND	800
1,2,4-Trimethylbenzene	ND	ND	ND	ND	ND	ND	5J	ND	ND	13,000
1,3,5-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	3,300
Xylenes (total)	ND	ND	ND	ND	ND	ND	660	300	ND	1,200

Notes:
Only detected analytes are reported.
ND =Not detected.
B =Analyte detected in associated blank.
E =Quantitation is estimated. Concentration is greater than calibration range.
J =Quantitation is estimated. Concentration is less than calibration range.
DCE =Concentrations and NYSDEC Objective are reported for cis-DCE.
- =No NYSDEC Objective available.
Bold values indicate an exceedence of the NYSDEC Recommended Soil Cleanup Objectives (TAGM 4046).

Source: Enviroscience Consultants, Inc. – 2001
AG18222-035971-080103-HAB

TABLE 1-2 (cont.)
Subfloor Soil Chemical Analytical Results
Former Kliegman Bros. Site
76-01 77th Avenue, Glendale, Queens

Sample Location	S-7	S-8	S-9	S-10	S-11	S-12		NYSDEC Recommended Soil Cleanup Objectives
Depth (in feet below grade)	0-1	NA	NA	0-1	0-1	0-1	5-6	
Volatile Organic Compounds ***(in micrograms per kilogram)***								
Benzene	ND	14	ND	ND	ND	ND	ND	60
Bromomethane	ND	ND	ND	580J	ND	ND	ND	-
tert-Butylbenzene	ND	7J	ND	ND	ND	ND	ND	-
Chlormethane	ND	ND	ND	320J	ND	ND	ND	-
Chloroform	ND	ND	23J	ND	ND	ND	6J	300
1,2-Dichloroethylene (DCE)	ND	**360**	ND	ND	ND	ND	ND	250
Ethylbenzene	ND	1,800	140	ND	ND	ND	ND	5,500
Isoproplbenzene	ND	36	ND	ND	ND	ND	ND	5,000
p-Isopropyltoluene	ND	ND	9J	ND	ND	ND	ND	11,000
Methylene Chloride	73B	**130B**	**1,100BJ**	**4,400B**	ND	ND	47B	100
Naphthalene	ND	23	56J	ND	ND	ND	ND	13,000
n-Propylbenzene	ND	10	8J	ND	ND	ND	ND	14,000
Styrene	ND	67	23J	ND	ND	ND	ND	-
Tetrachloroethylene (PCE)	140	280	**25,000**	**10,000**	1,400	**48,000**	**2,000**	1,400
Toluene	ND	25	81J	470J	ND	ND	3J	1,500
Trichlorethylene (TCE)	ND	85	ND	ND	ND	ND	5J	700
Trichloroethane (TCA)	ND	ND	44J	ND	ND	ND	1J	800
1,2,4-Trimethylbenzene	ND	68	57J	ND	ND	ND	1J	13,000
1,3,5-Trimethylbenzene	ND	21	26J	ND	ND	ND	2J	3,300
Xylenes (total)	ND	**8,700**	940	400J	10	ND	1J	1,200

Notes:
Only detected analytes are reported.
ND =Not detected.
B =Analyte detected in associated blank.
E =Quantitation is estimated. Concentration is greater than calibration range.
J =Quantitation is estimated. Concentration is less than calibration range.
DCE =Concentrations and NYSDEC Objective are reported for cis-DCE.
\- =No NYSDEC Objective available.
Bold values indicate an exceedence of the NYSDEC Recommended Soil Cleanup Objectives (TAGM 4046).

Source: Enviroscience Consultants, Inc. – 2001
AG18222-035971-080103-HAB

TABLE 1-2 (cont.)
Subfloor Soil Chemical Analytical Results
Former Kliegman Bros. Site
76-01 77th Avenue, Glendale, Queens

Sample Location	S-13	S-14	S-15	S-16				S-17	S-18	NYSDEC Recommended Soil Cleanup Objectives
Depth (in feet below grade)	0-1	0-1	0-1	0-1	6-7	10-11	11-12	0-1	0-1	
Volatile Organic Compounds *(in micrograms per kilogram)*										
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	60
Bromomethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
tert-Butylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
Chlormethane	ND	ND	ND	310	ND	ND	ND	110J	ND	-
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	300
1,2-Dichloroethylene (DCE)	ND	ND	ND	ND	ND	ND	ND	**350**	ND	250
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	5,500
Isoproplbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	5,000
p-Isopropyltoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	11,000
Methylene Chloride	80B	ND	**760B**	**2,000B**	ND	ND	ND	**1,000B**	**3,700B**	100
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	13,000
n-Propylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	14,000
Styrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
Tetrachloroethylene (PCE)	180	**19,000**	**12,000**	**71,000**	27	30	980	**12,000**	**32,000**	1,400
Toluene	ND	140J	100	160J	ND	ND	ND	ND	ND	1,500
Trichlorethylene (TCE)	ND	ND	ND	190J	ND	ND	7	140	ND	700
Trichloroethane (TCA)	ND	ND	ND	ND	ND	ND	ND	ND	ND	800
1,2,4-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	13,000
1,3,5-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	3,300
Xylenes (total)	ND	ND	ND	ND	ND	ND	ND	ND	ND	1,200

Notes:
Only detected analytes are reported.
ND =Not detected.
B =Analyte detected in associated blank.
E =Quantitation is estimated. Concentration is greater than calibration range.
J =Quantitation is estimated. Concentration is less than calibration range.
DCE =Concentrations and NYSDEC Objective are reported for cis-DCE.
- =No NYSDEC Objective available.
Bold values indicate an exceedence of the NYSDEC Recommended Soil Cleanup Objectives (TAGM 4046).

Source: Enviroscience Consultants, Inc. – 2001
AG18222-035971-080103-HAB

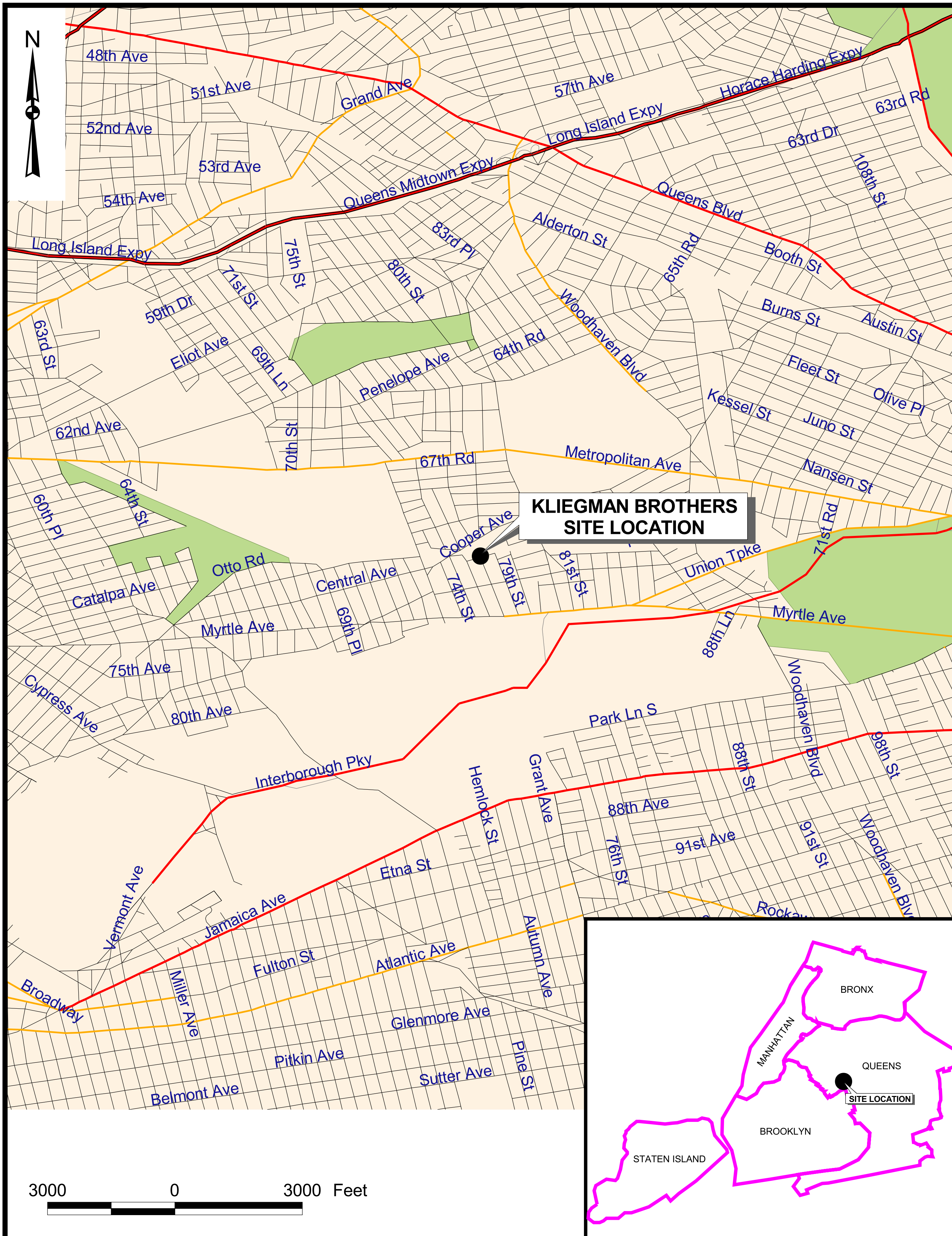
TABLE 1-2 (cont.)
Subfloor Soil Chemical Analytical Results
Former Kliegman Bros. Site
76-01 77th Avenue, Glendale, Queens

Sample Location	S-19	S-20	S-21	S-22			S-23	S-24	S-25	S-26	NYSDEC Recommended Soil Cleanup Objectives
Depth (in feet below grade)	0-1	0-1	0-1	0-1	3-4	11-12	0-1	0-1	0-1	0-1	
Volatile Organic Compounds *(in micrograms per kilogram)*											
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	60
Bromomethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
tert-Butylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
Chlormethane	ND	ND	210J	ND	ND	ND	ND	ND	ND	ND	-
Chloroform	ND	ND	ND	ND	6J	ND	ND	ND	ND	ND	300
1,2-Dichloroethylene (DCE)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	250
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5,500
Isoproplbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5,000
p-Isopropyltoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	11,000
Methylene Chloride	77B	**14,000B**	ND	**1,900B**	71B	ND	41B	44B	91B	41B	100
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	13,000
n-Propylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	14,000
Styrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-
Tetrachloroethylene (PCE)	700	**7,500**	**11,000**	**23,000**	190	120	190	280	1,000	95	1,400
Toluene	ND	**2,200**	ND	ND	2J	ND	ND	ND	ND	ND	1,500
Trichlorethylene (TCE)	ND	ND	ND	ND	2J	ND	ND	ND	ND	ND	700
Trichloroethane (TCA)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	800
1,2,4-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	13,000
1,3,5-Trimethylbenzene	ND	ND	ND	ND	1J	ND	ND	ND	ND	ND	3,300
Xylenes (total)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1,200

Notes:
Only detected analytes are reported.
ND =Not detected.
B =Analyte detected in associated blank.
E =Quantitation is estimated. Concentration is greater than calibration range.
J =Quantitation is estimated. Concentration is less than calibration range.
DCE =Concentrations and NYSDEC Objective are reported for cis-DCE.
- =No NYSDEC Objective available.
Bold values indicate an exceedence of the NYSDEC Recommended Soil Cleanup Objectives (TAGM 4046).

