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NARRATIVE

BERKS LANDFILL GROUNDWATER STUDY AND REMEDIAL INVESTIGATION

Prepared for

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AND

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AR300001

TABLES (In Narrative)

EXHIBITS (Reduced copies with Narrative; Full Scale Copies in Separate Map Folio)

I	Site Geology (1: = 100')
II	Fracture Traces (1" = 100')
III	Regional Geology (1" = 400')
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EXECUTIVE SUMMARY

Berks landfill is located in an area of complex geology at the northern border of a geologic sub-province known as the Triassic Basin or Lowlands. There are five (5) bedrock units at the site. From oldest to youngest these are (1) a Paleozoic carbonate which is probably the Millbach formation, (2) a fault slice of Martinsburg formation phyllite and quartzite, (3) a lower Triassic limestone pebble conglomerate unit, (4) sandstones of the Triassic Hammer Creek formation, and (5) Triassic diabase. Intrusion of the Triassic diabase adjacent to the Paleozoic carbonate unit and the lower Triassic limestone pebble conglomerate resulted in iron ore deposits within the limestone units. These ores were mined within the site and adjacent areas from the mid-nineteenth to the early twentieth century in a discontinuous series of open pit surface mines and deep mines known collectively as the Wheatfield mines.

Landfilling at the site started in abandoned Wheatfield Iron mine pits in the northeast corner of the site in the 1950's. The main landfill areas are south of Wheatfield Road and south of an unnamed tributary to Cacoosing Creek which parallels Wheatfield Road. Landfilling has covered a 43 acre tract on the eastern side of the site referred to as the "eastern" or "permitted" landfill, and a 17 acre tract on the western side of the site referred to as the "inactive" or "western" landfill. The original landfill tract as permitted in 1975 included land which was retained by Mr. Sebastian Lombardo when ownership of the landfill was transferred in 1984. The portion of land retained by Lombardo contains some landfill areas including some possible small landfill areas on the north side of Wheatfield Road.

Over its life, the landfill accepted primarily municipal solid waste and demolition waste. However levels of certain organic contaminants in some of the site monitoring wells and leachate are too high to have stemmed from municipal waste only and this indicates that the landfill received industrial wastes. This was confirmed by reports of long term landfill employees. These same employees report that the industrial wastes were received from several industries in the Reading area from the 1960's through the early 1980's. A small area in the southern portion of the western landfill was used as a disposal area by Stabatrol in 1979-1980 for the disposal of a stabilized (mixed with cement) chrome sludge. Although Stabatrol had approval to take other industrial wastes to the site, no records were found which indicate that any waste other than the chrome waste was received at the site.

There are three aquifers in use in the site area. These are (1) the Triassic Hammer Creek formation, (2) a carbonate aquifer consisting of the combined Paleozoic limestone and Triassic limestone pebble conglomerate, and (3) the Triassic diabase. The Triassic diabase is the poorest aquifer, although it will yield enough water for private water supplies, and regionally the diabase functions as an aquitard (a geologic unit which inhibits the flow of ground water). A thick diabase mass encircles the site and passes beneath it in the form of a saucer, hydrogeologically isolating the site area from the regional area. The Triassic Hammer Creek formation outcrops over most of the landfill. The structural attitude of the Hammer Creek formation at the site has resulted in ground water flow to the north (strike-parallel) towards the unnamed tributary of Cacoosing Creek. The carbonate aquifer outcrops in the stream valley on the north side of the site, and dips to the south beneath the site. The carbonate aquifer is the most permeable aquifer at the site. The extent of ground water contamination at the site is limited by natural ground water discharge to the unnamed tributary to Cacoosing Creek and by the carbonate aquifer which has an underdraining effect. The old Wheatfield Iron mines are also locally controlling the directions of ground water flow and extent of contamination.

Geologic mapping and available well records indicate that, with the exception of the James Lombardo well, private wells in the area tap the low permeability diabase aquifer, and are therefore not likely to be contaminated by the landfill. Private wells are also across perennial streams from the landfill, which affords a degree of hydrogeologic isolation. The James Lombardo well is an old shallow, hand dug well which taps the carbonate aquifer, and this well is prone to contamination from several possible sources including the landfill. Replacement of the Lombardo well is recommended. Public water supply wells within 1 mile of the site are hydrogeologically isolated from the landfill by the diabase aquitard.

Sampling of ground water at the site monitoring wells, on-site and off-site springs and mine-related discharges, and off-site private wells shows the contamination from the site to be of limited extent. Because contaminants have entered the carbonate aquifer in the valley bottom on the north side of the site, a recovery well network is recommended. This network was sized to contain the plume from the eastern landfill area which is high in chloroethenes. The system will involve an estimated 9 to 15 recovery wells on a line along the north side of the eastern landfill, pumping at a combined rate of 200,000 gpd. Once treated, reinjection of the recovered ground water could cause more problems than the recovery solves. Therefore, treatment and stream discharge of the recovered ground water is recommended.

Installation of interceptor drains are only recommended in areas of leachate toe seeps to prevent stream discharges. Installation of an upslope diversion drain is also recommended to the south of the inactive landfill to reduce the amount of ground water flowing toward the landfill.

It is recommended that the landfill be allowed to reopen for demolition waste disposal to generate revenues for remedial work and to effect regrading of the site which will maximize runoff and minimize infiltration and leachate generation. Continued demolition waste disposal within the permitted area and within the area of degraded ground water at the site is not expected to significantly affect the degree or extent of contamination.

CONCLUSIONS AND RECOMMENDATIONS

1. The extent of ground water contamination at the landfill is controlled by a carbonate aquifer in the valley on the north side of the landfill and by natural discharge of contaminated ground water to the unnamed tributary to Cacoosing Creek. The carbonate aquifer is a combination of a Triassic limestone pebble conglomerate unit and a Paleozoic carbonate unit which is probably the Millbach formation. Geologic mapping indicates that the off-site James Lombardo well is the only private well in the landfill area which taps this carbonate aquifer. The off-site Roberts and Riefsnyder wells are near the martin of this carbonate aquifer, however, these wells are probably completed in the underlying diabase. Past EPA and PaDER sampling has shown the James Lombardo well to be contaminated by some of the same contaminants found at the landfill, although recent sampling has shown these contaminants to be absent in the Lombardo well. Although the contamination is apparently transient and although there are other possible sources of the contamination of this well, Berks should provide the James Lombardo residence with a replacement water supply or activated carbon filter or both, until the other possible off-site sources of contamination of the Lombardo well are investigated. This remedial action should be completed in the short term.

2. The contaminant plume from the eastern or permitted landfill contains high levels of the Chloroethenes Trichloroethene, 1,2

Dichloroethene, and Vinyl Chloride (Chloroethene). Recovery and treatment of the contaminated ground water from the eastern fill area is recommended because of the elevated levels of these chloroethenes. The contaminant plume from the western or inactive landfill area is high in dissolved solids but contains only trace to low levels of volatiles, and recovery of this plume is not warranted.

3. The recommended remedial alternative for the recovery of the contaminated ground water from the eastern fill area is a 9 (minimum) well recovery network on a line between wells MW18 and C4, pumping at a combined rate of approximately 200,000 gpd. The recovered ground water will require conventional biological treatment for reduction of BOD and air-stripping to remove volatile organics. Reinjection of the recovered ground water could cause more problems than the recovery solves, and stream discharge of the treated water is therefore recommended. As the leachate recovered by the underdrains and perimeter drains at the site requires the same basic treatment process (biological and air stripping), and as trucking is not a viable long term leachate management option, combination of these two waste streams under one discharge permit is recommended. Additional leachate interceptor drains are only recommended in those areas where leachate toe seeps occur. To be entirely effective, the recovery well network should include wells in the deep mines in the northeastern portion of the site. Portions of these mine workings and areas of waste fill in these old mine workings are

within the portion of the original landfill property retained by Mr. Sebastian Lombardo. Lombardo's participation in the completion and operation of the recovery well system is therefore recommended. With the replacement of the off-site Lombardo water supply and continued off-site monitoring, there is no urgency to installation of the recovery well system, and this is a long term remedial action.

4. Monitoring data in the area of the Stabatrol disposal area shows anomalous contaminants, however there is no clear correlation between these contaminants and the contaminants known to be in the "stabilized" chrome waste reported to have been placed in the Stabatrol fill area. It is recommended that the Stabatrol waste be sampled to allow a better determination of the waste's characteristics. If this sampling shows constituents which clearly correlate to contaminants in the downgradient monitoring wells, and if continued monitoring shows levels of contamination beyond drinking water limits, capping of the Stabatrol vault with a flexible synthetic membrane cap is recommended.

5. Based on reports of long term landfill employees, and the nature, extent, and concentration of the volatile organic contaminants in the eastern fill area at the landfill, the volatile contaminants at the landfill stem from disposal of certain industrial wastes accepted at the site during the period when Berks Landfill Corporation was owned by Mr. Sebastian

Lombardo. These wastes probably included cutting oils, degreasing solvents, glues, paints and paint thinners, and inks.

6. Aerial photographic interpretation and reports of long term landfill employees indicate that there are possible small waste fill areas on the Lombardo property on the north side of Wheatfield Road. These fill areas are other possible sources of the contamination of the James Lombardo well, and PaDER should further investigate these areas.

7. With the exception of the James Lombardo well, and possible exceptions of the Roberts and Riefsnyder wells, private wells located in or near the valley on the north side of Berks landfill are in a different aquifer than that impacted by the landfill, and there is little if any risk of significant contamination of these wells from the landfill. Monitoring of the network of ten (10) private wells located in and near the valley on the north side of the landfill for volatiles should continue on a quarterly basis for one year to establish a longer record on the quality of these wells.

8. Public Water supply wells of the Citizens Utilities Water Company are hydrologically isolated from the landfill by a thick diabase aquitard, and there is no significant risk that pumping of these public water supply wells could induce ground water contaminants to flow across this aquitard to these public wells.

9. Installation of an upslope diversion drain is recommended along the southern property lines, to the south of the western landfill area, to cut off some ground water moving toward the landfill. This drain should be installed no deeper than 10 feet in this area to avoid reversing the gradient toward the landfill.

10. The recommended long term monitoring network should include perimeter monitoring points only. Interior monitoring wells should be deleted. The recommended network includes MP17 and C2 as background points, and C7S, C7D, MP14S, MP14D, MP11, MP10, and mine drainage discharge MD2 as down gradient points.

11. Berks Landfill should be allowed to reopen for the disposal of demolition waste to generate revenues for remedial work and to effect regrading of the site which will maximize runoff and minimize infiltration and leachate generation. Continued demolition waste disposal within the permitted area should not measurably affect the degree or extent of ground water contamination.

BERKS LANDFILL
GROUND WATER STUDY AND REMEDIAL INVESTIGATION

CONTENTS

1.0 INTRODUCTION

1.1 Background

Berks landfill has been in operation since the 1950's, and under a PaDER Solid Waste Management permit since 1975. Berks Landfill Corporation, the owner and operator of Berks Landfill, was originally owned by Mr. Sebastian Lombardo, who sold the stock of the Corporation to Mr. Robert DeMeno, Sr., in 1984. Mr. DeMeno formed Berks Sanitary Landfill, Inc., and has pending before PaDER an application to reissue Berks Landfill Corporation Solid Waste Permit No. 100347 to Berks Sanitary Landfill, Inc.

Prusuant to the terms of an August 1986 Consent Order and Agreement between Berks (Berks Landfill Corporation and Berks Sanitary Landfill, Inc.) and PaDER, the landfill temporarily ceased accepting waste at the end of September, 1986. One of PaDER'S concerns which lead to the consent order and agreement was the detection of certain leachate contaminants in the site monitoring well network.

Paragraph G. of the Consent Order and Agreement called for the completion of a ground water study of the landfill site. A work plan for the study was submitted to PaDER on August 1, 1986, and approved on August 15, 1986. The approved work plan called for a two phase study. The first phase was to be a ground water study which would define the nature and extent of ground water contamination, and determine the location and recovery rate of ground water recovery wells or drains. The second phase was to be an analysis and selection of appropriate treatment technology, and the design of the final remedial ground water capture and treatment system. This report presents the results of Phase I of that ground water study.

1.2 Overview of Report

This report represents the results of a six month study of the hydrogeology of the Berks Landfill and surrounding area, the nature and extent of ground water contamination stemming from Berks Landfill, existing and potential impacts on private and public ground water supplies in the area, and a discussion of the Remedial Actions recommended to prevent an escape of the contaminants-of-concern from the Berks Landfill property.

The landfill site is in an area of consolidated, fractured bedrock aquifers. As the bedrock geology of the site area strongly controls directions and rates of ground water flow, and as the Berks Landfill site is located in a somewhat complex area of geology, much of the study was directed toward defining the local geology in detail. Nineteenth and early twentieth century surface and deep mining of iron ore in the site and surrounding area has also had a local impact on ground water flow, and historical records on this mining activity were investigated to better define the extent of mining.

Ground water sampling at the site during the study involved a network of 26 on-site monitoring wells within the site and the Lombardo property, several springs and mine discharge points, and 10 off-site private wells. The locations of these sampling points are shown on several figures within this report including Figures 4.4.3.1 and 4.4.4.1. Isocon maps of key contaminants were developed to define the areal extent of contamination. The location, spacing, and withdrawal rate of a ground water recovery well system necessary to contain contaminants-of-concern to the site was determined with the aid of a computer aquifer simulation model.

1.3 Nature and Extent of the Problem

Ground water monitoring of on-site wells during the period from 1984 to mid-1986 showed the presence of some or all of the chloroethenes Trichloroethene, 1,2 Dichloroethene, and Vinyl Chloride (Chloroethene) in on-site monitoring wells MW11, MW18S, MW18D, and MW3. These same three chloroethenes were also detected in relatively low concentrations in one off-site well, the James Lombardo well, in EPA and DER samples. These chloroethenes were not detected in any other private wells in the area of the landfill sampled during the period from 1984 to mid-1986. Contamination by the chloroethenes was PaDER's main concern, and these, as well as other volatiles were the key contaminants investigated in this study.

2.0 SITE FEATURES

2.1 Location and Physiography

The Berks Landfill site is located near the northern border of the Triassic Lowlands Section of the Piedmont Physiographic Province, approximately 7 miles southwest of the City of Reading, in Spring Township, Berks County, Pennsylvania. The site lies to the south of a perennial, west-flowing, unnamed tributary to Cacoosing Creek. Wheatfield Road follows this stream on the north side of the site, and Chapel Hill Road, which runs generally north-south, is to the west of the site. The original landfill property as permitted by PaDER in 1975 included a strip of land along the south side of Cacoosing Creek, including the area used by Lombardo Equipment Company, and land to the north of the unnamed tributary to Cacoosing Creek and Wheatfield road, but these areas were retained by the original order of Berks Landfill, Mr. Sebastian Lombardo, and are not part of the current Berks landfill property.

There are two main fill areas south of Wheatfield Road - a western fill area which is referred to as the "old," "inactive" or western fill, and the larger eastern fill area which is referred to as the "permitted" landfill. Aerial photographic interpretations which are discussed in Section 2.4 of this report suggest that some small areas of landfilling may have occurred on the south facing slope on the north side of Wheatfield Road, on the tract retained by Mr. Sebastian Lombardo. The existence of at least one small fill area on the north side of Wheatfield Road was also reported by a long term Berks landfill employee. Aerial photographic interpretations and the reports of this employee also indicate that there are landfill areas within the portion of the Lombardo tract used by Lombardo Equipment Company, on the south side of Cacoosing Creek.

The pre-landfill site was a generally north-facing hillside, dissected by north and northwest trending drainageways. Landfilling has changed this original topography, more so in some areas than in others. Instead of hillsides, the fill areas between the drainageways are now mounds of greater slope and elevation than the original topography.

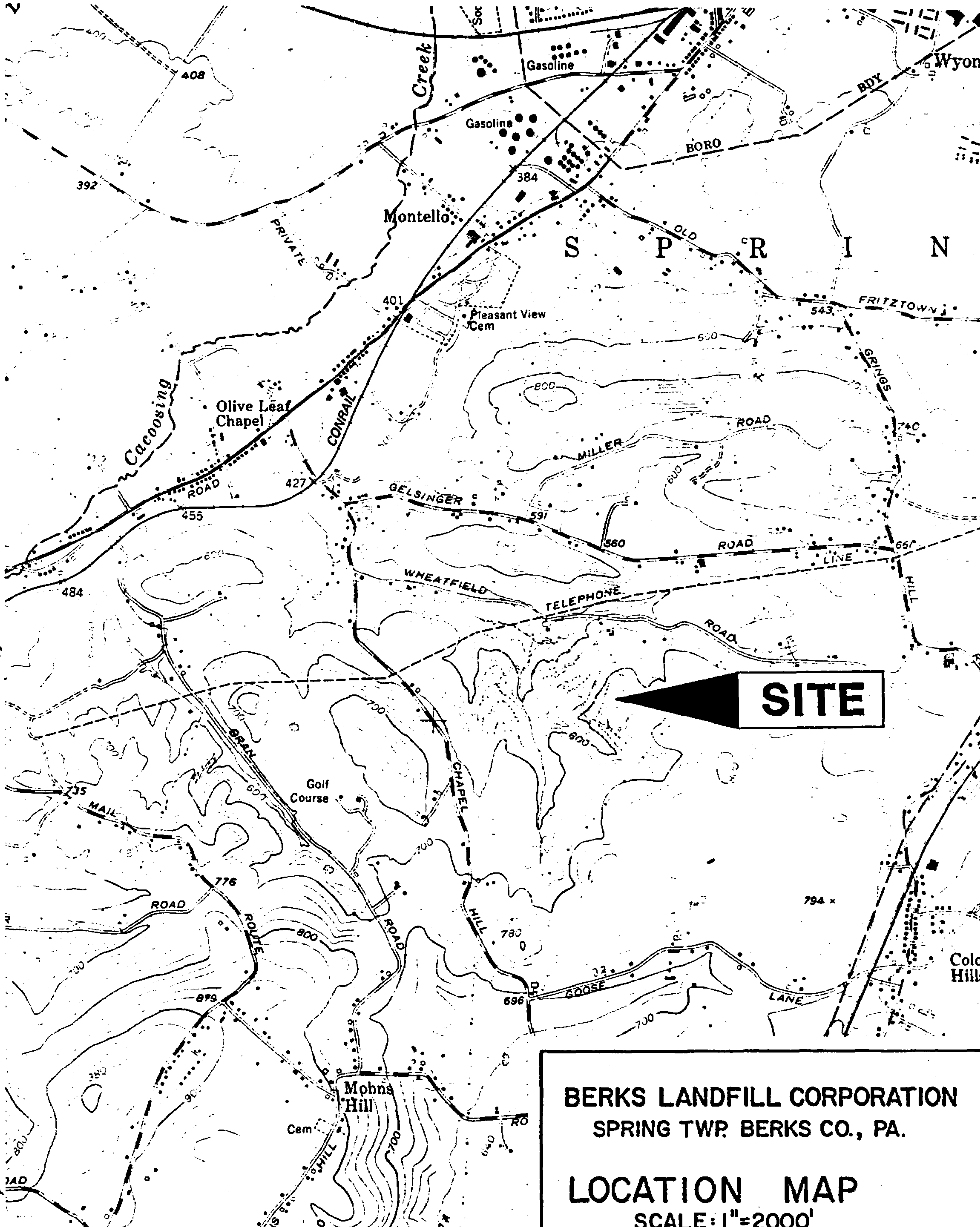
Flow in the drainageways which cross the site is to the north into the unnamed tributary to Cacoosing Creek. The westernmost north-trending drainageway divides the inactive landfill from the recently developed on-site borrow area in the extreme western portion of the site. The central north-trending drainageway divides the inactive landfill area on the west from the permitted landfill area on the east. Both the western and central north-trending drainageways contain small perennial streams. A northwest trending drainageway originally crossed the central portion of the permitted landfill area and joined the central north-trending drainageway. This northwest trending drainageway has been covered by the permitted landfill, and the flow in this drainageway diverted around the southern portion of the site into the central drainageway. A north-trending drainageway occurs just off of the property along the eastern side of the site. Perennial flow begins in the lower reaches of this drainageway, at a point approximately 500 feet south of Wheatfield Road.