Source: Enviroscience Consultants, Inc. – 2001
AG18222-035971-080103-HAB

FIGURES

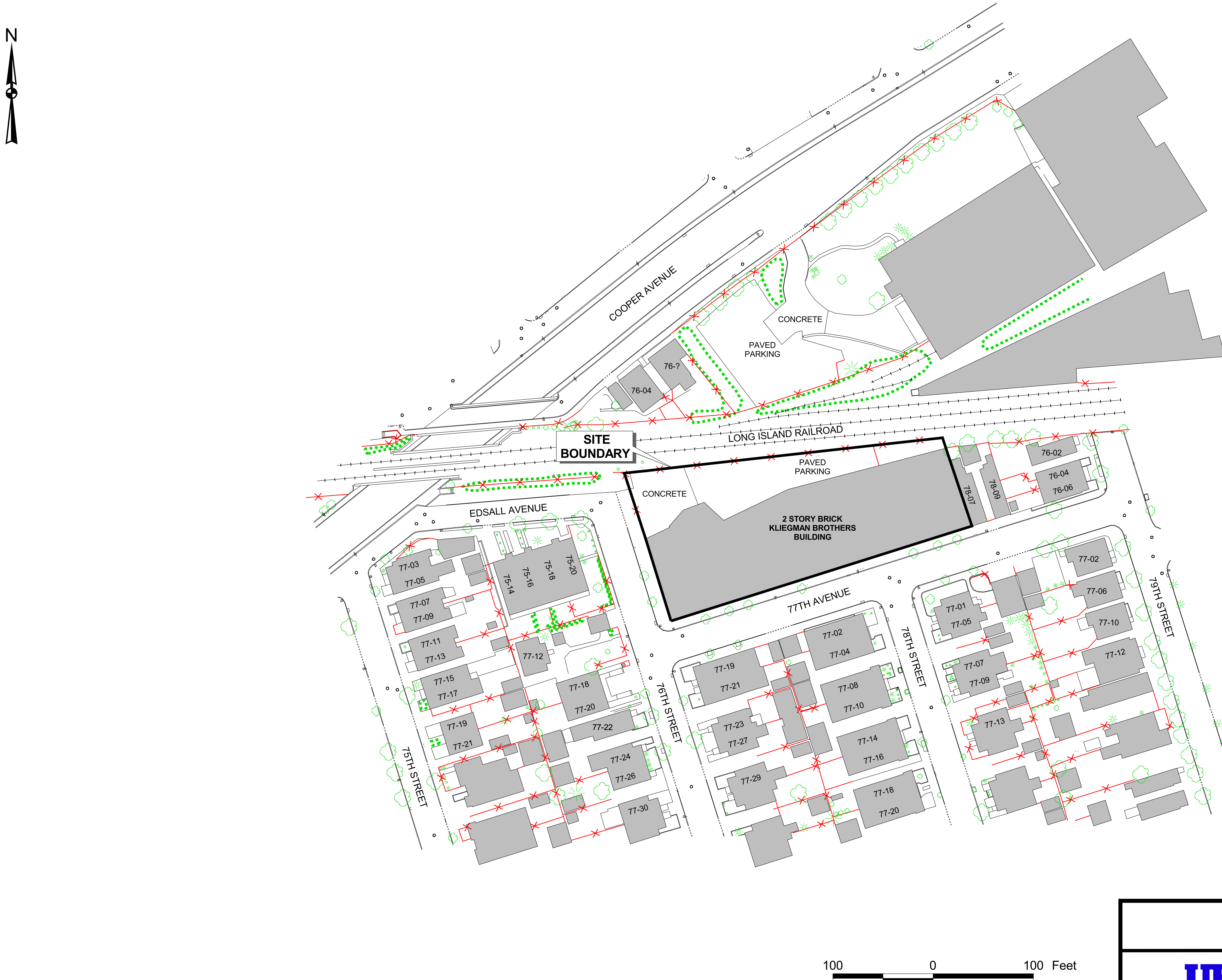


URS

KLIEGMAN BROTHERS
SITE LOCATION MAP

FIGURE 1-1

N:\11171964.00000\DB\GIS\site.apr SITE LOCATION
7/22/2005

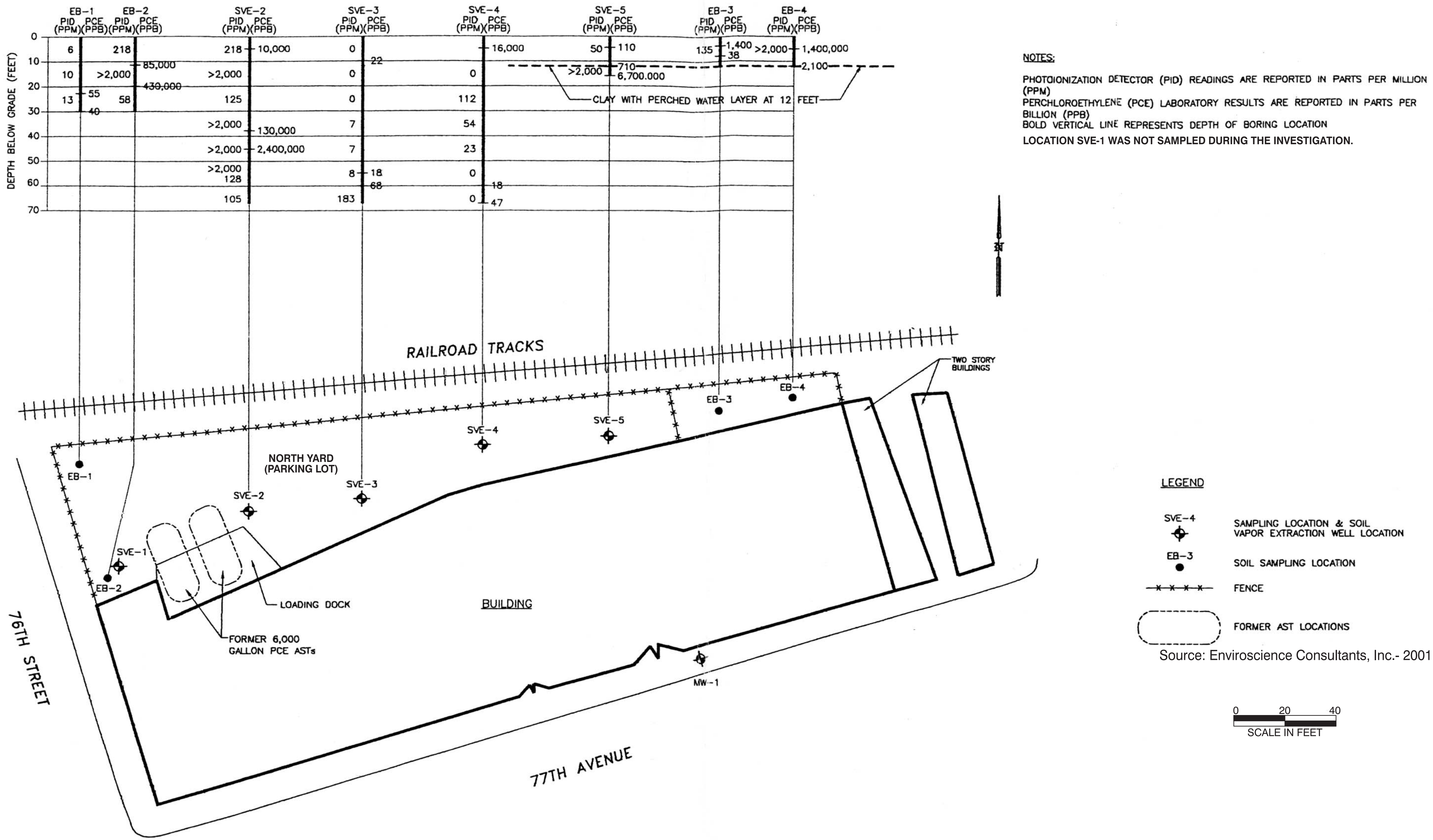


KLIEGMAN BROTHERS
SITE PLAN

URS

FIGURE 1-2

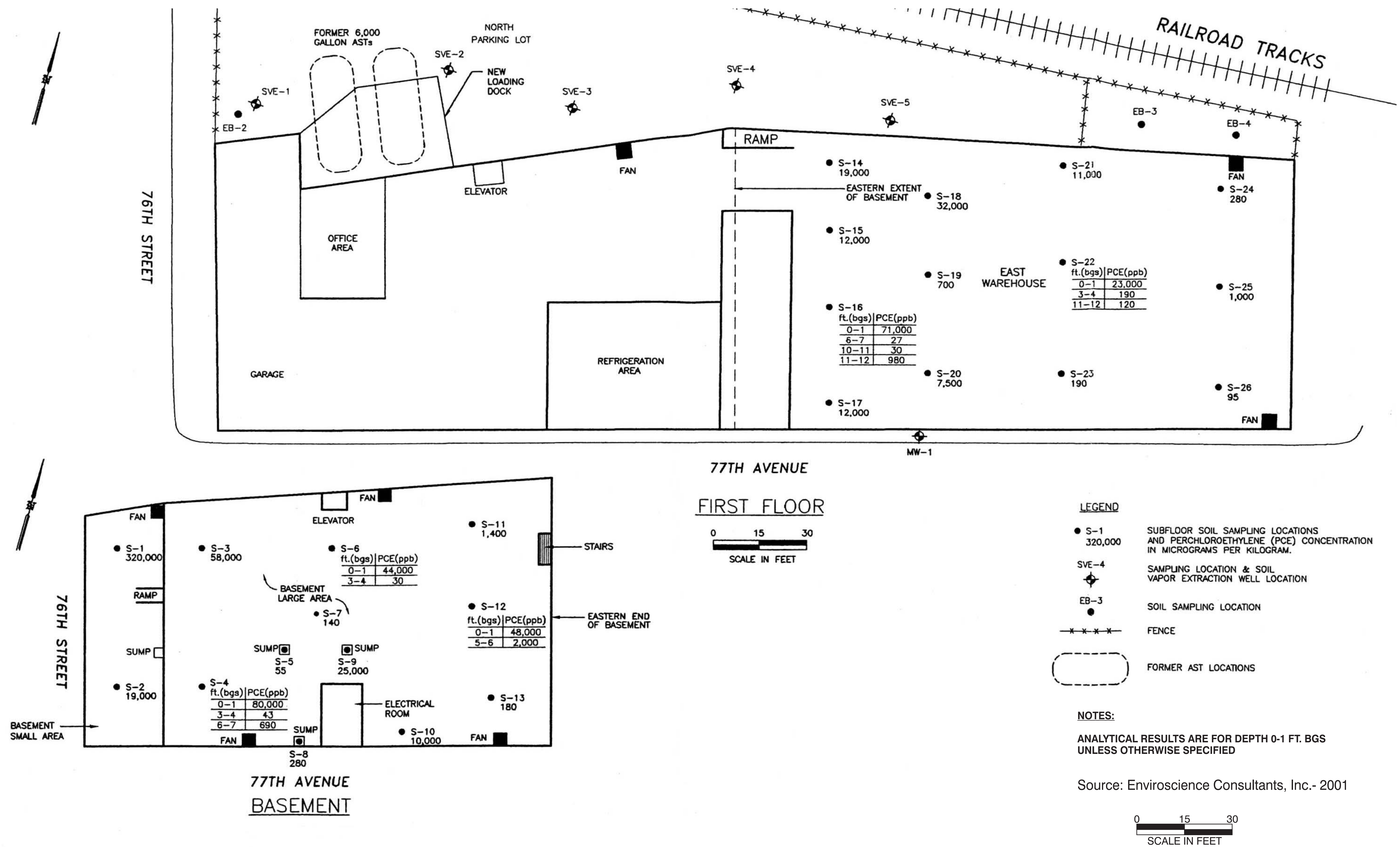
N:\11171964.00000\DB\GIS\geology.apr SITE PLAN
7/7/2005



URS

BORING LOCATIONS AND PCE SOIL RESULTS

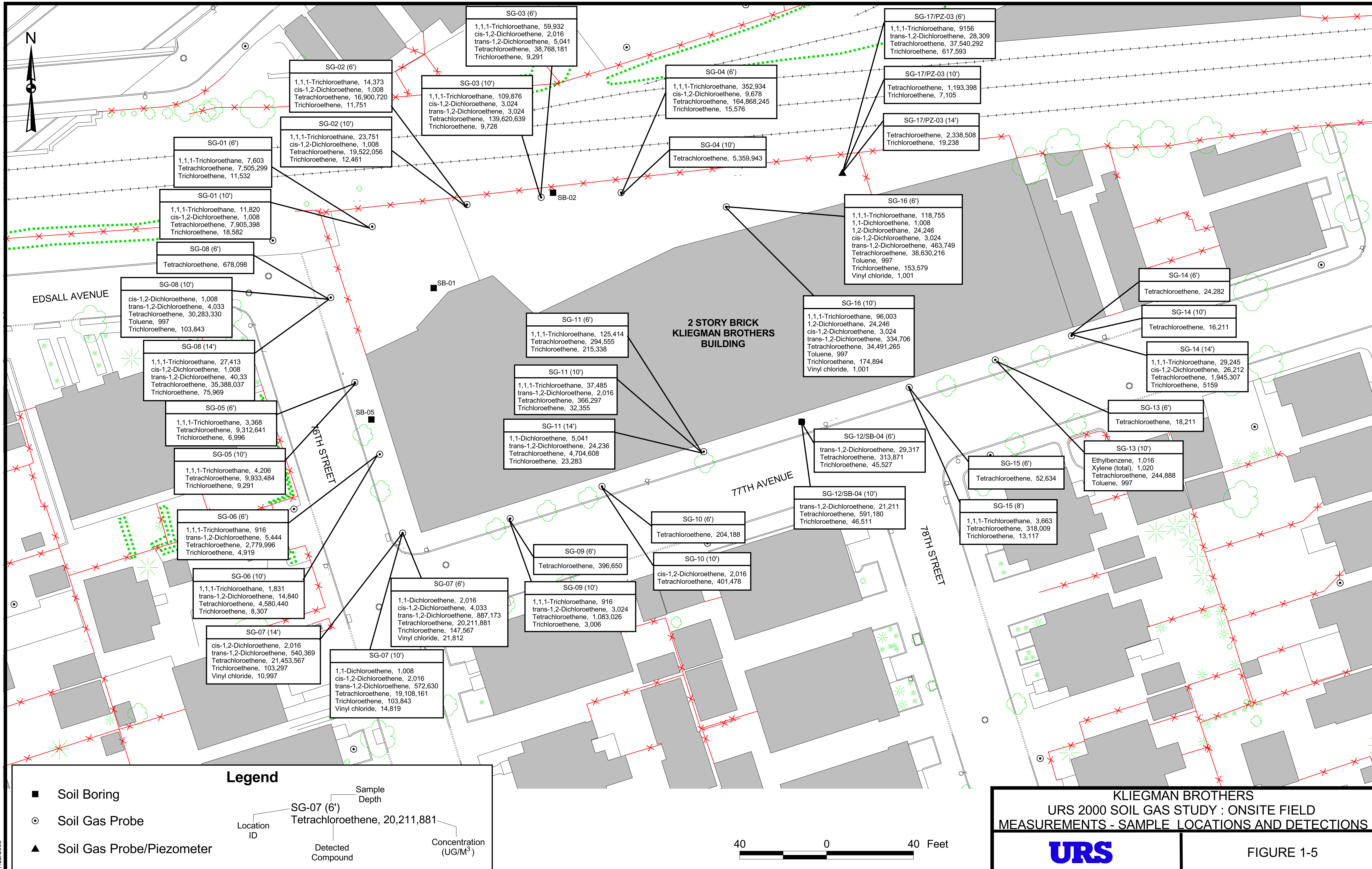
FIGURE 1-3



URS

INTERIOR SAMPLING LOCATIONS AND PCE SOIL RESULTS

FIGURE 1-4

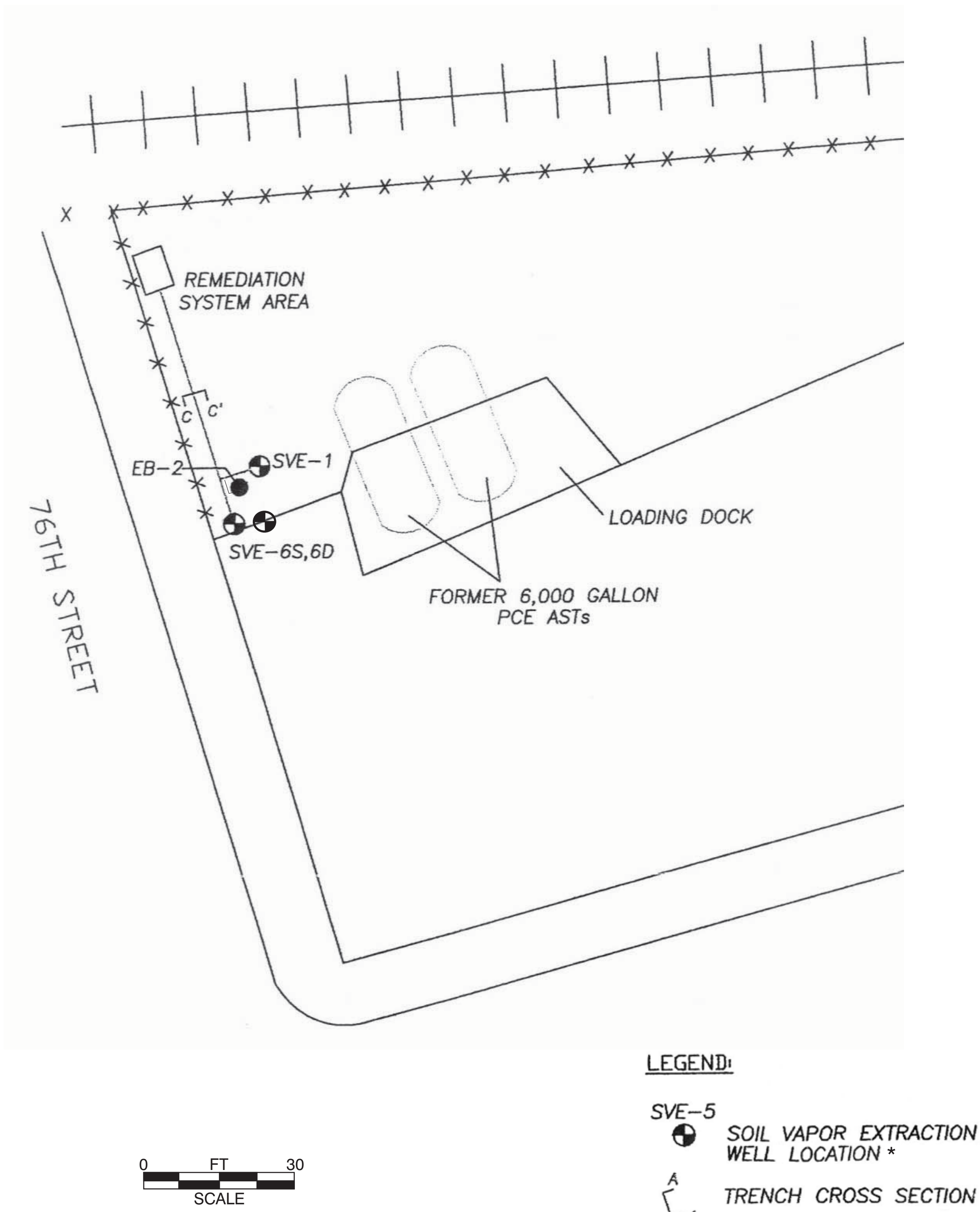


KLIEGMAN BROTHERS
URS 2000 SOIL GAS STUDY : ONSITE FIELD MEASUREMENTS - SAMPLE LOCATIONS AND DETECTIONS

URS

FIGURE 1-5

N:\11171964.00000\DB\GIS\chem.apr SOIL GAS ANALYTICAL RESULTS (UG/M3)
7/22/2005



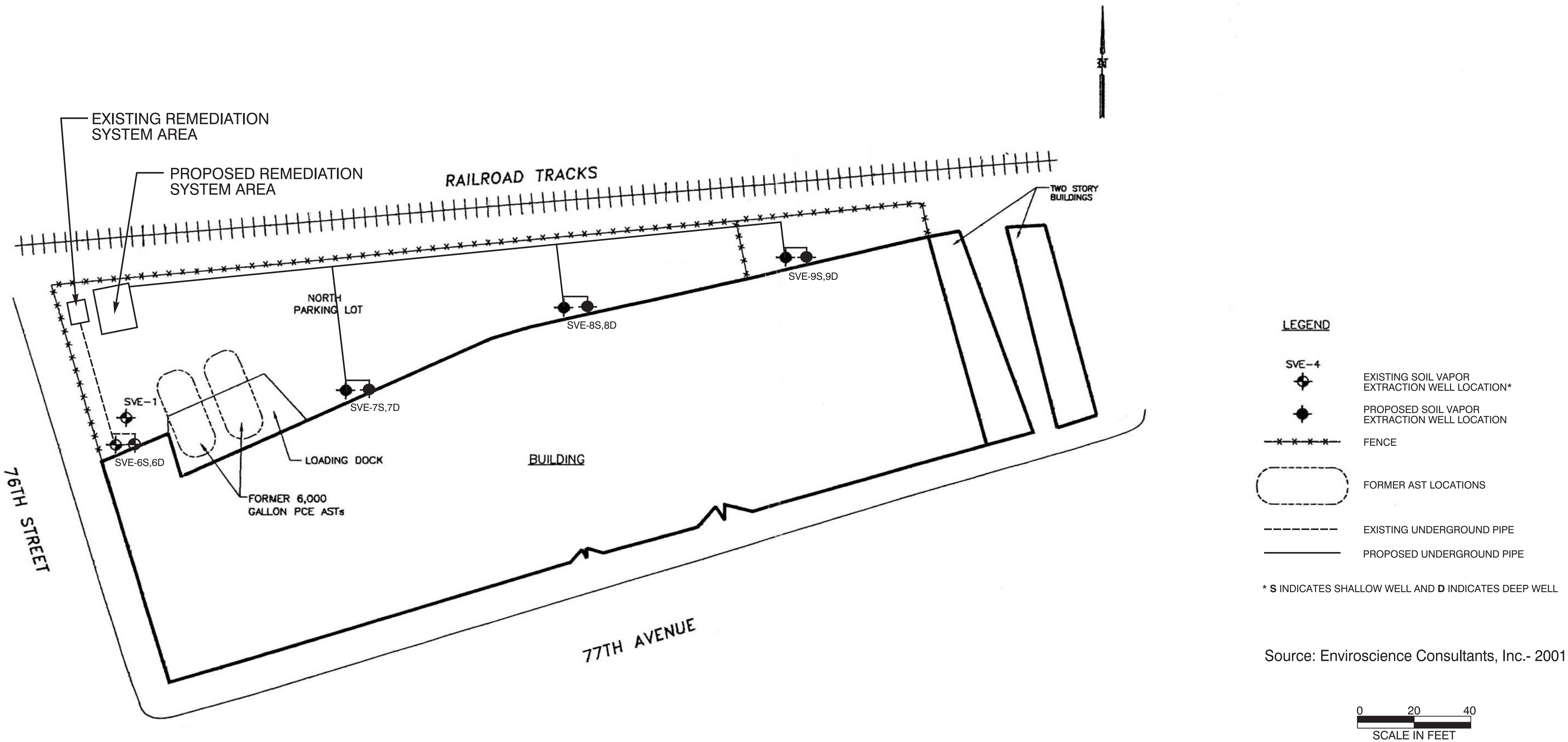
* **S** INDICATES SHALLOW WELL AND
D INDICATES DEEP WELL

AG19060-11171964-061505-GCM

URS

CURRENT IRM
SITE PLAN

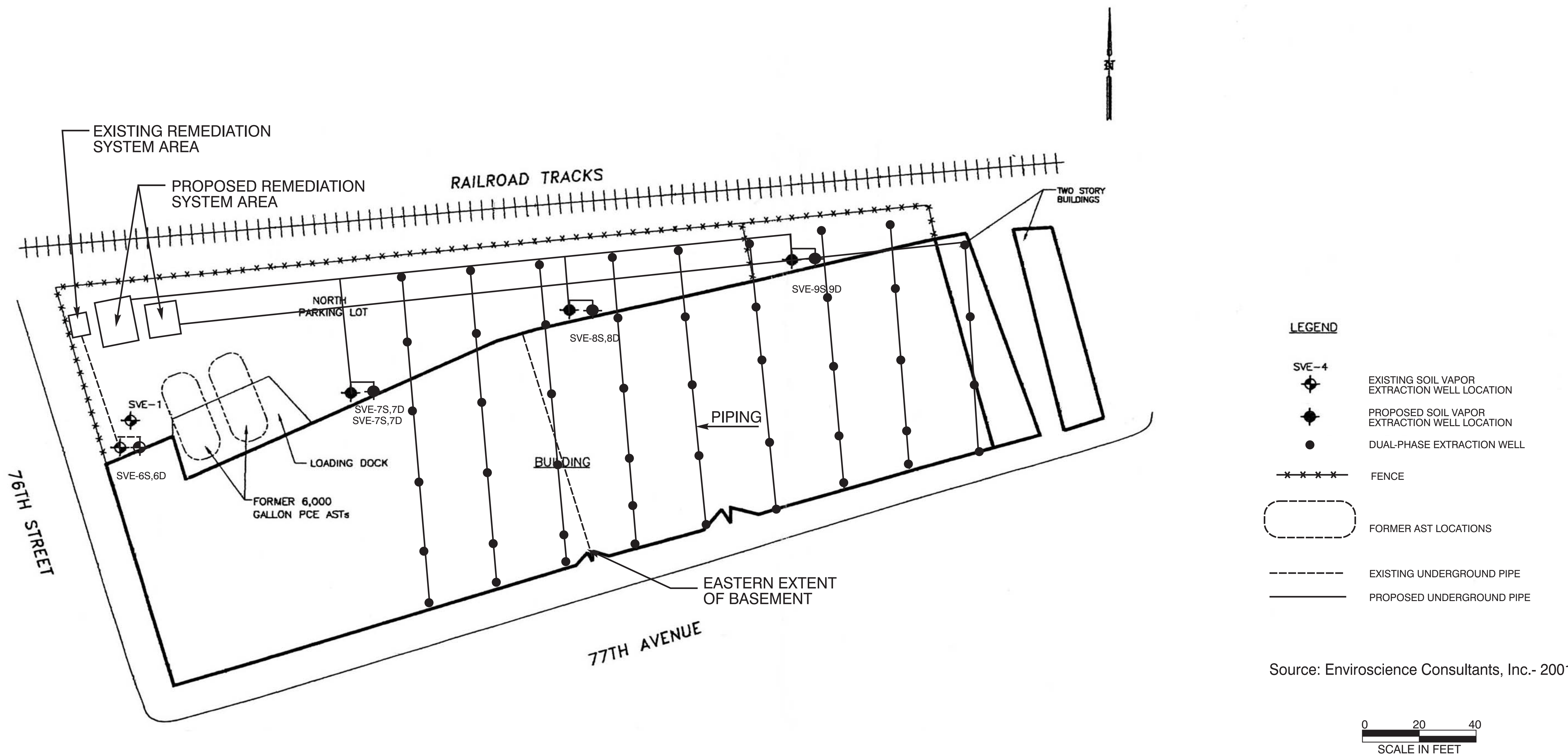
FIGURE 1-6



URS

SVE ALTERNATIVE SITE PLAN

FIGURE 2-1



URS

ESVE ALTERNATIVE SITE PLAN

FIGURE 2-2

APPENDIX A

DEWATERING OF THE PERCHED ZONE

URS

EXHIBIT 4.7-2

CALCULATION COVER SHEET

Client: NYSDEC

Project Name: Kliegman Brothers

Project/Calculation Number: 11172 382

Title: Dewatering of the Perched Zone

Total Number of Pages (including cover sheet): 27 (26 + cover)

Total Number of Computer Runs: 0

Prepared by: Marek Ostrowski

Date: July 5, 2005

Checked by: [signature]

Date: 5 July 2005

Description and Purpose: To perform conceptual design of dewatering system for perched water zone.

Design Basis/References/Assumptions: See text.

Remarks/Conclusions/Results: Between 40 and ~ 9,000 wells would be required, depending on the ratio of recharge to infiltration, which is not known. Total extraction rate of ~ 1 gpm.

Calculation Approved by: [signature]

Project Manager/Date

Revision No.:	Description of Revision:	Approved by:

Project Manager/Date

MADE BY: M.O. DATE: July 5, 2005
CHKD. BY: C.T.T. DATE: July 5, 2005

PROJECT: Kliegman Brothers
SUBJECT: Dewatering of the Perched Water Zone

1. PURPOSE

The purpose of this calculation is to perform a preliminary-level design of the system required to dewater the perched water zone identified in the eastern portion of the Kliegman Brothers site. The purpose of dewatering is to expose the contamination to the remediation by the SVE system.

2. GENERAL

Information about the site is based on Reference 1. The site is located in New York City, Queens County.

The top 10 - 15 feet are made up of the mixture of silt, sand and clay. Underneath, there is a thick sand and gravel aquifer. The aquifer is unconfined, with the water table located approximately 70 feet below ground surface.

There is a silty clay layer approximately 15 feet below ground surface. Perched water was observed in and above this layer. This occurs over the eastern part of the site. The saturated thickness of the perched zone is approximately 5 feet.

The remediation of the unsaturated zone of the aquifer is being conducted by means of soil vapor extraction. In order to expose the contamination within the zone saturated by perched water to the action of the SVE system, the thickness of the perched zone has to be reduced.

3. METHODOLOGY

The perched zone is created by recharge, whose downward percolation into the aquifer is blocked by the low-permeability layer of silty clay. Considering that the material is clayey, and that the thickness of the saturated zone is very low, the lateral flow is likely to be negligible. Here, it is assumed for simplicity, that the bottom of this layer is impervious. If wells are placed within the layer in the form of a uniform array, each well will extract water from its tributary zone, fed by infiltration. The line at mid-point between the wells (the boundary of the tributary zone) can be considered as a no-flow boundary.