Mine pits and mining related depressions occurred mostly to the south of the unnamed tributary of Cacoosing Creek, on the north and east side of the current site. These were the Wheatfield Iron Mines which operated from the mid 19th to the early 20th century. The largest of these pits were just to the northeast of the northeast corner of the current site in an area now used for equipment storage by Lombardo Equipment Company. The pits occurred in a hook-shaped pattern which wrapped around the northern side of the site on the Lombardo tract, and around the eastern side of the site on the Ritter property. Only one pit occurs to the north of the unnamed tributary to Cacoosing Creek, to the north of the north-central portion of the site, on the Lombardo tract. Many of these mine pits were entirely or partially filled by early landfill operations at the site in the 1950's and 1960's. In fact, these abandoned pits probably attracted initial dumping and gave rise to the landfill. The history and extent of the Wheatfield mines and associated impacts will be discussed in Section 4.3 of this narrative.

The site is in a topographic and structural basin, encircled or rimmed by hills which rise to elevations between 680' and 800'

MSL. The unnamed tributary to Cacoosing Creek crosses the northern portion of this basin, between the site and the east-west trending ridge which forms the northern margin of the basin.

The location and topography of the Berks Landfill site are shown on Figure 2.1, which is a portion of the USGS Sinking Springs 7 1/2 minute quadrangle. The main western and eastern landfill areas are delineated in Figure 2.2. Throughout this report reference will be made to several key areas within the site and surrounding area, including the "wood dump," "Lombardo Property," "Lombardo Equipment Company area," "Stabatrol fill area," and "permitted area." These areas are also delineated on Figure 2.2. That that the James Lombardo residence situated immediately north of the landfill, is not a separate property, but part of the larger tract referred to herein as the "Lombardo property."



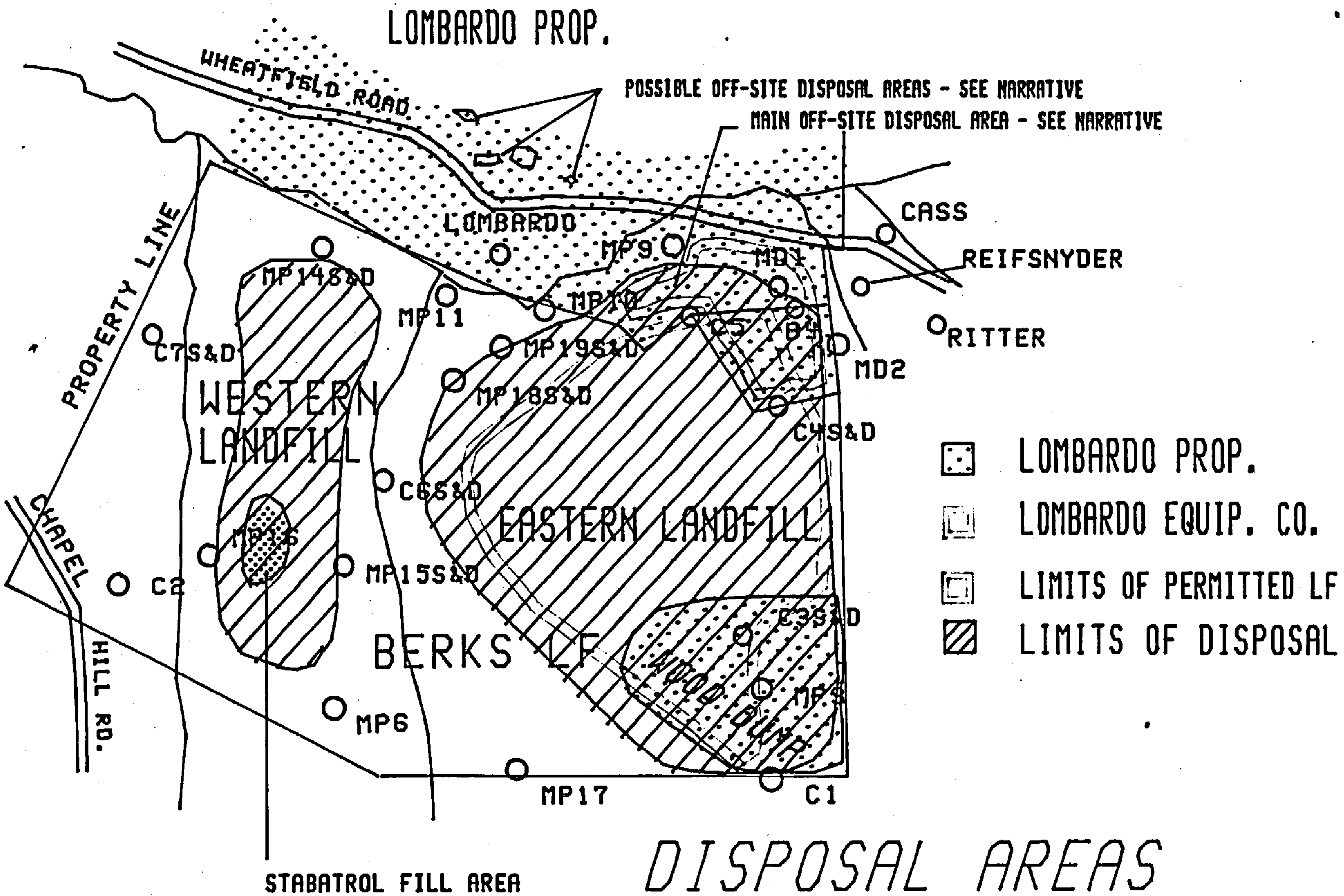
BERKS LANDFILL CORPORATION
SPRING TWP. BERKS CO., PA.

LOCATION MAP
SCALE: 1"=2000'

(PORTION OF SINKING SPRINGS U.S.G.S. 7.5 min. QUADRANGLE)

FIG. 2.1

AR300025



DISPOSAL AREAS

FIG. 2.2

2.2 Landfill History

The Berks Landfill is reported to have started operation under Mr. Sebastian Lombardo in 1953. Aerial photographs taken by U.S. Government agencies and private contractors over the period from 1946 to the present were used to chart the development of the landfill. These included photos taken in the following years: 1946, 1958, 1964, 1968, 1971, 1973, 1980, 1983, 1984, 1985, and 1986. Copies of photos from 1946, 1958, 1964, 1968, 1971, 1980, 1983 and 1986 are included in this section of the report as Figures 2.2.1 through 2.2.8 with overlays showing key features such as the limits of fill at the time of the photos.

The 1946 aerial photographs of the site depict prelandfill conditions. As discussed in the previous section, remnants of the Wheatfield Mine pits occurred along the northeastern and eastern side of the property. The remainder of the site was farmland and woodland.

The 1958 aerial photographs show the initial landfill operations in the mine pits in the northeast corner of the site, in the area now occupied by Lombardo Equipment. Landfilling operations covered approximately 3-4 acres of the old mine pits in these photos. The abandoned mine pits undoubtedly attracted the initial dumping of waste at the site and gave rise to the landfill.

By 1964, the landfill had filled-in virtually all of the mine pits at the northeast corner of the site, and the landfill had expanded significantly along the entire eastern side of the site, covering approximately 40 areas, including much of the eastern side of the permitted landfill, and the "wood dump" area in the southeastern portion of the property. An east-west striped vegetative pattern in the filled area to the south of the mine pits indicates trench landfilling in east-west trending trenches. On the south side of the site, landfill extended from the property line some 1300-1400 feet to the west. A tongue of fill or disturbed area extended approximately 1600 feet west into the property along the south side of the unnamed tributary to Cacoosing Creek. This tongue of fill included areas to the north of the permitted fill area, on the north side of the current access road.

The 1968 aerial photographs show filling underway in the northern portion of the western or inactive landfill area, where approximately 15 acres has been filled. The southern portions of the eastern or permitted fill area and wood dump area are still in use, apparently for select waste disposal. There is a network of roads in the wood dump area, and a small fill area including a steep dumping face. Three (3) pits are visible in this area. One of these pits appears to be dry and one appears to be filled with a dark liquid. Dry pits were reported to be used as burn pits for cardboard waste and for the disposal of some liquid waste. Based on reports of long term landfill employees, the black liquid in the one pit was probably ink. Some disturbed or filled area is included in the area of the current leachate lagoons. The meadow on the north side of the unnamed tributary of Cacoosing Creek, to the north of the western landfill area, has been disturbed, apparently to effect a rechanneling of the creek in this area. This is some filling or disturbance on the north side of Wheatfield Road, in the area of Mine Slope No. 1, on the portion of the property retained by Mr. Sebastian Lombardo. A trench-like mine depression at Mine Slope No. 1 has been filled. A long term landfill employee reported that a small fill area was placed along the telephone line right-of-way southeast of Mine Slope No. 1, however this fill area could not be discerned on the 1968 photo or the photos from any other years.

The 1971 and 1973 photos show essentially the same pattern of disturbed area. Two (2) small pits are still visible in the wood dump area. By 1971 the entire 21 +/- Acre western fill area has been affected. Landfilling was still underway in the wood dump area and in the north central portion of the permitted fill area, in the area of the current leachate lagoons, and to the south of the access road in the lagoon area.

Photographs from 1980 to 1986 show the progression of the landfill as permitted by PaDER. The treatment lagoons have been developed to the northwest of the permitted fill area. Areas on the east side of the site filled prior to 1968 are being reexcavated and refilled with a greater thickness of refuse in an area fill operation. The 1980 photograph shows the Stabatrol fill area in the west-central portion of the inactive landfill area, and an off-site borrow area to the east of the wood dump from which soil was removed to construct the Stabatrol vault. The Ritter, Reifsynder, Cass, Lombardo, Roberts, Buller, and Berkel residences are identified on the 1980 photo.

Landfill areas dating to before 1975 were either trench or area fills completed without leachate collection drains or any type of liner. The permitted fill area developed after 1975 was constructed with a soil lines, underdrains, and a downslope perimeter interceptor drain. No records could be found which documented the permeability or degree of impermeability of the soil liner.

As permitted by PaDER in 1975 the landfill is a hybrid, involving ground water manipulation and a compacted low permeability soil subbase liner. Within the permitted area, leachate collection is accomplished in part through flow off of the soil subbase liner, and in part through the interception of leachate contaminated ground water in underdrains and downgradient of the landfill in perimeter interceptor drains before this leachate contaminated ground water reaches adjacent streams or off-site wells. As it involves ground water collection, it is, in essence, a controlled contamination type landfill (75.25(o)(6)).

The leachate lagoons at the site were originally constructed with sprayed asphalt liners. Reports of long term landfill employees indicate that the sprayed asphalt liners did not survive long after their installation. These lagoons were relined in 1986 with synthetic membrane liners.