The distribution of hydraulic heads around an extraction well is described on pages 12 to 17 of this calculation. The final result is:

$$h(r)^2 - h_w^2 = 0.5\ (N/K)\ (r_w^2 - r^2) + R^2\ (N/K)\ \ln(r/r_w)$$

Terms used in this methodology are listed below in alphabetical order:

- $h(r)$ - saturated thickness at distance "r" from extraction well, [ft]
- h_w - saturated thickness at the extraction well, [ft]
- K - hydraulic conductivity, [ft/d]
- N - recharge, [ft/d]
- Q_w - extraction rate, [ft^3/d]
- R - half-distance between extraction wells, [ft]
- r - radial distance from extraction well, [ft]

The greatest saturated thickness occurs at $r = R$.

$$h(R)^2 - h_w^2 = 0.5\ (N/K)\ (r_w^2 - R^2) + R^2\ (N/K)\ \ln(R/r_w)$$

$$h(R)^2 = h_w^2 + 0.5\ (N/K)\ (r_w^2 - R^2) + R^2\ (N/K)\ \ln(R/r_w)$$

Define $h(R) = h_R$

$$h_R = [h_w^2 + 0.5\ (N/K)\ (r_w^2 - R^2) + R^2\ (N/K)\ \ln(R/r_w)]^{1/2}$$

This way, the saturated thickness at the mid-point between the extraction wells can be assessed based on the distance between the wells, which is equal to 2R.

The extraction rate from each well is:

$$Q_w = N\ \pi\ R^2$$

4. PARAMETERS AND CALCULATION

Water in the perched zone occurs in silty clay and the sandy silt/silty sand immediately above. Parameters of these deposits are not known. It is assumed here that the hydraulic conductivity can be between $1*10^{-6}$ and $1*10^{-4}$ cm/s. Recharge in the New York state is typically on the order of 1 ft/yr. Here, assumed 0.25 to 1.5 ft/yr. Use a 2-inch diameter extraction well. Assume that the water level in the extraction well will be maintained at a negligible depth, using extraction technology based on suction and a drop tube placed near well bottom.

$K = 1*10^{-6}$ to $1*10^{-4}$ cm/s = 0.003 to 0.3 ft/d
N = 0.25 to 1.5 ft/yr = 0.0007 to 0.004 ft/d
r_w = 1 in = 0.08 ft
h_w = 0.1 ft

From this, the value of ratio N/K can vary between the following limits:

N/K = 0.0007 / 0.3 to 0.004 / 0.003 = 0.002 to 1.3

Say order of 0.001 to 1

Plot of the saturated thickness at mid-point between wells as a function of half-distance between wells is shown on page 6. The plot includes values of N/K of 0.001, 0.01, 0.1 and 1. Supporting calculations are shown on pages 7 to 11. A hand-check of one of the calculations is provided below.

N/K = 0.01
R = 10 ft

$$h_R = [h_w^2 + 0.5\ (N/K)\ (r_w^2 - R^2) + R^2\ (N/K)\ \ln(R/r_w)]^{1/2}$$

$$h_R = [0.1^2 + 0.5*0.01*(0.08^2 - 10^2) + 10^2*0.01*\ln(10/0.08)]^{1/2}$$

$$h_R = [0.01 - 0.5 + 4.8]^{1/2} = 2.08 \text{ ft}$$

Compare to the result of 2.07 ft on page 9 (spreadsheet). Calculation in the spreadsheet table is verified.

5. DISCUSSION

The current saturated thickness of the perched water zone is approximately 5 feet. In order to accomplish a successful SVE operation, most of that thickness has to be exposed to the flow of air. Full desaturattion is not possible because water needs some saturated thickness to flow into the well. Assume that the thickness should drop from the current 5 feet to less than 1 foot.

Based on the plot on page 6, depending on the ratio of recharge to conductivity, this can be accomplished by placing wells anywhere between every two feet and every 30 feet (half-distance between approximately one foot and 15 feet). Corresponding tributary areas are approximately 4 to 900 square feet. The size of the area covered by the perched zone is approximately 350 by 100 feet. Based on that, the number of wells required is:

$$n_{min} = 350*100 / 900 = 39$$

$$n_{max} = 350*100 / 4 = 8,750$$

The total extraction rate is, depending on the actual recharge:

$$Q_{tot} = N\ (350*100)$$

$$Q_{tot\text{-}min} = 0.0007\ ft/d * 35,000\ ft^2 = $$
$$= 25\ ft3/d = 0.1\ gpm$$

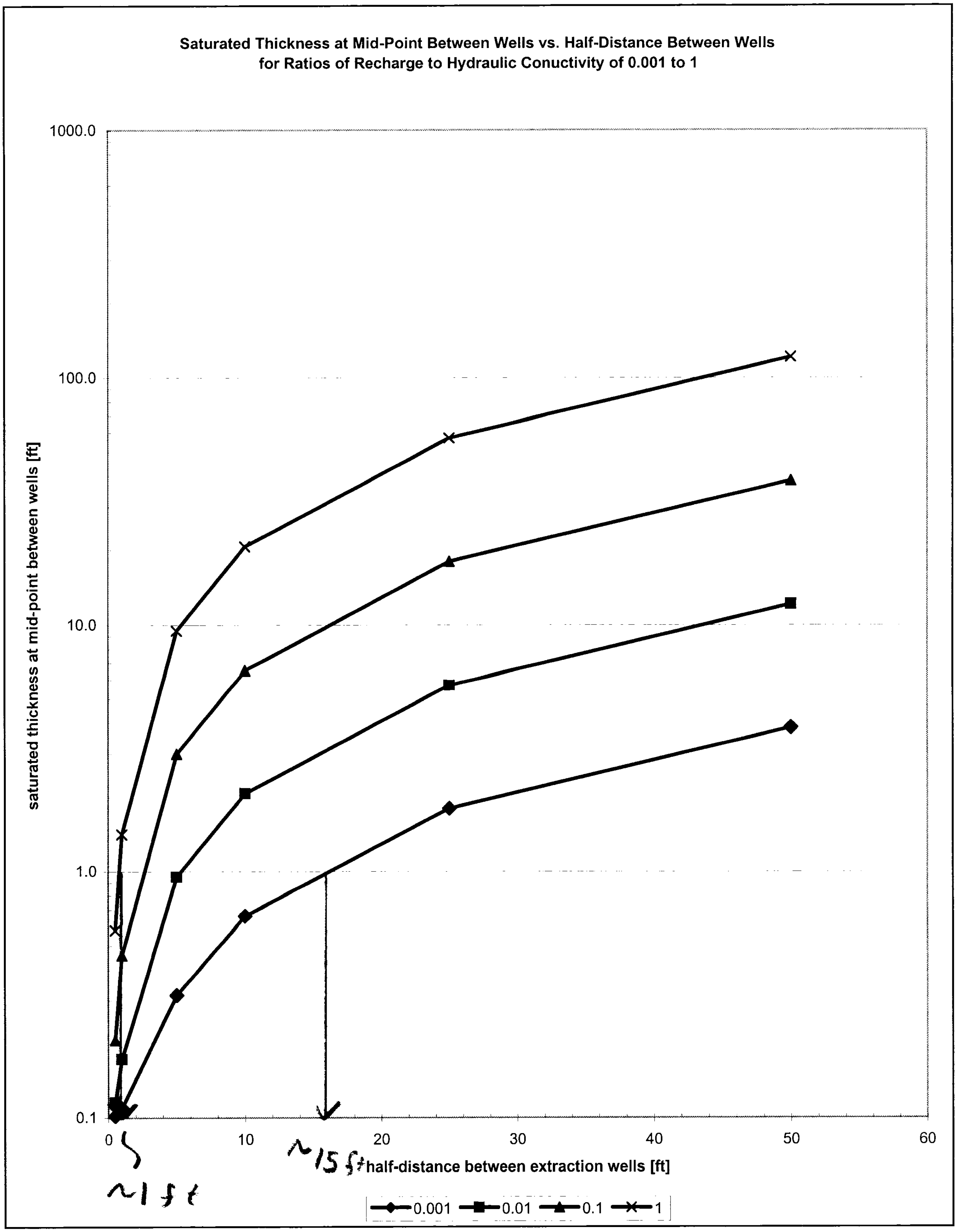
$$Q_{tot\text{-}max} = 0.004\ ft/d * 35,000\ ft^2 = $$
$$= 140\ ft3/d = 0.7\ gpm$$

If the ratio of N/K were high, the number of wells would be prohibitive. Regardless of the actual value of N/K, several wells would have to be placed within the building. The overall water extraction rate would be approximately 1 gpm, making the extraction per well negligible. Most likely water would be vaporized in the drop tube and enter the system as moisture dissolved in soil gas.

6. REFERENCES

1. Remedial Investigation Report
   Kliegman Brothers Site
   URS Corporation, Final February 2004

2. Hydraulics of Groundwater
   J. Bear
   McGraw-Hill, 1979


Saturated Thickness at Mid-Point Between Wells vs. Half-Distance Between Wells
for Ratios of Recharge to Hydraulic Conuctivity of 0.001 to 1
saturated thickness at mid-point between wells [ft]
1000.0
100.0
10.0
1.0
0.1
0
10
20
30
40
50
60
half-distance between extraction wells [ft]
~1 ft
~15 ft
0.001
0.01
0.1
1

Determines saturated thickness at half-distance between extraction wells arranged in an array.
Based on:

$$h_R = \{h_w^2 + (N / K) [0.5 (r_w^2 - R^2) + R^2 \ln(R / r_w)]\}^{1/2}$$

Where:

- h_R - saturated thickness at mid-point between extraction wells, [ft]
- h_w - saturated thickness at the extraction well, [ft]
- K - hydraulic conductivity, [ft/d]
- N - recharge, [ft/d]
- R - half of the distance between extraction wells, [ft]
- r_w - radius of extraction well, [ft]

Input Data:

Radius of extraction well	r_w = 1	inch =	0.083 ft
Saturated thickness at extraction well	h_w = 0.1	ft	

Results:

R [ft]	h_R [ft] for different values of N/K [-] N/K = 0.001	0.01	0.1	1
0.5	0.10	0.12	0.21	0.58
1	0.11	0.17	0.46	1.41
5	0.32	0.95	3.00	9.48
10	0.66	2.07	6.55	20.71
25	1.81	5.70	18.03	57.03
50	3.84	12.14	38.40	121.42

$$h_R = \{h_w^2 + (N / K)\,[0.5\,(r_w^2 - R^2) + R^2 \ln(R / r_w)]\}^{1/2}$$

Echo input:

Radius of extraction well	rw =	1 inch =	0.083 ft
Saturated thickness at extraction well	hw =	0.1 ft	
ratio of recharge to conductivity	N/K =	0.001	

Calculate:

R	h_w^2	N / K	$r_w^2 - R^2$	$\ln(R/r_w)$	h_R
0.5	0.01	0.001	-0.243	1.792	0.10
1	0.01	0.001	-0.993	2.485	0.11
5	0.01	0.001	-24.993	4.094	0.32
10	0.01	0.001	-99.993	4.787	0.66
25	0.01	0.001	-624.993	5.704	1.81
50	0.01	0.001	-2499.993	6.397	3.84

$$h_R = \{h_w^2 + (N / K) [0.5 (r_w^2 - R^2) + R^2 \ln(R / r_w)]\}^{1/2}$$

Echo input:

Radius of extraction well	rw =	1	inch =	0.083 ft
Saturated thickness at extraction well	hw =	0.1	ft	
ratio of recharge to conductivity	N/K =	0.01		

Calculate:

R	h_w^2	N / K	$r_w^2 - R^2$	$\ln(R/r_w)$	h_R	
0.5	0.01	0.01	-0.243	1.792	0.12	
1	0.01	0.01	-0.993	2.485	0.17	
5	0.01	0.01	-24.993	4.094	0.95	
10	0.01	0.01	-99.993	4.787	2.07	← HAND CHECK
25	0.01	0.01	-624.993	5.704	5.70	
50	0.01	0.01	-2499.993	6.397	12.14	

$$h_R = \{h_w^2 + (N / K) [0.5 (r_w^2 - R^2) + R^2 \ln(R / r_w)]\}^{1/2}$$

Echo input:

Radius of extraction well	rw =	1 inch =	0.083 ft
Saturated thickness at extraction well	hw =	0.1 ft	
ratio of recharge to conductivity	N/K =	0.1	

Calculate:

R	h_w^2	N / K	$r_w^2 - R^2$	$\ln(R/r_w)$	h_R
0.5	0.01	0.1	-0.243	1.792	0.21
1	0.01	0.1	-0.993	2.485	0.46
5	0.01	0.1	-24.993	4.094	3.00
10	0.01	0.1	-99.993	4.787	6.55
25	0.01	0.1	-624.993	5.704	18.03
50	0.01	0.1	-2499.993	6.397	38.40

$h_R = \{h_w^2 + (N / K) [0.5 (r_w^2 - R^2) + R^2 \ln(R / r_w)]\}^{1/2}$

Echo input:

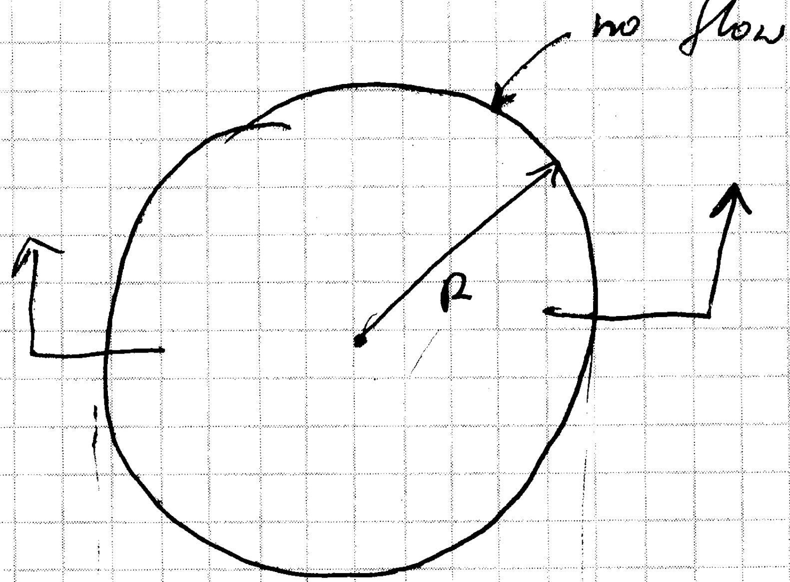
Radius of extraction well	rw =	1 inch =	0.083 ft
Saturated thickness at extraction well	hw =	0.1 ft	
ratio of recharge to conductivity	N/K =	1	

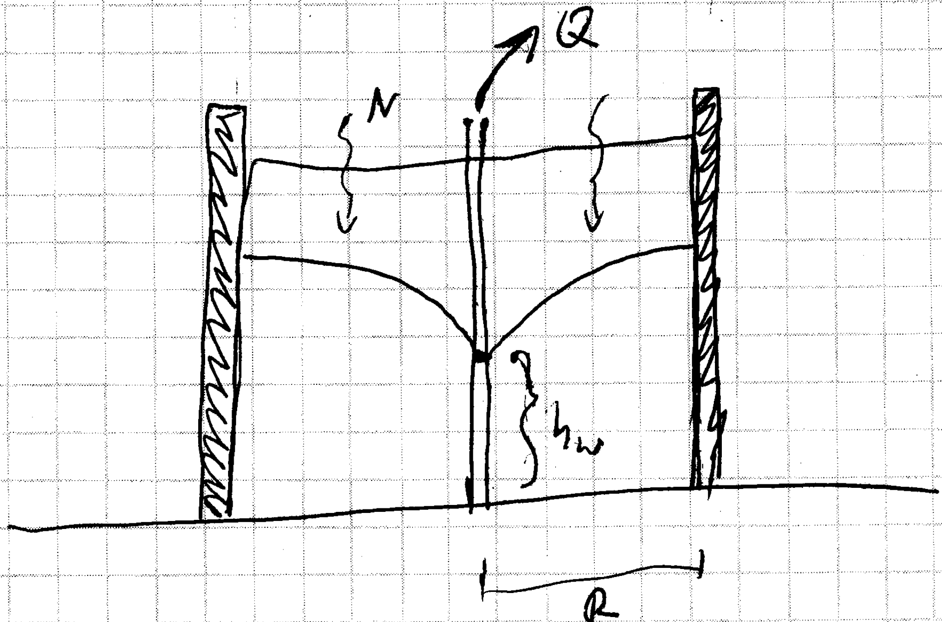
Calculate:

R	h_w^2	N / K	$r_w^2 - R^2$	$\ln(R/r_w)$	h_R
0.5	0.01	1	-0.243	1.792	0.58
1	0.01	1	-0.993	2.485	1.41
5	0.01	1	-24.993	4.094	9.48
10	0.01	1	-99.993	4.787	20.71
25	0.01	1	-624.993	5.704	57.03
50	0.01	1	-2499.993	6.397	121.42

PROJECT ....
SUBJECT ....

REF. PAGE





REF. PAGE

2-D depth averaged eq. for phreatic flow

$$\frac{\partial^2(h^2)}{\partial x^2} + \frac{\partial^2(h^2)}{\partial y^2} + \frac{2N}{K} = \frac{S}{T}\frac{\partial(h^2)}{\partial t}$$

Bear 5-82
Ref 2

For steady state

$$\frac{\partial^2(h^2)}{\partial x^2} + \frac{\partial^2(h^2)}{\partial y^2} = -\frac{2N}{K}$$

$$\nabla^2(h^2) = -\frac{2N}{K}$$

In cylindrical coordinate system

$$\nabla^2\phi = \frac{\partial^2\phi}{\partial r^2} + \frac{1}{r}\frac{\partial\phi}{\partial r} + \frac{1}{r^2}\frac{\partial^2\phi}{\partial\theta^2}.$$

Bear p 116

Here, assume axi-symmetric case

$$\frac{\partial\phi}{\partial\theta} = 0$$

So;

$$\frac{\partial^2(h^2)}{\partial r^2} + \frac{1}{r}\frac{\partial(h^2)}{\partial r} = -\frac{2N}{K}$$

$$\frac{\partial^2(h^2)}{\partial r^2} + \frac{1}{r}\frac{\partial(h^2)}{\partial r} + \frac{2N}{K} = 0$$

Solve using

From sheet # 2, the eqn is

$$\frac{\partial^2(h^2)}{\partial r^2} + \frac{1}{r}\frac{\partial(h^2)}{\partial r} + \frac{2N}{K} = 0$$

$$v = \frac{\partial(h^2)}{\partial r}$$

$$\frac{\partial v}{\partial r} + \frac{1}{r}v + \frac{2N}{K} = 0$$

From sheet # 3

$$v = -\frac{Nr}{K} + \frac{C_1}{r}$$

B.C. #1

$$\left.\frac{\partial h}{\partial r}\right|_{r=R} = 0$$

$$v = \frac{\partial(h^2)}{\partial r} = 2h\frac{\partial h}{\partial r} = -\frac{Nr}{K} + \frac{C_1}{r}$$

$$0 = -\frac{NR}{K} + \frac{C_1}{R}$$

$$C_1 = \frac{NR^2}{K}$$

B.C. #2

$$h\Big|_{r=r_w} = h_w$$

REF. PAGE

$$0 = \frac{\partial(h^2)}{\partial r} = -\frac{Nr}{K} + \frac{NR^2}{Kr}$$

$$h^2 = -\frac{Nr^2}{2K} + \frac{NR^2}{K} \ln r + C_2$$

$$h_w^2 = -\frac{Nr_w^2}{2K} + \frac{NR^2}{K} \ln r_w + C_2$$

$$C_2 = h_w^2 + \frac{Nr_w^2}{2K} - \frac{NR^2}{K} \ln r_w$$

So;

$$h^2 = -\frac{Nr^2}{2K} + \frac{NR^2}{K} \ln r + h_w^2 + \frac{Nr_w^2}{2K} - \frac{NR^2}{K} \ln r_w$$

$$h^2 - h_w^2 = \frac{N}{2K}(r_w^2 - r^2) + \frac{NR^2}{K} \ln \frac{r}{r_w}$$

Note: First, set your h_R & h_w (i.e. $h_R^2 - h_w^2$)
Then, iteratively, determine R

$$h_R^2 - h_w^2 = \frac{N}{2K}(r_w^2 - R^2) + \frac{NR^2}{K} \ln \frac{R}{r_w}$$

$$R = \left\{ \frac{K}{N \ln(R/r_w)} \left[(h_R^2 - h_w^2) + \frac{N}{2K}(R^2 - r_w^2) \right] \right\}^{1/2}$$

REF. PAGE

Check

$$h^2 = h_w^2 + \frac{N}{2K}(r_w^2 - r^2) + \frac{NR^2}{K} \ln \frac{r}{r_w}$$

$$\frac{\partial(h^2)}{\partial r} = -\frac{Nr}{K} + \frac{NR^2}{Kr}$$

$$\frac{\partial^2(h^2)}{\partial r^2} = -\frac{N}{K} - \frac{NR^2}{Kr^2}$$

Substitute to gov. eqn

$$\frac{\partial^2(h^2)}{\partial r^2} + \frac{1}{r}\frac{\partial(h^2)}{\partial r} + \frac{2N}{K} = 0$$

$$-\frac{N}{K} - \frac{NR^2}{Kr^2} + \frac{1}{r}\left(-\frac{Nr}{K} + \frac{NR^2}{Kr}\right) + \frac{2N}{K} =$$

$$= -\frac{N}{K} - \frac{NR^2}{Kr^2} - \frac{N}{K} + \frac{NR^2}{Kr^2} + \frac{2N}{K} = 0$$

OK

B.C. # 1

$$\left.\frac{\partial h}{\partial r}\right|_{r=R} = 0 \qquad h = \left\{h_w^2 + \frac{N}{2K}(r_w^2 - r^2) + \frac{NR^2}{K} \ln \frac{r}{r_w}\right\}^{1/2}$$

$$\frac{\partial h}{\partial r} = \frac{-\frac{Nr}{K} + \frac{NR^2}{Kr}}{2\sqrt{\quad}}$$

REF. PAGE

$$\frac{\partial h}{\partial r} = 0 \rightarrow \quad -\frac{N r}{K} + \frac{N R^2}{K r} = 0$$

$$r = R$$

$$-\frac{N R}{K} + \frac{N R^2}{K R} = 0 \qquad \text{ok}$$

B.C. # 2

$$h\Big|_{r=r_w} = h_w$$

$$h^2 = h_w^2 + \frac{N}{2K}\left(r_w^2 - r_w^2\right) + \frac{N R}{K} \ln \frac{r_w}{r_w}$$

$$h^2 = h_w^2 \qquad \text{ok}$$

pg 18 of 26

REMEDIAL INVESTIGATION REPORT

KLIEGMAN BROS. SITE
SITE #2-41-031
GLENDALE, NEW YORK

Prepared For:

NYS DEPARTMENT OF ENVIRONMENTAL CONSERVATION
DIVISION OF ENVIRONMENTAL REMEDIATION
WORK ASSIGNMENT D003825-37

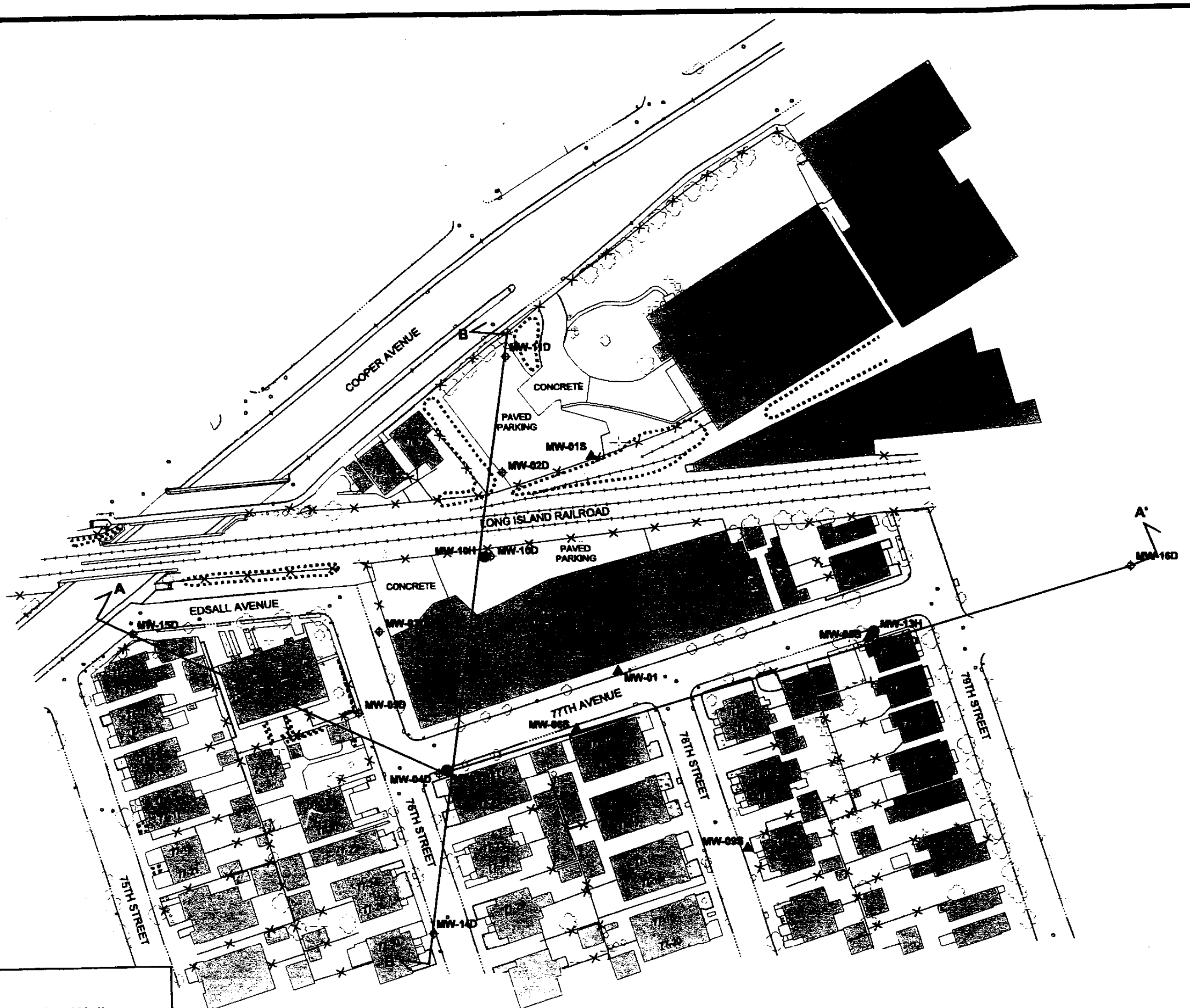
FINAL

Reference 1

Prepared By:

URS CORPORATION GROUP CONSULTANTS
640 ELLICOTT STREET
BUFFALO, NEW YORK 14203

FEBRUARY 2004



Legend

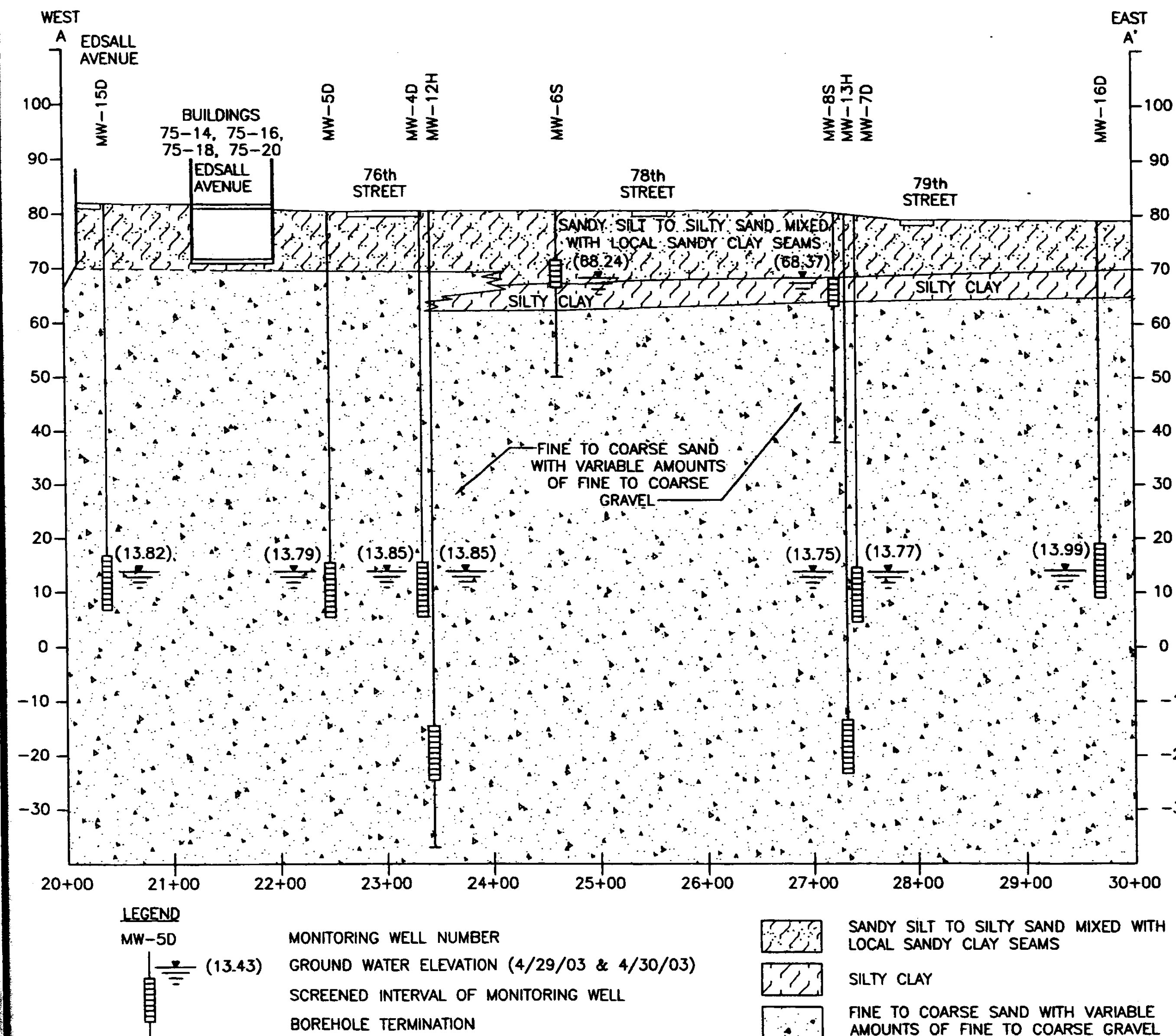
- ▲ Phase I Perched Water Zone Monitoring Well
- ⊕ Phase I Shallow Groundwater Zone Monitoring Well
- ⊕ Phase II Shallow Groundwater Zone Monitoring Well
- ● Phase II Deep Groundwater Zone Monitoring Well
- A A' Geologic Cross Section Line

KLIEGMAN BROTHERS
MONITORING WELL LOCATION MAP

URS

FIGURE 2-2

J:\35971.01\dxGIS\geology.apr MONITORING WELL LOCATION MAP
7/22/2003



NOTES:

1. GEOLOGIC CONDITIONS SHOWN ARE REPRESENTATIVE OF CONDITIONS ENCOUNTERED AT EACH BORING LOCATION TO THE DEPTH DRILLED. EXTRAPOLATIONS BETWEEN BORINGS HAVE BEEN INTERPRETED USING STANDARDLY ACCEPTED GEOLOGIC PRACTICES AND PRINCIPLES. ACTUAL CONDITIONS MAY VARY BETWEEN BORINGS FROM THOSE SHOWN.
2. ELEVATIONS BASED ON THE NORTH AMERICAN VERTICAL DATUM, 1988.
3. PAIRED MONITORING WELLS SEPARATED SLIGHTLY FOR CLARITY.

100' 0 100'
SCALE: 1"= 100'
HORIZONTAL

20' 0 20'
SCALE: 1"= 20'
VERTICAL

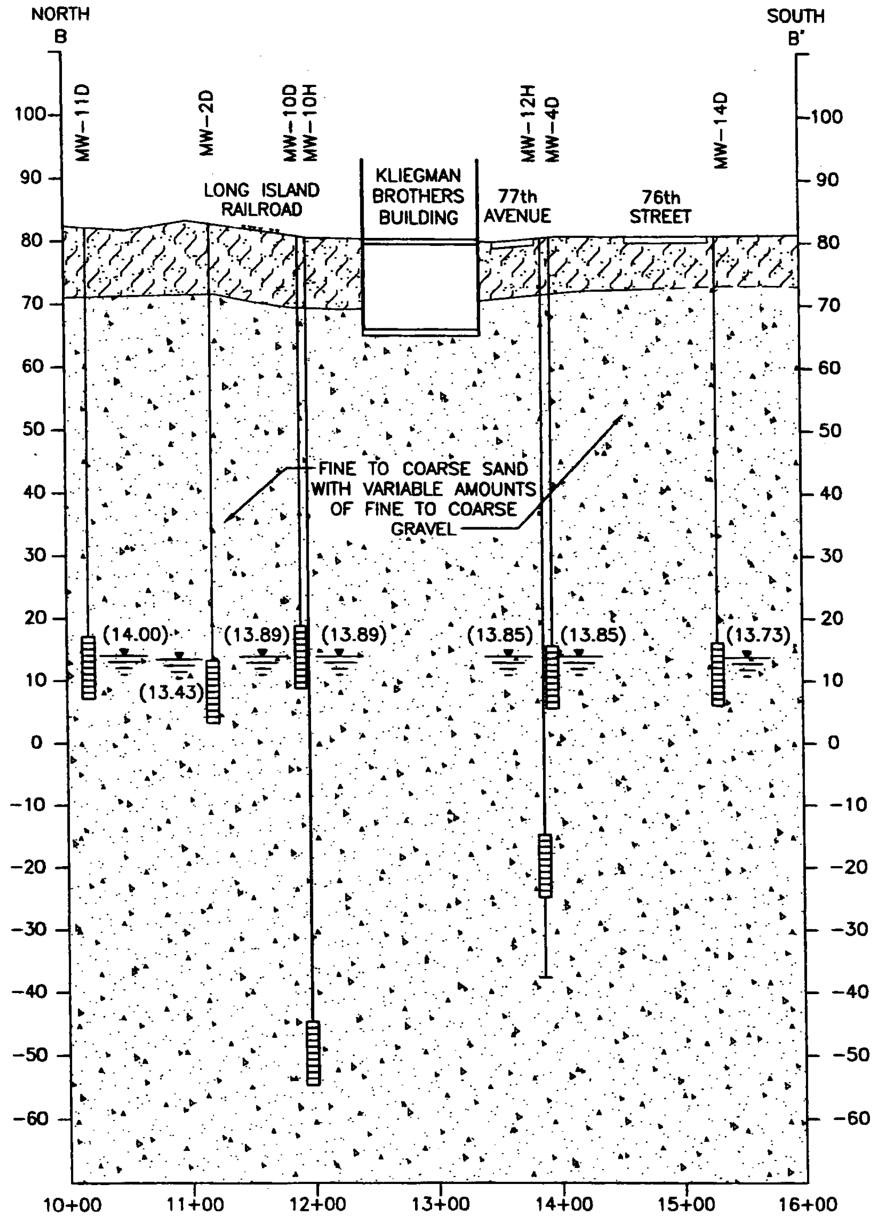
Pg 20 of 26

KLIEGMAN BROTHERS
GEOLOGIC CROSS SECTION A-A'

URS

FIGURE 3-1

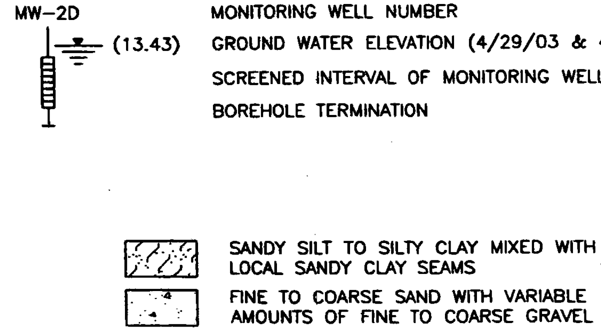
J:\35971.01\CAD\ 1=100 8/4/03-1 PAL



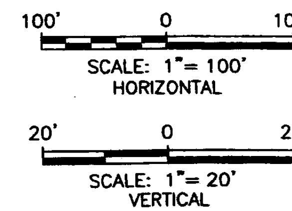
NOTES:

1. GEOLOGIC CONDITIONS SHOWN ARE REPRESENTATIVE OF CONDITIONS ENCOUNTERED AT EACH BORING LOCATION TO THE DEPTH DRILLED. EXTRAPOLATIONS BETWEEN BORINGS HAVE BEEN INTERPRETED USING STANDARDLY ACCEPTED GEOLOGIC PRACTICES AND PRINCIPLES. ACTUAL CONDITIONS MAY VARY BETWEEN BORINGS FROM THOSE SHOWN.
2. ELEVATIONS BASED ON THE NORTH AMERICAN VERTICAL DATUM, 1988.
3. PAIRED MONITORING WELLS SEPARATED SLIGHTLY FOR CLARITY.

LEGEND



MONITORING WELL NUMBER
GROUND WATER ELEVATION (4/29/03 & 4/30/03)
SCREENED INTERVAL OF MONITORING WELL
BOREHOLE TERMINATION



Pg 21 of 26

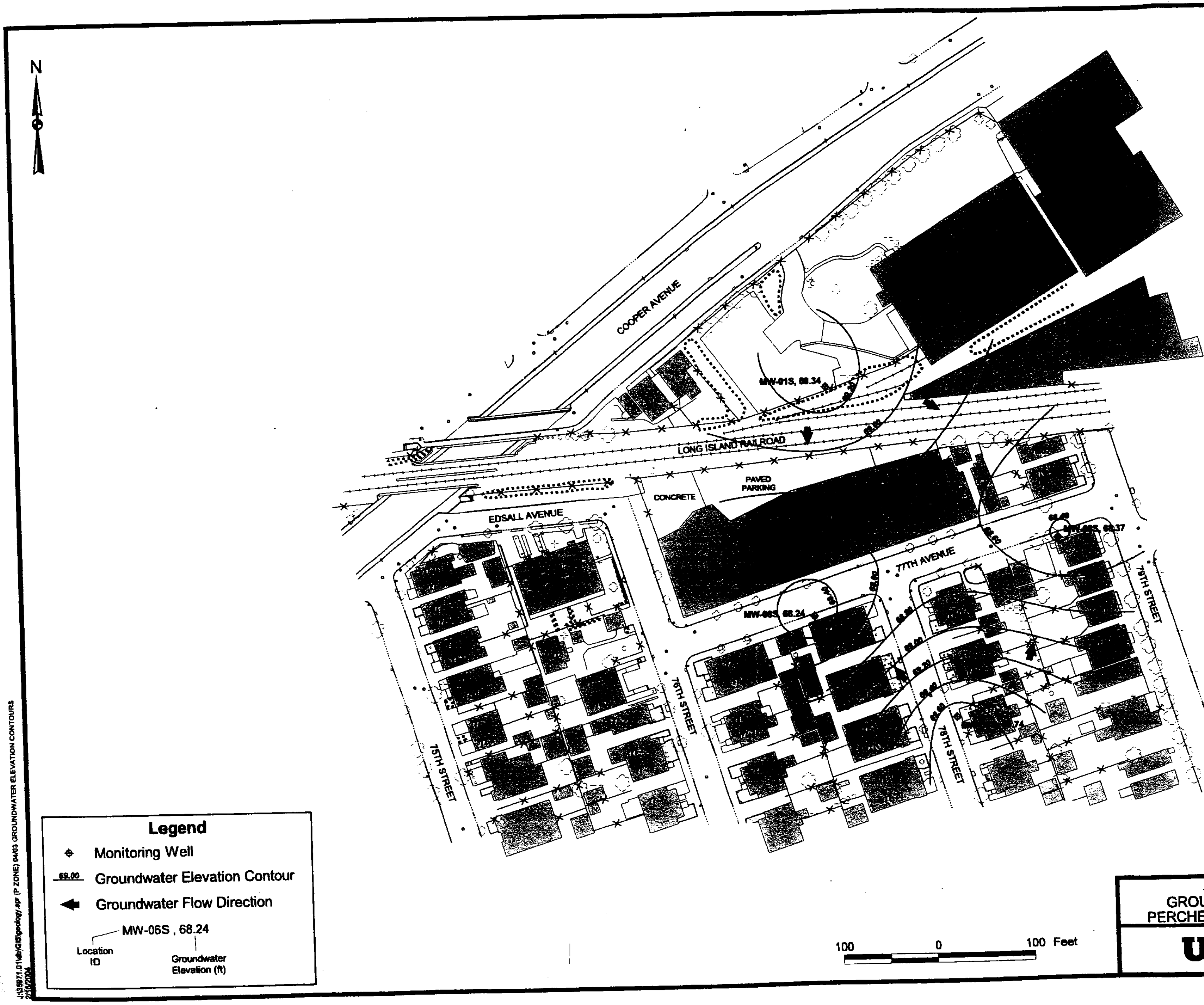
KLIEGMAN BROTHERS
GEOLOGIC CROSS SECTION B-B'