BERKS LANDFILL PROPERTY 1946

LEGEND

PROPERTY LINE

FRACTURE TRACE

ROADS

RESISTANT BEDROCK "RIDGES" OR "LEDGES"

MINE PITS OR DEPRESSIONS

MINE RELATED TRENCHES

QUESTIONABLE DEPRESSION

MINE WASTE PILES

BEDDING TRACE, ALIGNED SAGS OVER LIMESTONE PEBBLE CONGLOMERATE

BUILDINGS

FIG. 2.2.1

AR300032

BERKS LANDFILL PROPERTY 1958

LEGEND

——— — — ———	PROPERTY LINE
===============	ROADS
—— P ———— T ——	POWER OR TELEPHONE LINE

FIG. 2.2.2

BERKS LANDFILL PROPERTY 1964

LEGEND

PROPERTY LINE

POWER OR TELEPHONE LINE

ROADS

OLD BARN FOUNDATION ?

POND OR PIT

EAST-WEST TRENCH PATTERN

FIG. 2.2.3

BERKS LANDFILL PROPERTY 1968

LEGEND

PROPERTY LINE

ROADS

ACCESS ROADS

OLD BARN FOUNDATION ?

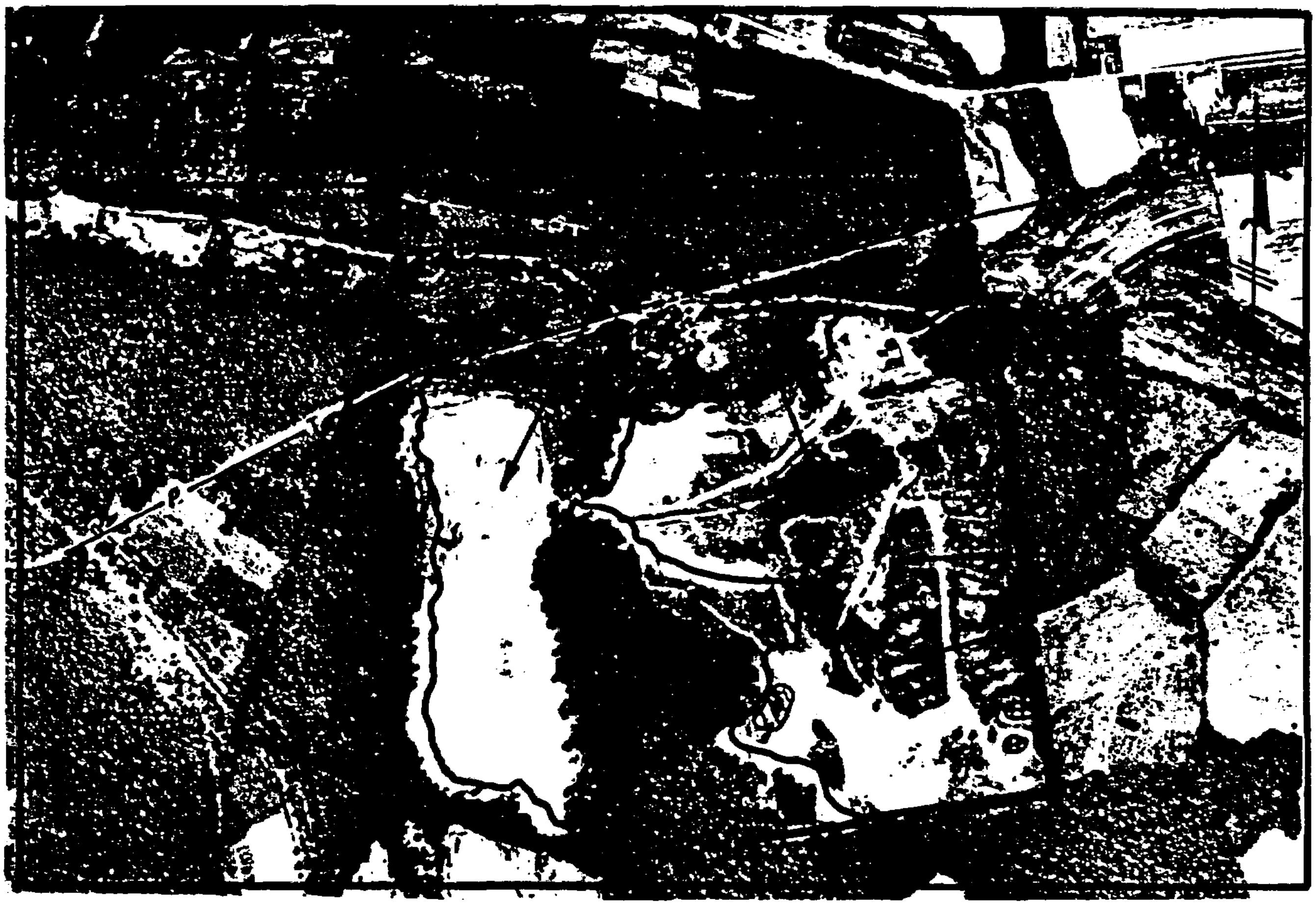
POND

PITS

EAST-WEST TRENCH PATTERN

POWER OR TELEPHONE LINE

FIG. 2.2.4



BERKS LANDFILL PROPERTY 1971

LEGEND

—— - - ——	PROPERTY LINE
==============	ROADS
- - - - - - - - - -	ACCESS ROADS
	PONDS
	PITS
←——→	EAST-WEST TRENCH PATTERN
—P———T—	POWER OR TELEPHONE LINE

FIG. 2.2.5

BERKS LANDFILL PROPERTY 1980

LEGEND

PROPERTY LINE

ROADS

ACCESS ROADS

PONDS

MINE PIT

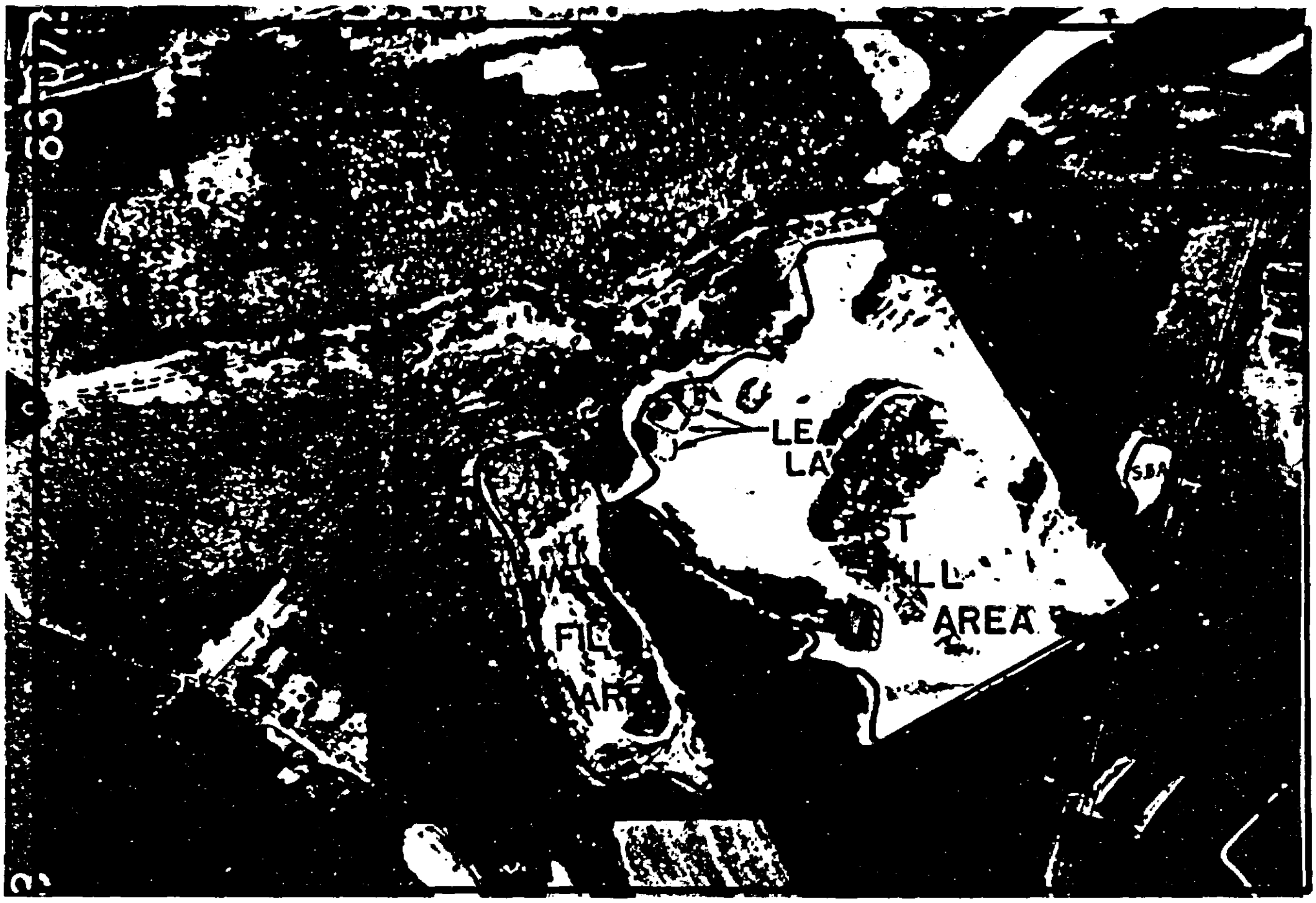
STABATROL VAULT

STABATROL BORROW AREA

POWER OR TELEPHONE LINE

STREAM - SURFACE DRAINAGE

FIG. 2.2.6



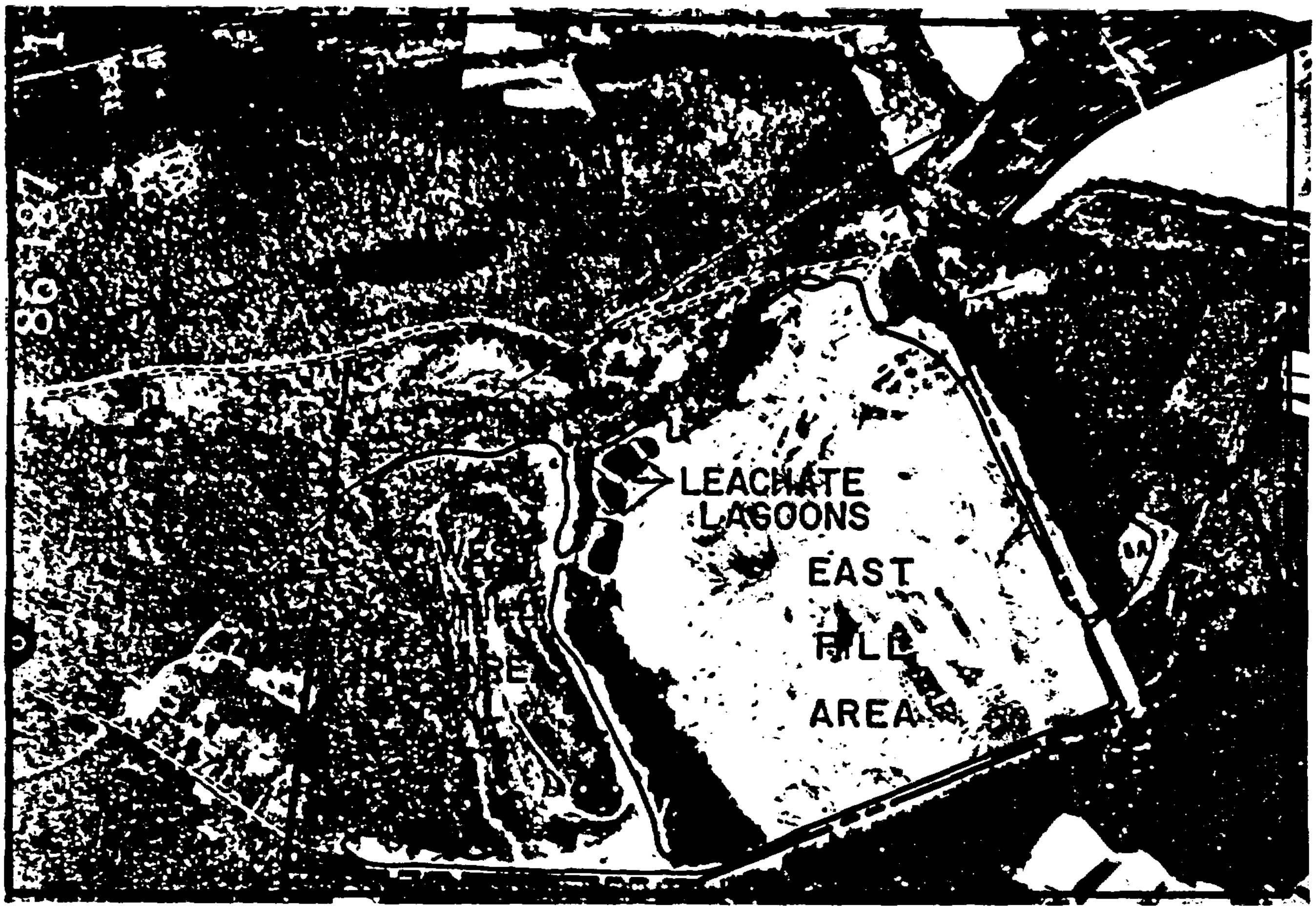
BERKS LANDFILL PROPERTY 1983

LEGEND

——— —— ———	PROPERTY LINE
================	ROADS
(pond symbol)	POND
——P————T——	POWER OR TELEPHONE LINE
(S.B.A.)	STABATROL BORROW AREA

FIG. 2.2.7

300038



BERKS LANDFILL PROPERTY 1986

LEGEND

PROPERTY LINE

ROADS

POWER OR TELEPHONE LINE

S.B.A. STABATROL BORROW AREA

FIG. 2.2.8

300039

3.0 CHARACTERIZATION OF WASTES AND CONTAMINANTS

Over its 30+ year life, Berks landfill received primarily municipal solid waste and demolition waste. However, certain contaminants that are present in the leachate and some monitoring wells at concentrations higher than typically found in municipal waste leachate indicate that the site received industrial wastes. Long term employees of the landfill have confirmed that the landfill accepted industrial wastes from several sources during the 1960's, 1970's and early 1980's during the time when Berks Landfill Corporation was owned and operated by Mr. Sebastian Lombardo.

Tables 3-1, 3-2, and 3-3 summarize monitoring data for key parameters collected at the fifteen (15) existing wells at the site over the period from July 1984 to August 1986, up to the approximate time of initiation of this study. Sample results are included from three private labs and PaDER's lab. Included on Table 3-1 are the inorganic indicator parameters Chloride, Sulfate, and Conductance; and BOD. Table 3-2 lists the results for dissolved metals analyses. Only those recent results which were clearly field filtered for dissolved metals analysis are included on Table 3-2. Table 3-3 summarizes analyses for volatile organics in the monitoring wells. Table 3-4 lists volatile organics detected in the leachate in various analyses over the same 1984 - 1986 period.

Chloride is a useful indicator parameter, as it occurs at relatively high concentrations in landfill leachate and it is a conservative contaminant. Unfortunately elevated chloride in ground water can also stem from other contamination sources such as on-lot sewage disposal and road deicing salts. Chloride in the monitoring data shows an expected pattern. Background wells MW6 and MW17 show chloride less than 40 mg/l, while most contaminated downgradient wells show chloride greater than 40 mg/l, ranging to as high as 1580 mg/l. The highest chloride concentrations were found in wells MW16 and MW14 located at the western or inactive fill area.

High sulfate occurs in landfill leachate. In the Triassic Basin in which Berks landfill is located, high sulfate also occurs naturally in ground water. This is caused by the oxidation of sulfide minerals, such as those associated with the Wheatfield Ore deposits in the site area. Naturally high sulfate may also occur in the Triassic red beds at the site as the evaporite mineral gypsum. Natural sulfate in ground water in the Triassic Basin is usually greater at depth, where ground water circulation is more sluggish, in discharge zones where deep ground water is upwelling, and near diabase intrusions (Wood, 1980). Naturally occurring sulfate is discussed at greater length in Section 4.4.3 of this report. Sulfate in the anerobic zone around the landfill would be prone to reduction to sulfide, hence sulfate is not a conservative contaminant. The monitoring data in Table 3-1 shows elevated sulfate, although there is no clear correlation with chloride.

Electrical Conductance (E.C.) or Conductivity is a useful indicator parameter that reflects the level of dissolved solids. The monitoring well data shows elevated conductivity in most downgradient wells. Elevated conductivity can stem from other contaminant sources such as on-lot sewage disposal and deicing salts, and natural sources such as natural high sulfate waters.

BOD shows a wide range in the monitoring wells, but is generally in the range of 1-250 mg/l. As references, raw sewage can have a BOD of 200 mg/l, while municipal solid waste leachate can have a BOD of from 1000 to 10,000 mg/l depending on age and dilution with ground water. The BOD reported at well MW16 is over 1000 mg/l, indicating that well MW16 is producing virtually raw leachate, and not leachate contaminated ground water.

Metallic species listed in Table 3-2 are generally low except for the common metals Iron and Manganese. Chrome occurs above background levels in wells MW3 and MW14, although well within drinking water limits. The only species approaching drinking water limits is Barium in well MW14. The data indicates that dissolved heavy metals are not contaminants-of-concern at Berks. The metallic mineralization associated with the Wheatfield mines is certain to provide a higher than normal background level of certain metals.

The volatile organic monitoring data presented in Table 3-3 for downgradient monitoring wells and Table 3-4 for raw leachate samples shows levels of certain compounds too high to have stemmed from normal municipal waste. Background wells MW6 and MW17 are virtually free of volatiles except for occasional trace levels. The dominant contaminants in downgradient wells and/or the leachate are (1) the chloroethenes Trichloroethene, 1,2 Dichloroethene, and Vinyl Chloride (Chloroethene); (2) the aromatics Toluene, Benzene and Xylene, (3) the ketones acetone, 2-Butanone (MEK or Methyl Ethyl Ketone), and 4-Methyl 2 Pentanone (Methyl Isobutyl Ketone), (4) Methylene Chloride, (5) Chloroform, and (6) several chloroethanes. Several other volatile contaminants occur. The occurrence of Chloroform, Acetone, and Methylene Chloride should be interpreted with caution as these are common lab contaminants.

Many of these volatile organics are subject to transformations due to microbial decomposition, and this explains the variety of such compounds found at the site. Parsons et. al. (1984 & 1985) and Wood et. al. (1985) discuss these transformations in anerobic, methenogenic environments such as occur at the Berks landfill site. Typically, Trichloroethene successively dehalogenates to 1,2 Dichloroethene and then to Vinyl Chloride (Chloroethene). The variety of 1,2 Dichloroethene stemming from this decomposition is usually cis- 1,2 Dichloroethene and not trans-1,2 Dichloroethene, although both species were found to occur by Woods et. al. and Parsons et. al. due to microbial decomposition.

Based on the occurrence of two or three of these chloroethenes together in the monitoring data, the microbial decomposition of Trichloroethene is the likely source of the 1,2 Dichloroethene and the Vinyl Chloride, and Trichloroethene is the probably original contaminant.

In a similar fashion Wood et al. (1985) indicate that other transformations such as the degradation of 1,1,1 Trichloroethane into 1,1 Dichloroethane occur, so that the variety of volatiles found at the site probably stems from the decomposition of a few key industrial wastes deposited at the landfill.

Table 3-5 presents specific gravities for several of the volatile contaminants. Most of the chlorinated hydrocarbons such as 1,2 Dichloroethene are heavier than water (S.G. > 1), and these contaminants tend to sink once they reach the water table. Others such as the ketones and aromatics are lighter than water and they tend to float once they reach the water table. The impact of this is a vertical differentiation or density separation of these contaminants below the water table, and the monitoring data at Berks landfill reflects this density separation. For example, the "sinker" 1,2 Dichloroethene is found in higher concentrations in certain downgradient monitoring wells than in the raw leachate. The leachate is collected at the site in a series of perimeter drains and underdrains which would only collect the shallow ground water near the water table. The downgradient monitoring wells tap deeper ground water that has underflowed the drains. This data indicates that 1,2 Dichloroethene and other high density volatiles at the Berks Landfill site tend to sink in the flow system. Conversely the "floater" Toluene is found at significantly higher levels in the leachate than in the monitoring wells. Toluene tends to stay in the shallow zone near the water table where it is readily picked up by the leachate underdrains and perimeter drains, and not to sink and underflow these drains.