URS

FIGURE 3-2

J:\35971.01\CAD\ 1=100 8/4/03-1 PAL

CC-7479A



pg 22 of 26

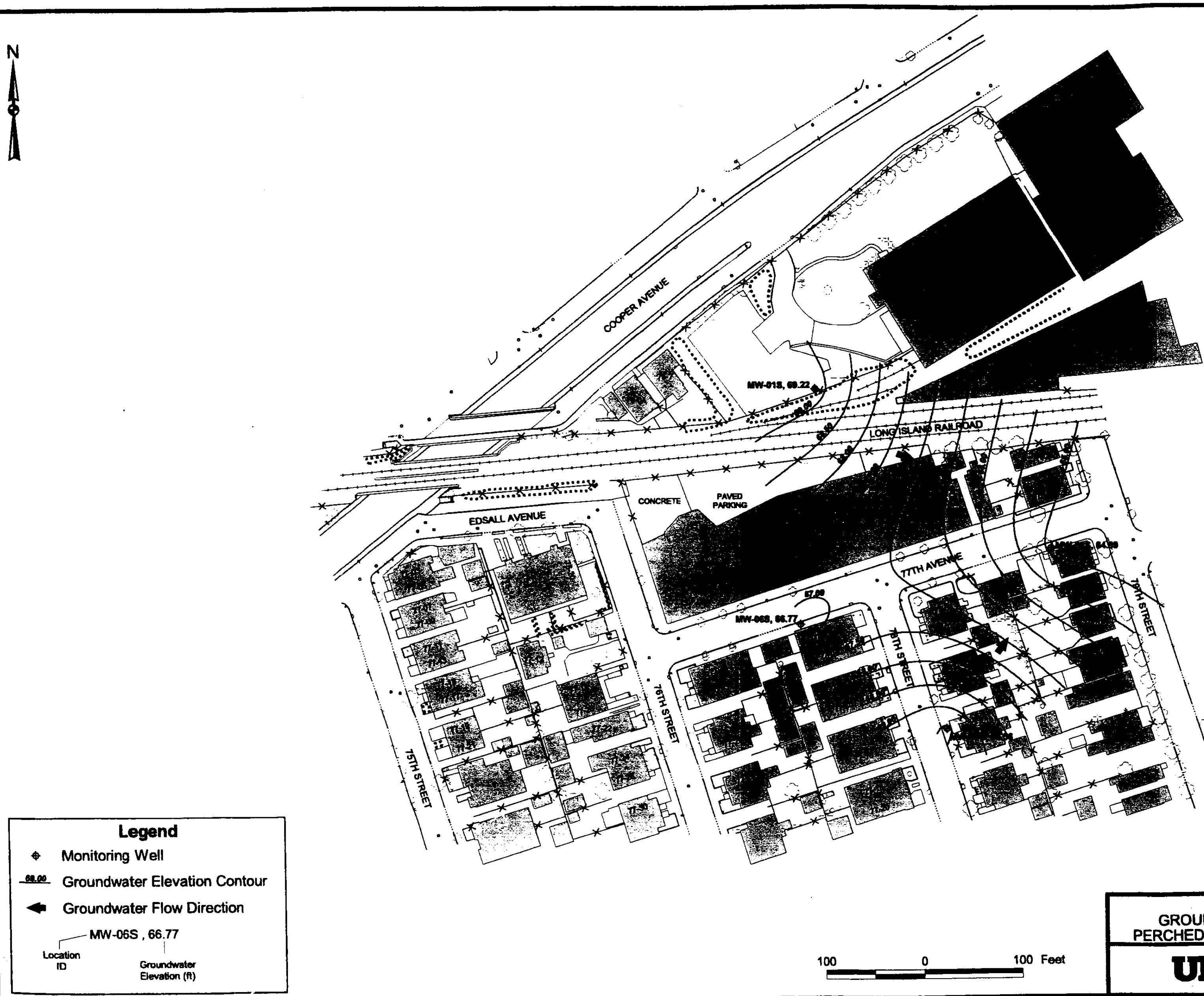
KLIEGMAN BROTHERS
GROUNDWATER ELEVATION CONTOURS IN THE PERCHED GROUNDWATER ZONE (APRIL 29 - 30, 2003)

URS

FIGURE 3-3

J:\35971.01\db\GIS\geology.apr (P ZONE) 04/03 GROUNDWATER ELEVATION CONTOURS
2/18/2004

Pg 23 of 26



KLIEGMAN BROTHERS
GROUNDWATER ELEVATION CONTOURS IN THE PERCHED GROUNDWATER ZONE (DECEMBER 16, 2003)

URS

FIGURE 3-4

J:\35871.01\GIS\geology.apr (P ZONE) 12/16/03 GROUNDWATER ELEVATION CONTOURS
2/18/2004

pg 24 of 26

McGRAW-HILL BOOK COMPANY

New York
St. Louis
San Francisco
Auckland
Bogotá
Hamburg
London
Madrid
Mexico
Montreal
New Delhi
Panama
Paris
São Paulo
Singapore
Sydney
Tokyo
Toronto

Reference 2

JACOB BEAR

Department of Civil Engineering
Technion—Israel Institute of Technology
Haifa
Israel

Hydraulics of Groundwater

of the phreatic aquifer. However, unlike the transmissivity in a confined aquifer, here it may vary both in space and in time, as $h = h(x, y, t)$.

Two methods of linearization are often applied to (5-75) in order to facilitate a solution.

(i) Assume that $T = \bar{T} + \mathring{T}$; $\bar{T}$ ($\gg \mathring{T}$) is the average constant transmissivity of the phreatic flow and $\mathring{T}$ is a deviation from the average. Then (5-75) reduces to the linear equation in h

$$\bar{T}\left(\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2}\right) + N = S\,\partial h/\partial t; \qquad \bar{T} = K\bar{h} \tag{5-81}$$

to be compared with (5-60).

(ii) We rewrite the right-hand side of (5-76) as $(S/h)\,\partial(h^2/2)/\partial t$ and assume that S/h may be considered as a constant $S/\bar{h}$, where $T = K\bar{h}$. Then (5-76) reduces to

$$\left(\frac{\partial^2 h^2}{\partial x^2} + \frac{\partial^2 h^2}{\partial y^2}\right) + \frac{2N}{K} = \frac{S}{T}\frac{\partial h^2}{\partial t} \tag{5-82}$$

which is a linear equation in h^2.

Equation (5-81) is the one commonly used to describe unsteady groundwater flow in phreatic aquifers. The approximation involved in the linearization (further to that introduced by the Dupuit assumptions) is justified in view of the relatively small changes in h (with respect to the total thickness h) in most phreatic aquifers. Whenever the situation is different, (5-75) or (5-76) should be used.

By replacing h in (5-81) by ϕ (measured from the same datum level as h), (5-60) and (5-81) become identical. We may, therefore, regard (5-81) with h replaced by ϕ, as the general continuity equation describing flow in both phreatic and confined aquifers. For a phreatic aquifer this is true whenever linearization is justified.

Flow in a Leaky Phreatic Aquifer

In this case, the phreatic aquifer is located above a semipermeable layer, which, in turn, overlies a leaky confined aquifer. Figure 5-11 shows such a case. The continuity equation can be easily derived by considering a control box in the phreatic aquifer, taking into account a leakage (q_{v1}) between the leaky confined aquifer and the overlying leaky phreatic one. Obviously, the direction of q_{v1} depends on whether $h > \phi$, or $\phi > h$. We would then obtain

$$\frac{\partial}{\partial x}\left(Kh\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(Kh\frac{\partial h}{\partial y}\right) + N - \frac{h - \phi}{\sigma^{(1)}} = S\frac{\partial h}{\partial t} \tag{5-83}$$

where the piezometric head in the leaky confined aquifer, ϕ, is measured from the same datum level as h. Here S ($\equiv S_y$) stands for the storativity of the phreatic aquifer. This is the basic continuity equation describing groundwater flow in a leaky phreatic aquifer. It can be obtained by integration. We start from (5-79), noting that n_e ($\equiv S$) $\gg S_0 B$ and that $\mathbf{q}'|_{b_1} \cdot \nabla' b_1 - q_z|_{b_1} \equiv \mathbf{q} \cdot \nabla(z - b_1) =$

$\mathbf{q}_l \cdot \nabla(z - b_1)$, where $\mathbf{q}_l$ denotes the leakage through b_1. For a horizontal semipervious layer, $\nabla' b_1 = 0$, $\mathbf{q}_l \cdot \nabla z \equiv q_z|_{b_1} \equiv q_{v1} = (\phi - h)/\sigma^{(1)}$.

As was already emphasized above, when we have a system of leaky aquifers, each equation will also include the piezometric head in the underlying and/or overlying aquifer. This means that a continuity equation must be written for each of the aquifers and the system of equations must be solved simultaneously. Sometimes, delayed storage in a semipervious layer is taken into account by writing also a continuity equation for that layer as shown above.

Whenever we consider an inhomogeneous aquifer, with $T = T(x, y)$, the distribution $T(x, y)$ must be continuous up to and including the first derivative. If surfaces of discontinuity in T or in ∇T exist within the considered flow domain, we have to divide the aquifer into subdomains along the lines of discontinuity and solve simultaneously for all subdomains.

It may be of interest to note that when the aquifer is anisotropic, that is $T_x \neq T_y$, a procedure presented in Sec. 5-9 can be employed in order to transform the problem into one dealing with an equivalent isotropic aquifer (Bear, 1972, Sec. 7.4).

Mathematically, (5-58), (5-59), (5-60), (5-81), and (5-82) are second order linear partial differential equations of the parabolic type. They are often called heat conduction equations, or diffusion equations, as they are encountered in these fields. Equation (5-61) is also a second order linear partial differential equation, but of the elliptic type; it is known as the Laplace equation.

When necessary, they can easily be written in any other coordinate system by expressing $\nabla \cdot (T \nabla \phi)$ or $\nabla^2 \phi$ properly in that coordinate system. For example, in radial coordinates

$$\nabla^2 \phi \equiv \frac{1}{r}\frac{\partial}{\partial r}\left(r \frac{\partial \phi}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 \phi}{\partial \theta^2} = \frac{\partial^2 \phi}{\partial r^2} + \frac{1}{r}\frac{\partial \phi}{\partial r} + \frac{1}{r^2}\frac{\partial^2 \phi}{\partial \theta^2}$$

5-5 COMPLETE MATHEMATICAL STATEMENT OF A GROUNDWATER FLOW PROBLEM

As was already explained in Sec. 5-3, a complete mathematical statement of a groundwater flow problem (and a correct mathematical statement is always the first step of solving a problem, no matter which method of solution is to be applied) consists of five parts.

(*a*) *Specifying the geometry* of the (two-dimensional) flow-domain in the aquifer.
(*b*) *Determining which dependent variable* (*or variables*) is to be used. Usually we use $\phi(x, y, t)$ for flow in confined and in leaky confined aquifers, and $h(x, y, t)$ for flow in phreatic and in leaky phreatic aquifers. When the linearized equation (5-81) is used, we often replace $h(x, y, t)$ by $\phi(x, y, t)$.
(*c*) *Stating the continuity equation* describing the flow in the aquifer (depending on the type of aquifer and on its properties).
(*d*) *Specifying the initial conditions* $\phi = \phi(x, y, 0)$, or $h = h(x, y, 0)$ at some initial time referred to as $t = 0$.

APPENDIX B

COST ESTIMATES

URS

EXHIBIT 4.7-2

CALCULATION COVER SHEET

Client: NYSDEC Project Name: KLIEGMAN BROS.

Project/Calculation Number: 11171964

Title: SVE ALTERNATIVE - CAPITAL COST ESTIMATE

Total Number of Pages (including cover sheet): 7

Total Number of Computer Runs: 0

Prepared by: P. BAKER Date: 6/22/05

Checked by: C. PAWLEWSKI Date: 6/23/05

Description and Purpose: FEASIBILITY STUDY COST ESTIMATE

Design Basis/References/Assumptions

MEANS COST DATA REFERENCE BOOKS

Remarks/Conclusions/Results:

Calculation Approved by: [signature]
Project Manager/Date

Revision No.:	Description of Revision:	Approved by:

Project Manager/Date

NYSDEC
KLIEGMAN SITE
FEASIBILITY STUDY COST ESTIMATE

Client:	NYSDEC	Project Number:	11171964		
Project:	Kliegman Site	Calculated By:	P. Baker	Date:	22-Jun-05
Description:	Feasibility Study Cost Estimate	Checked By:	C. Pawlewski	Date:	23-Jun-05

SUMMARY

DESCRIPTION	ESTIMATED COST
SVE TREATMENT SYSTEM	$93,120
SVE PIPING	$19,861
WELL INSTALLATION	$35,609
SYSTEM STARTUP	$10,680
CONFIRMATION SOIL SAMPLING	$57,000
SUBTOTAL	$216,271
MOBILIZATION/DEMOBILIZATION 5%	$10,814
CONTRACTOR SUPERVISION 10%	$21,627
DESIGN AND CONSTRUCTION MGT. 20%	$43,254
CONTINGENCY 25%	$54,068
TOTAL	$346,033
BUDGET TOTAL	$350,000

URS CORPORATION
FEASIBILITY STUDY CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11171964		
Project:	Kliegman Site	Calculated By:	P. Baker	Date:	22-Jun-05
Title:	SVE Treatment System	Checked By:	C. Pawlewski	Date:	23-Jun-05

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	**SVE Treatment System**				
2	Moisture Separator Tank - 220 gallon	1	each	$4,700.00	$4,700
3	Carbon Adsorber Unit (Vapor Phase)	2	each	$8,400.00	$16,800
4	Regenerative Blower - 750 SCFM	1	each	$3,200.00	$3,200
5	Skid Fabrication and Component Mounting - Allow:	1	ls	$10,000.00	$10,000
6	Instrumentation and Controls - Allow:	1	ls	$12,000.00	$12,000
7	Electrical Power Drop and Connection - Allow:	1	ls	$27,000.00	$27,000
8	Delivery / Offloading - Allow:	1	LS	$3,900.00	$3,900
9					
10				**Subtotal**	**$77,600**
11					
12	**Contractor's Overhead and Profit**			**20%**	**$15,520**
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
	TOTAL COST:				**$93,120**

URS CORPORATION
FEASIBILITY STUDY CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client: NYSDEC	Project Number: 11171964		
Project: Kliegman Site	Calculated By: P. Baker	Date: 22-Jun-05	
Title: SVE Piping	Checked By: C. Pawlewski	Date: 23-Jun-05	