Of all of the volatile organics identified at Berks Landfill, the chloroethenes Trichloroethene (TCE), 1,2 Dichloroethene, and Vinyl Chloride present the greatest public health concern, and these chloroethenes will be the key volatile organics addressed in this study. Certain Base/Neutral organics were identified at the site by past monitoring, however these compounds were fewer and of less significance than the volatiles, and are therefore not discussed in this report.

In light of the extensive monitoring data base that existed up until the initiation of this study, it was decided to concentrate the efforts of this study on defining the extent of ground water contamination using the indicators chloride, sulfate, and conductance; and the VOA series. The monitoring data generated from new and existing wells by this study is presented in

Appendix E and interpretations of this data are presented in Section 4.4.3 of this report.

The only industrial waste disposal at Berks Landfill which is well documented in PaDER files and the files of Berks Landfill Corporation is the Stabatrol disposal area in the southern portion of the western or inactive landfill area. Stabatrol had PaDER approval in 1979-1980 to operate two disposal areas at Berks Landfill, one in the western landfill area and one in the eastern fill area. The Stabatrol disposal area in the western fill area was dedicated to a waste water treatment sludge high in chrome generated by Carpenter Technology. Stabatrol's eastern fill area was dedicated to various wastes from Allied Chemical, Vineland Chemical, CPS Chemical, and Armstrong Corporation. Records indicate that only the Stabatrol fill area for the Carpenter Technology waste was completed at the site. No records were found which indicate that wastes from the other industries were received or that the Stabatrol disposal area in the eastern fill area was ever developed. The heavy metal sludge from Carpenter Technology was reported to be "stabilized" in a cement or soil-cement mixture.

Less well documented than the Stabatrol disposal area was industrial waste disposal that occurred at Berks Landfill during the 1960's, 1970's and early 1980's when the landfill corporation was owned by Mr. Sebastian Lombardo. Data collected in this study indicates that this industrial waste disposal activity resulted in the elevated levels of the several volatile organics found at the site. Two long term employees of Berks landfill report that a Continental Can plant in Reading was the major industrial contributor. Continental's waste included relatively harmless bailed cardboard which was reported to have been routinely burned in pits at the landfill. However, waste from Continental Can is also reported to have included cutting oils and glues. These wastes were reported to have been brought to the site on a weekly basis over a period of several years. The liquid waste from Continental was reported to have arrived at the site in drums, some of which were emptied at the landfill to reuse the drums or recover them as scrap metal, and some of which were buried intact. Many of the drums were reported to have been emptied by hand at the landfill to avoid spraying chemicals when the bulldozer crushed the drums during covering. The drummed liquid waste was reported to be a skin irritant, and an intoxicant when inhaled. The "cutting oils" were reported to have a strong odor, and these possibly contained spent degreasing solvents such as Trichloroethene. The glues probably contained an organic solvent.

Another reported source of industrial waste accepted at the site was a Glidden Plant in Reading. Waste from Glidden was reported to include water and oil based paints and thinners. Toluene was a possible constituent of the thinners or oil based paints.

Another reported source of industrial wastes accepted at the site was a nearby battery manufacturer. Ink was also reported to have been accepted at the site in tanker truck loads. This ink was reported to have been dumped in pits predominantly in the southeast corner of the eastern fill area in an area referred to as the "wood dump." These inks may have contained an organic solvent or vehicle. Methyl Ethyl Ketone (2 Butanone) and Acetone are common vehicles or solvents used with inks in the printing industry. Other wastes included foundry sands and flyash. Most of the liquid industrial wastes were reported to have been deposited in the wood dump area in the southeast corner of the eastern or permitted fill, as the liquid would readily drain away in the porous demolition waste. Although concentrated in the wood dump area, the several types of industrial wastes described above were reported to have been deposited almost anywhere at the landfill.

The only reference in PaDER's files to past industrial waste disposal other than the Stabatrol activity was a sketch map of the landfill prepared by Richard Kraybill in 1970. In this map, Mr. Kraybill shows a lagoon in the area referred to as the wood dump with the label "old fill site with IW (Industrial Waste)-waste lagoon." The lack of good documentation of industrial waste disposal before 1981 is common as this period predated key Hazardous Waste legislation which called for clear differentiation between industrial wastes and municipal wastes.

BERKS LANDFILL

TABLE 3-1

Summary of Ground Water Quality Monitoring Data Indicator Parameters and BOD
July 1984 - August 1986

Tabulated Values Represent Range of Values Over Period
Including data from the following labs: PaDER, RMC, Century, and Wastex

Note: Wells 14 through 19 include only data from 1986

Monitoring Point	Chloride mg/l	Sulfate mg/l	Conductivity Micromhos/cm	BOD mg/l
MW3	84 - 399	2 - 54	1320 - 2750	5 - 309
MW6(U.G.)	1 - 35	<10 - 37	162 - 1230	1 - 168
MW9	6 - 40	46 - 225	544 - 1100	2 - 330
MW10	26 - 210	66 - 129	760 - 1270	1 - 126
MW11	37 - 164	180 - 289	940 - 1150	1 - 162
MW14-Shallow	178 - 1560	21 - 26	800 - 5580	9 - 87
MW14-Deep	248 - 960	18 - 107	2780 - 3900	7 - 45
MW15-Shallow	8 - 38	49 - 56	252 - 730	1 - 120
MW15-Deep	1 - <10	14 - 15.2	199 - 240	0.3- 63
MW16	47 - 772	<10 - 165	1222 - 3900	679 - >1000
MW17(U.G.)	2 - 12	43 - 55	250 - 270	2 - 38
MW18-Shallow	61 - 92	94 - 134	760 - 1200	2 - 42
MW18-Deep	18 - 25	213 - 229	1290 - 2450	1 - 40
MW19-Shallow	24 - 100	104 - 110	661 - 760	1 - 234
MW19-Deep	47 - 202	16 - 21	848 - 1010	2 - 25

BERKS LANDFILL

TABLE 3-2

Summary of Ground Water Quality Monitoring Date – Dissolved Metals
1985 - 1986

Note: Includes only recent monitoring data where lab report or available records clearly indicate that samples were field filtered for Dissolved Metals - RMC 8/86, PaDER 8/86, RMC 5/86, NUS 9/85

	FE Iron mg/1	MN Manganese mg/1	AS Arsenic mg/1	CD Cadmium mg/1	CR (total) Chromium mg/1	CU Copper mg/1	PB Lead mg/1	NI Nickel mg/1	AG Silver mg/1	ZN Zinc mg/1	Selenium SE mg/1	Mercury HG mg/1	Barium mg/1
MW3	7.3	10.2	.002 .001	<.001 <.001	.01 .004 <.003	<.001	.0043 <.001 <.001	<.01	<.001 <.001	.04 .02	.0002 .007 .002	<.0002 <.0002	.130 <.50
MW6	1.0	.320		.0004			.006			.07			.04
MW9	.210	1.5	.004	.0004	.01		.0026			.02	.0001		.07
MW10	.08 .063	.80 1.62	<.001 <.04	.001 <.01	<.001 <.05	<.001 <.01	.002 <.001 <.004	.08 <.025	<.001 0	.001 <.01 <.01	.0005 <.001 <.006	<.0002 <.001	.05 .055
MW11	3.2 2.34	3.89 2.60	.002 <.001 <.001 <.004	.0062 <.001 <.01 <.001	<.001 <.001 <.05	<.001 <.01	.001 <.001 <.001 <.004	<.01 <.025	.01 <.001 <.001 0.0	.150 <.01 <.01	.0007 <.001 <.006	.00022 <.0002 <.001 <.0002	.06 <.50 .053
MW14-Shallow			.006	<.001	.009		<.001		<.001			<.0002	0.90
MW14-Deep			<.001	<.001	.001		<.001		<.001		.005	<.0002	<.50
MW18-Shallow	<.010	.123	<.001 <.004	<.001 <.01	.001 <.05	<.001 <.01	<.001 <.004	.06 <.025	<.001 0.0	<.01 <.01	<.001 <.006	<.0002 <.001	.039
MW18-Deep	<.010	<.010	<.001 <.004	<.001 <.01	<.001 <.05	<.001 <.010	<.001 <.004	<.01 <.025	<.001 0.0	<.01 <.01	<.001 <.006	<.0002 <.001	.076
MW19-Shallow	.028	.011	<.001 <.004	<.001	<.001	<.001 .011	<.001 <.004	<.01 <.025	<.001 0.0	<.01 0.31	<.001 <.006	<.0002 <.001	.027
MW19-Deep	.092	.038	<.001 <.02	<.001 <.01	<.001 <.05	.002 .011	<.001 <.004	.03 <.025	<.001 0.0	<.01 0.29	<.001 <.006	<.0002 <.001	.135
Recommended Drinking Water Limit	0.3	0.05	0.05	0.01	0.05	1.0	0.05		0.05	5.0	0.01	0.002	1.0

BERKS LANDFILL

TABLE 3-3

Summary of Ground Water Quality Monitoring Data - Volatiles
July 1984 - August 1986

Tabulated Values Represent Range of Values Over Period
Includes Data from the following Labs: PaDer, RMC, Century and Wastex
Note: Wells 14 through 19 include only data from 1986

	TCE and Decomposition Products			BTX			
Monitoring Pt.	Trichloroethene ppb	1,2, Dichloroethene ppb	Chloroethene Vinyl Chloride ppb	Tolune ppb	Benzene ppb	Xylene ppb	Others (Major compounds reported - not all inclusive) ppb
MW3	N.D.-2.2	N.D.-110	N.D.-89	N.D.-82	N.D.-4	N.D.- 2	Methylene Chloride N.D.-14 Chloroform N.D.-34 Chloroethane N.D.-47 1,1 Dichloroethane N.D.-19
MW6	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Chloroform N.D.-0.5
MW9	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Methylene Chloride N.D.-4 Chloroform N.D.-0.6 1,1, Dichloroethane N.D.-0.2
MW10	N.D.	N.D.	N.D.	N.D.-1	N.D.	N.D.	Tetrahydrofuram N.D.-1500 2-Butanone N.D.-49 Chloroform N.D.-1 1,1 Dichlorethane N.D.-3 Tetrachloroethene N.D.-1
MW11	N.D.-104	N.D.-108	N.D.-4	N.D.	N.D.	N.D.	1,1,1 Trichloroethane N.D.-1.5 1,1 Dichloroethane N.D.-1.4
MW14-Shallow	N.D.	N.D.	N.D.	N.D.	N.D.-39	N.D.	Chloroform N.D.-3.4 Chlorobenzene N.D.-19 Dichlorobenzene N.D.-18
MW14-Deep	N.D.-0.5	N.D.	N.D.	N.D.	N.D.	N.D.	Methylene Chloride N.D.-0.7 Chloroform N.D.-0.13 Chlorobenzene N.D.-1.2 1,1,1 Trichloroethane N.D.-2.1 1,1, Dichlorethane N.D.-1
MW15-Shallow	N.D.	N.D.	N.D.	N.D.-0.6	N.D.-0.6	N.D.-77	Ethyl Benzene N.D.-1.4
MW15-Deep	N.D.	N.D.	N.D.	N.D.-9	N.D.	N.D.	Methylene Chloride N.D.-3.3
MW16	N.D.-10	N.D.-26	N.D.-6	N.D.-325	N.D.-20	N.D.-200	Methylene Chloride N.D.-133 Chloroform N.D.-18.5 Ethyl Benzene N.D.-3 1,2 Dichloropropane N.D.-3 4 Methyl 2 Pentanone N.D.-6333 1,1 Dichloroethane N.D.-6 1,2 Dichloroethane N.D.-20
MW17	N.D.	N.D.	N.D.	N.D.-2.3	N.D.	N.D.	Methylene Chloride N.D.-6
MW18-Shallow	N.D.-1250	N.D.-5000	N.D.-750	N.D.	N.D.	N.D.	Methylene Chloride N.D.-18 1,1 Dichloroethane N.D.-263 Chloroethane N.D.-16
MW18-Deep	N.D.-450	N.D.-900	N.D.-4.0	N.D.-13	N.D.	N.D.	Methylene Chloride N.D.-25 Chloroform N.D.-115
MW19-Shallow	N.D.-1	N.D.	N.D.	N.D.	N.D.	N.D.	Methylene Chloride N.D.-53 1,1,1 Trichloroethane N.D.-19 1,1 Dichloroethane N.D.-5
MW19-Deep	N.D.-0.4	N.D.	N.D.	N.D.	N.D.	N.D.-2.1	Methylene Chloride N.D.-1.4 1,1,1 Trichloroethane N.D.-2.0 Ethyl Benzene N.D.-0.2 1,1 Dichloroethane N.D.-2 Chlorobenzene N.D.-0.07 1,2 Dichloroethane N.D.-2

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TABLE 3-4

Volatiles Detected in Leachate

Lab and Date	Trichloroethene ppb	1,2 Dichloroethene ppb	Vinyl Chloride ppb	Toluene ppb	Benzene ppb	Xylene ppb	Others ppb
PaDER 7/11/84	15	63	9	250	4.5	60	Methylene Chloride - 200 Tetrachloroethene - 6.6 Ethyl Benzene - 48 Chloro Benzene - 1.5 Chloroethane - 5 Trichlorofluororethane - 4 1,1,1 Trichloroethane 1,1 Dichloroethane and others
PaDER 3/19/85	N.D.	N.D.	N.D.	80	N.D.	N.D.	1,1,1 Trichloroethane - <50
Century 3/19/85	5	N.D.	25	56	N.D.	N.D.	Methylene Chloride - 210 Ethyl Benzene - 21 1,1 Dichloroethane - 10 Dichlorodifluoromethane - 25 Chloromethane - 28 Chloroethane - 3 Bromomethane - 6
NUS/EPA Contract labs 9/85	75	55	18	1200	35	450	Acetone - 2700 2 Butanone - 3900 4 Methyl 2 Pentanone - 320 Methylene Chloride - 3800 1,1,1 Trichloroethane - 200 1,1 Dichloroethane - 200 Tetrachloroethene - 45 Ethyl Benzene - 120 1,1,1 Trichloroethane - 200 1,1 Dichloroethane - 200 and others
PaDER 3/5/86	70	300	35	260	15	200	1,1,1 Trichloroethane - 57 1,1, Dichloroethane - 120 Methylene Chloride - 440 Tetrachloroethene - 20 Ethyl Benzene - 70 and others

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TABLE 3-5

Specific Gravities of Primary Volative Contaminants

	Specific Gravity	Behavior in Ground Water Flow System
Trichloroethene	1.49	Sinker
1,2 Dichloroethene	1.21	Sinker
Methylene Chloride	1.33	Sinker
Chloroform	1.48	Sinker
Toluene	0.87	Floater
Benzene	0.88	Floater
Xylene	0.86	Floater
Acetone	0.79	Floater
2 Butanone	0.80	Floater
4 Methyl 2 Pentanone	0.80	Floater

4.0 HYDROGEOLOGIC STUDY

4.1 Soils

An SCS soils map of the landfill site which shows pre-landfill soils is included as Figure 4.1. Few areas of "native" soil remain at the site, as most areas have either been stripped of soil for cover or landfilled. Original soil series and phases mapped at the site by the SCS were the following:

- NaC3 - Neshaminy silty clay loam, 8-15% slopes
- NsD - Neshaminy very stoney silt loan, 5-25% slopes
- BsC2 - Brecknock channery silt loam, 8-15% slopes
- BsD3 - Brecknock channery silt loam, 15-25% slopes
- BsB - Brecknock channery silt loam, 3-8% slopes
- BrC2 - Brandywine channery loam, 8-15% slopes
- BrD2 - Brandywine channery loam, 15-25% slopes
- EdF - Edgemont and Dekalb very stoney sandy loams, 25-70% slopes
- Au - Atkins silt loam (drainageways)

Most older areas of the landfill were excavated to bedrock and refuse filled directly on bedrock. The oldest fill areas were in the mine pits at the site or in excavated trenches, while more recent fill areas were operated as area fills. A compacted soil liner was placed below the refuse in the permitted fill area, however no information was found documenting the degree of permeability or impermeability of this soil liner.

FIG 4.1

BERKS LANDFILL CORPORATION

SPRING TWP. BERKS CO., PA.

LOCATION MAP

SCALE: 1" = ~1600'

(FROM BERKS COUNTY SOIL SURVEY)

4.2 Geology

4.2.1 Formations

Bedrock at the site includes (1) the Triassic Hammer Creek formation which is predominantly a sandstone, (2) a lower unnamed earlier Triassic unit with thick limestone pebble conglomerate sequences which is unconformable with the overlying Hammer Creek sandstones, (3) Triassic Diabase, (4) a fault slice of Ordovician Martinsburg formation phyllite and quartzite, and (5) a fault slice of Cambro-Ordovician limestone beneath the Martinsburg, which is probably the Millbach formation. These units are shown on the geologic section of the site in Figure 4.2.1.

Bedrock immediately beneath the central and southern portions of the property belongs to the Triassic Hammer Creek formation. This unit is well exposed due to excavations around the landfill, and is predominantly fine to coarse grained, medium to thick to massive bedded sandstone, with numerous conglomeratic (quartz and quartzite pebbles) zones. Bedding is mostly poorly developed or irregular, however some well bedded units were observed. Some thin beds occur. Shale and siltstone interbeds occur, but make up less than 20% of the beds exposed.

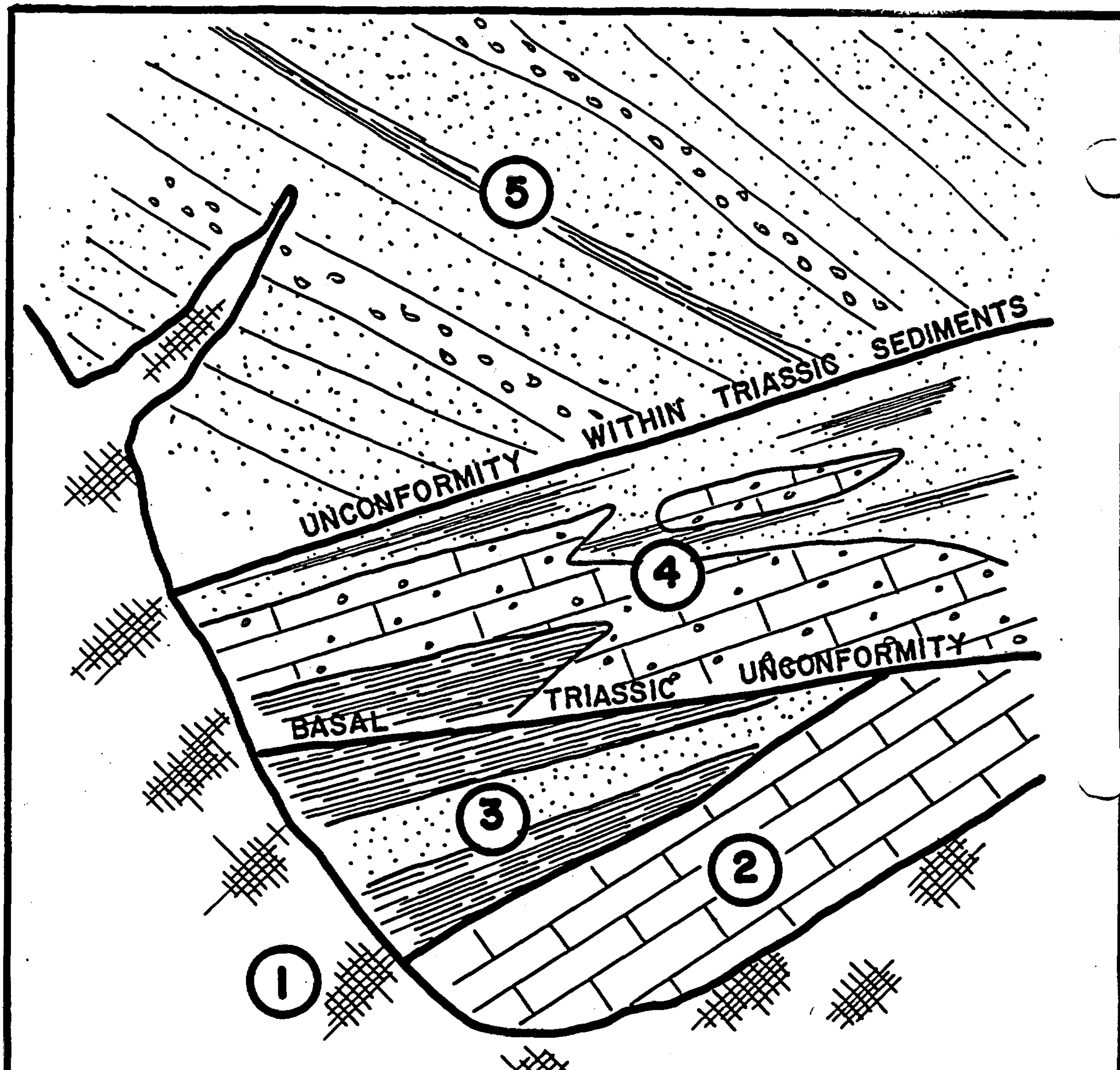

FIG.4.2.1

GEOLOGIC SECTION-BERKS LANDFILL

(5) TRIASSIC HAMMER CREEK FORMATION - MOSTLY SANDSTONE (CONGLOMERATE TO FINE GRAINED) SOME SILTSTONE, SHALE AND LIMESTONE PEBBLE CONGLOMERATE INTERBEDS.