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	Trench Excavation and Pipe Bedding	330	lf	$9.10	$3,003
2	Pipe - Sch. 80 PVC - 6" diameter	330	lf	$29.00	$9,570
3	Pavement Restoration - Allow:	74	sy	$17.00	$1,258
4	Offsite Transportation and Disposal of Soil - Non-Haz.	34	cy	$80.00	$2,720
5					
6					
7				**Subtotal**	**$16,551**
8					
9					
10	**Contractor's Overhead and Profit**			**20%**	**$3,310**
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
	TOTAL COST:				**$19,861**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11171964
Project:	Kliegman Site	Calculated By:	P. Baker	Date: 22-Jun-05
Title:	SVE Extraction Wells	Checked By:	C. Pawlewski	Date: 23-Jun-05

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	Mobilize / Demobilize Drill Rig - Allow:	1	LS	$3,500.00	$3,500
2	Drill Bore Holes - 6" Diameter	255	lf	$53.50	$13,643
3	Well Casing - 4" Diameter - Carbon Steel	255	lf	$12.86	$3,279
4	Well Screen - 2" Diameter - PVC	160	lf	$19.75	$3,160
5	Well Riser - 2" Diameter - PVC	95	lf	$14.25	$1,354
6	Well Filter Pack 4" Diameter	160	lf	$25.00	$4,000
7	Annular Seal - Portland Cement -	95	lf	$2.00	$190
8	Surface Concrete Pad - 4' x' 4' x 4"	3	each	$183.00	$549
9					
10				**Subtotal**	**$29,675**
11					
12	**Contractor's Overhead and Profit**			**20%**	**$5,935**
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
	TOTAL COST:				**$35,609**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11171964	
Project:	Kliegman Site	Calculated By:	P. Baker	Date: 22-Jun-05
Title:	SVE System Startup	Checked By:	C. Pawlewski	Date: 23-Jun-05

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	**System Startup**				
2	System Technician (2)	80	hr	$55.00	$4,400
3	Equipment and Supplies-Allow:	1	ls	$3,000.00	$3,000
4	Sample Analysis-Allow:	1	ls	$1,500.00	$1,500
5					
6				**Subtotal**	**$8,900**
7					
8	**Contractor's Overhead and Profit**			**20%**	**$1,780**
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
	TOTAL COST:				**$10,680**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11171964		
Project:	Kliegman Site	Calculated By:	P. Baker	Date:	22-Jun-05
Title:	Confirmation Soil Sampling	Checked By:	C. Pawlewski	Date:	23-Jun-05

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	Mobilize / Demobilize Drill Rig - Allow:	1	LS	$3,500.00	$3,500
2	Drilling-4.25-inch HSA	1400	lf	$15.00	$21,000
3	Split Spoon Sampling	100	each	$15.00	$1,500
4	Soil Analytical-VOCs	100	each	$125.00	$12,500
5	Decon Pad and Equipment	1	LS	$2,000.00	$2,000
6	Drill Cuttings-Disposal and Transportation	20	drum	$350.00	$7,000
7					
8					
9					
10				**Subtotal**	**$47,500**
11					
12		**Contractor's Overhead and Profit**		**20%**	**$9,500**
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
	TOTAL COST:				**$57,000**

URS **EXHIBIT 4.7-2**

CALCULATION COVER SHEET

Client: NYSDEC Project Name: KLIEGMAN BROS.

Project/Calculation Number: 11171964

Title: SVE ALTERNATIVE – O&M COST ESTIMATE

Total Number of Pages (including cover sheet): 3

Total Number of Computer Runs: 0

Prepared by: CRAIG PAWLEWSKI Date: 6/22/05

Checked by: DON MCCALL Date: 7/6/05

Description and Purpose: FEASIBILITY STUDY COST ESTIMATE

Design Basis/References/Assumptions

Remarks/Conclusions/Results:

Calculation Approved by: ____________________
Project Manager/Date

Revision No.:	Description of Revision:	Approved by:

Project Manager/Date

NYSDEC
KLIEGMAN SITE
FEASIBILITY STUDY COST ESTIMATE

Client:	NYSDEC	Project Number:	11171964		
Project:	Kliegman Site	Calculated By:	C. Pawlewski	Date:	22-Jun-05
Description:	Feasibility Study Cost Estimate	Checked By:	D. McCall	Date:	6-Jul-05

SUMMARY

DESCRIPTION	ESTIMATED COST
ANNUAL O&M COST - SVE	
ON-SITE LABOR	**$15,000**
OFFICE LABOR	**$15,000**
MAINTENANCE AND REPAIR-DIRECT COSTS	**$3,000**
ELECTRICITY	**$20,000**
CARBON	**$50,000**
AIR ANALYSIS	**$7,000**
CONTINGENCY	**$22,000**
TOTAL	**$132,000**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11171964		
Project:	Kliegman Site	Calculated By:	C. Pawlewski	Date:	22-Jun-05
Title:	SVE System Annual O&M Cost	Checked By:	D. McCall	Date:	6-Jul-05

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	On-Site Labor	250	hr	$60.00	$15,000
2	Office Labor	150	hr	$100.00	$15,000
3	Maintenance and Repair-Direct Costs	1	ls	$3,000.00	$3,000
4	Electricity	1	ls	$20,000.00	$20,000
5	Carbon	25,000	lb	$2.00	$50,000
6	Air Analysis	28	ea	$250.00	$7,000
7	Contingency(20%)				$22,000
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
	TOTAL COST:				**$132,000**

URS

EXHIBIT 4.7-2

CALCULATION COVER SHEET

Client: NYSDEC

Project Name: KLIEGMAN BROS

Project/Calculation Number: 11171964

Title: DUAL PHASE EXTRACTION – CAPITAL COST ESTIMATE

Total Number of Pages (including cover sheet): 6

Total Number of Computer Runs: 0

Prepared by: M. OSTROWSKI Date: 7/5/05

Checked by: C. PAWLEWSKI Date: 7/5/05

Description and Purpose: FEASIBILITY STUDY COST ESTIMATE

Design Basis/References/Assumptions MEANS COST DATA REFERENCE BOOKS

Remarks/Conclusions/Results:

Calculation Approved by: ____________________
Project Manager/Date

Revision No.:	Description of Revision:	Approved by:

Project Manager/Date

NYSDEC
KLIEGMAN SITE
FEASIBILITY STUDY COST ESTIMATE

Client:	NYSDEC	Project Number:	11171964		
Project:	Kliegman Site	Calculated By:	M. Ostrowski	Date:	5-Jul-05
Description:	Feasibility Study Cost Estimate	Checked By:	C. Pawlewski	Date:	5-Jul-05

SUMMARY

DESCRIPTION	ESTIMATED COST
DUAL PHASE EXTRACTION TREATMENT SYSTEM	$79,608
DUAL PHASE EXTRACTION PIPING	$123,111
DUAL PHASE EXTRACTION WELL INSTALLATION	$79,990
DUAL PHASE EXTRACTION SYSTEM STARTUP	$10,680
SUBTOTAL	$293,389
MOBILIZATION/DEMOBILIZATION 5%	$14,669
CONTRACTOR SUPERVISION 10%	$29,339
DESIGN AND CONSTRUCTION MGT. 20%	$58,678
CONTINGENCY 25%	$73,347
TOTAL	$469,422
BUDGET TOTAL	$470,000

URS CORPORATION
FEASIBILITY STUDY CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client: NYSDEC	Project Number: 11171964		
Project: Kliegman Site	Calculated By: M. Ostrowski	Date:	5-Jul-05
Title: Dual Phase Extraction Treatment System	Checked By: C. Pawlewski	Date:	5-Jul-05

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	**Dual Phase Extraction Treatment System**				
2	Moisture Separator Tank - 220 gallon	1	each	$4,700.00	$4,700
3	Carbon Adsorber Unit (Vapor Phase)	2	each	$1,600.00	$3,200
4	Carbon Adsorber Unit (Liquid Phase)	2	each	$770.00	$1,540
5	High-Vacuum Liquid Ring Pump	1	each	$4,000.00	$4,000
6	Skid Fabrication and Component Mounting - Allow:	1	ls	$10,000.00	$10,000
7	Instrumentation and Controls - Allow:	1	ls	$12,000.00	$12,000
8	Electrical Power Drop and Connection - Allow:	1	ls	$27,000.00	$27,000
9	Delivery / Offloading - Allow:	1	LS	$3,900.00	$3,900
10					
11				**Subtotal**	**$66,340**
12					
13	**Contractor's Overhead and Profit**			**20%**	**$13,268**
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
	TOTAL COST:				**$79,608**

URS CORPORATION
FEASIBILITY STUDY CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11171964		
Project:	Kliegman Site	Calculated By:	M. Ostrowski	Date:	5-Jul-05
Title:	Dual Phase Extraction Piping	Checked By:	C. Pawlewski	Date:	5-Jul-05

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	**Piping**				
2	Trench Excavation and Pipe Bedding	1280	lf	$9.10	$11,648
3	Pipe - Sch. 80 PVC - 6" diameter	1280	lf	$29.00	$37,120
4	Pavement Restoration - Allow:	100	sy	$17.00	$1,700
5	Floor Slab Demolition and Disposal	830	lf	$34.55	$28,677
6	Floor Slab Restoration	1660	sf	$7.86	$13,048
7	Offsite Transportation and Disposal of Soil - Non-Haz.	130	cy	$80.00	$10,400
8					
9					
10				**Subtotal**	**$102,592**
11					
12					
13	**Contractor's Overhead and Profit**			**20%**	**$20,518**
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
	TOTAL COST:				**$123,111**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11171964		
Project:	Kliegman Site	Calculated By:	M.Ostrowski	Date:	5-Jul-05
Title:	Dual Phase Extraction Wells	Checked By:	C. Pawlewski	Date:	5-Jul-05

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	**Well Installation**				
2	Mobilize / Demobilize Drill Rig - Allow:	1	LS	$3,500.00	$3,500
3	Drill Bore Holes - 6" Diameter	720	lf	$53.50	$38,520
4	Well Casing - 4" Diameter - Carbon Steel	672	lf	$12.86	$8,642
5	Well Screen - 2" Diameter - PVC	48	lf	$19.75	$948
6	Well Riser - 2" Diameter - PVC	672	lf	$14.25	$9,576
7	Well Filter Pack 4" Diameter	48	lf	$25.00	$1,200
8	Annular Seal - Portland Cement -	672	lf	$2.00	$1,344
9	Coring through slab	34	each	$10.78	$367
10	Surface Concrete Pad - 4' x' 4' x 4"	14	each	$183.00	$2,562
11					
12				**Subtotal**	**$66,658**
13					
14	**Contractor's Overhead and Profit**			**20%**	**$13,332**
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
	TOTAL COST:				**$79,990**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11171964		
Project:	Kliegman Site	Calculated By:	M.Ostrowski	Date:	5-Jul-05
Title:	Dual Phase Extraction System Startup	Checked By:	C. Pawlewski	Date:	5-Jul-05

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
1	**System Startup**				
2	Technician (2)	80	hr	$55.00	$4,400
3	Equipment and Supplies-Allow:	1	ls	$3,000.00	$3,000
4	Sample Analysis-Allow:	1	ls	$1,500.00	$1,500
5					
6				**Subtotal**	**$8,900**
7					
8	**Contractor's Overhead and Profit**			**20%**	**$1,780**
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
	TOTAL COST:				**$10,680**

URS **EXHIBIT 4.7-2**

CALCULATION COVER SHEET

Client: NYSDEC Project Name: KLIEGMAN BROS.

Project/Calculation Number: 11171964

Title: DUAL PHASE EXTRACTION - O+M COST ESTIMATE

Total Number of Pages (including cover sheet): 3

Total Number of Computer Runs: 0

Prepared by: M. OSTROWSKI Date: 7/5/05

Checked by: C. PAWLEWSKI Date: 7/5/05

Description and Purpose: FEASIBILITY STUDY COST ESTIMATE

Design Basis/References/Assumptions

Remarks/Conclusions/Results:

Calculation Approved by: [signature]
Project Manager/Date

Revision No.:	Description of Revision:	Approved by:

Project Manager/Date

NYSDEC
KLIEGMAN SITE
FEASIBILITY STUDY COST ESTIMATE

Client:	NYSDEC	Project Number:	11171964		
Project:	Kliegman Site	Calculated By:	M. Ostrowski	Date:	5-Jul-05
Description:	Feasibility Study Cost Estimate	Checked By:	C. Pawlewski	Date:	5-Jul-05

SUMMARY

DESCRIPTION	ESTIMATED COST
ANNUAL O&M COST - DUAL PHASE	
ON-SITE LABOR	**$15,000**
OFFICE LABOR	**$15,000**
MAINTENANCE AND REPAIR-DIRECT COSTS	**$3,000**
ELECTRICITY	**$10,000**
CARBON- GAS PHASE	**$6,600**
CARBON- LIQUID HASE	**$2,000**
AIR ANALYSIS	**$7,000**
WATER ANALYSIS	**$3,500**
CONTINGENCY	**$12,420**
TOTAL	**$74,520**

URS CORPORATION
CONSTRUCTION COST ESTIMATE
ESTIMATED UNIT COST

Client:	NYSDEC	Project Number:	11171964		
Project:	Kliegman Site	Calculated By:	M. Ostrowski	Date:	5-Jul-05
Title:	Dual Phase System Annual O&M Cost	Checked By:	C. Pawlewski	Date:	5-Jul-05

ITEM	DESCRIPTION	QTY.	UNITS	UNIT COST	TOTAL COST
	Annual O&M				
1	On-Site Labor	250	hr	$60.00	$15,000
2	Office Labor	150	hr	$100.00	$15,000
3	Maintenance and Repair-Direct Costs	1	ls	$3,000.00	$3,000
4	Electricity	1	ls	$10,000.00	$10,000
5	Carbon - Gas Phase	3,300	lb	$2.00	$6,600
6	Carbon - Liquid Phase	1,000	lb	$2.00	$2,000
7	Air Analysis	28	ea	$250.00	$7,000
8	Water Analysis	28	ea	$125.00	$3,500
9	Contingency(20%)				$12,420
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
	TOTAL COST:				**$74,520**