(4) LOWER TRIASSIC LIMESTONE - PEBBLE CONGLOMERATE UNIT - LIMESTONE PEBBLE CONGLOMERATE >25% TO >50% UNIT THICKNESS, ALSO SANDSTONE, SILTSTONE AND SHALE.

(3) MARTINSBURG FORMATION - PREDOMINANTLY PHYLLITE & QUARTZI

(2) PALEOZOIC LIMESTONE - PROBABLY MILLBACH FORMATION.

(1) TRIASSIC DIABASE - MAIN INTRUSIVE MASS > 700' THICK

AR300057

Limestone pebble conglomerate interbeds occur but are a small percentage of the total section except in the northeastern portion of the property in some of the lowest Hammer Creek beds in the area of Outcrops #200 and #201 (see Exhibit I) where several thick limestone pebble conglomerate interbeds occur. The thicker limestone pebble conglomerate beds in the northeast portion of the site may belong to the lower Triassic unit which contains thick limestone pebble conglomerate beds, and, if so, they were emplaced by strike faulting. This will be discussed at greater length in Section 4.2.2 of this narrative.

The Hammer Creek sandstone is mostly a quartzose sandstone, with some graywacke and feldsphathic or arkosic ("salt and pepper" appearance) sandstone beds observed. Colors are typically brown, light green, and red-brown (typical "Triassic Red"), except in the eastern portion of the site where baking from a nearly diabase intrusion has bleached the rocks leaving little red, and in this area gray, cream, light green, and brown colors predominate. In the eastern baked portion of the site, shales and siltstones are indurated and altered to argillites and hornfels, some of which have a purple cast.

The limestone pebble conglomerate interbeds within the Hammer Creek formation are comprised of both limestone and dolomite pebbles. They are various shades of gray but mostly light gray, weathering to light gray, cream, light green and brown. Thermal metamorphism has also created dark green serpentine coatings on the pebbles in some areas. The gray limestone pebbles are mostly bound by a gray, limey cement. One bed of limestone pebble conglomerate in the recently developed borrow area in the extreme western portion of the site has gray pebbles in a red-brown cement. Beds vary in thickness from 1 ft. to greater than 10 ft. Some beds of limestone pebble conglomerate were noted to thin quickly in outcrop over distances of a few hundred feet. Pebbles are mostly sub-angular to sub-rounded.

A narrow, hook-shaped band of earlier Triassic rocks consisting of a large percentage of limestone pebble conglomerate beds outcrops on the north side of the site in the valley along the unnamed tributary to Cacoosing Creek, and wraps around the east side of the site in the north-trending drainageway along the eastern property line. This unit contains limestone pebble conglomerate sequences up to 40 ft. thick and thicker, and limestone pebble conglomerate beds comprise from 25% to greater than 50% of the unit's total thickness. Due to poor surface exposure, this unit has in the past been incorrectly mapped by Spencer (1908) and MacLachlan et. al. (1975) as a brecciated Paleozoic limestone. However, recent drilling at the site shows that the thick limestone pebble conglomerate beds in this unit are interbedded with red siltstone and sandstone and that a small percentage of non-carbonate rocks including fragments of granite or granite greiss comprise the pebbles in the conglomerates. Clearly this is an early Triassic unit. This limestone pebble conglomerate unit is unconformable with the overlying Hammer Creek formation sandstones as will be discussed in Section 4.4.2 of this narrative.

Although limestone pebble conglomerate comprises 25 to 50+ % of this unit, it will be referred to in this narrative as the "Lower Limestone Pebble Conglomerate Unit" to distinguish it from the upper Hammer Creek formation at this site which has much less limestone pebble conglomerate and is predominantly sandstone. The position of the lower limestone pebble conglomerate unit at the northern border of the Triassic Basin, together with the angularity of the pebbles, indicates that it was derived from nearby Paleozoic carbonates to the north. Considering the angularity of the pebbles, historical references to the deposit as a breccia (Appendix D) are probably correct, although it is a sedimentary breccia and not a tectonic breccia. Drilling records, to be discussed in Section 4.2.6 of this narrative, indicate that this sequence varies significantly laterally, which is consistent with its depositional mode. Limestone pebble conglomerate beds within this unit do not maintain a uniform thickness or interval across the site. At outcrop #3 (See Exhibit I) a limestone pebble conglomerate cuts across a sandstone bed suggesting an ancient channel fill. This unit is interpreted to have resulted from an early stage of Triassic deposition at the northern border of the basin, prior to deposition of the higher Hammer Creek sandstone beds.

MacLachlan, Buckwalter, and Mclaughlin (1975) give the following descriptions which reflect their uncertainty over this limestone unit:

> (p.46)
> An isolated patch of carbonate rocks occurs south of a Triassic intrusive mass east of Fritztown. This rock has been considerably metamorphosed and somewhat mineralized (magnetite-sulfides-chlorite-zeolites, etc.) and lies in the Wheatfield Iron Mines area which produced a few hundred thousand tons of magnetite iron ore in the 19th Century. Present exposure in this area is extremely poor, but isolated fragments lead to the tentative inference that carbonates belong to the Millbach Formation. Material observed by the author appeared to be quite silty, suggesting probably Cambrian rather than Ordovician age. It was predominantly calcareous rather than dolomitic and

relatively light in color consistent with the suggested stratigraphic assignment.

(p.161)
One other occurrence of limestone "conglomerate" is problematical. This is an apparent breccia of limestone fragments in a limestone matrix that overlies apparently solid limestone in the easternmost pit at the old Wheatfield Mines east of Fritztown. The rock is intensely metamorphosed by a diabase intrusion. It is possible that this material is a tectonic breccia, but the writer considers it more probable that it is a conglomerate at an unconformable contact of the Newark rocks upon the Paleozoic limestone.

Fine grained Paleozoic limestones which are probably the Millbach formation occur in the northwest corner of the site and in the stream valley to the northwest of the site, beneath a fault slice of Martinsburg formation phyllite and quartzite. Approximately 20 ft. of this limestone outcrops in the Ruth mine located approximately 1/2 mile west of the site. Although this Paleozoic limestone is well fractured and in places brecciated at the Ruth mine, it is quite different in appearance from the lower Triassic limestone pebble conglomerates found along the northern portion of the site. The Paleozoic limestone occurs beneath the Martinsburg fault slice, while the lower Triassic limestone pebble conglomerate unit sits unconformably on top of the Martinsburg formation fault slice where it is present in the northwest portion of the site. Within the site, no fine grained Paleozoic limestone was found in outcrop or by drilling. Only the lower Triassic limestone pebble conglomerate unit was found within the site. In and along the stream valley on the northern side of the site, where the Martinsburg formation is thin or absent, the lower Triassic limestone pebble conglomerate unit joins the Paleozoic limestone along the northern Triassic border unconformity. These two carbonate units are considered to act as one hydrologic unit or aquifer in the valley bottom and southern side of the valley, as will be discussed in Section 4.4 of this report.

The lower limestone pebble conglomerate unit was the host rock of the Iron ore in the easternmost Wheatfield mines, and the best exposures of the unit were in the old mine workings. Historical descriptions of the rocks encountered in the mines are included in Appendix D. An outcrop of both a fine grained limestone and limestone breccia was located by Spencer (1908) in the bed of the unnamed tributary to Cacoosing Creek, between the westernmost north trending drainageway and the central north-trending drainageway at the site (See Exhibit I). This outcrop could not be found during recent field mapping at the site, and was apparently covered when the stream in this area was rechanneled in the late 1960's. The stream channel outcrop reported by Spencer is near the fault slice of the Martinsburg formation, and the fine grained limestone described may be the Paleozoic Millbach formation occurring beneath the Martinsburg. All of the other historical descriptions of the eastern group of Wheatfield mines at the site reference only a limestone breccia, which is interpreted to be the lower limestone pebble conglomerate unit previously described.

A large, relatively unweathered outcrop of the lower limestone pebble conglomerate unit was found at only one point, in a mine pit to the east of the site on the Ritter property, as shown on Exhibit I. At this point two ledges of limestone pebble conglomerate or breccia outcrop, one near the water's edge, and one on the southwest slope of the pit, for a combined thickness of approximately 15 ft. The rock is gray, massive, and comprised of limestone and dolomite fragments in a gray limey cement. The fragments are subangular to subrounded. A small outcrop of this limestone pebble conglomerate occurs as ridge like pinnacles just each of the scale house trailer at the entrance road off of Wheatfield Road, and highly weathered and disaggregated limestone pebble conglomerate outcropping in the base of Lagoon #1 (Outcrop #3) and in the basin shaped excavation area east of the treatment lagoons and south of well #10 (Outcrop #520) are interpreted to be part of this lower unit and not Hammer Creek limestone pebble conglomerate interbeds. An area of brown limestone pebble conglomerate saprolite at outcrop #710 is also interpreted to be part of this lower unit.

The fourth important bedrock unit at the site is Triassic Diabase, an intrusive igneous rock. The diabase at the site occurs as thick and thin, concordant and discordant bodies. A nearly continuous, thick diabase mass rims the site, forming the previously discussed encircling hills. This main intrusion is irregular in its outcrop pattern. Geologic mapping and drilling records indicate that this main diabase unit is saucer-shaped, outcropping on all sides of the site and passing beneath the site. Saucer-shaped diabase intrusions occur elsewhere in the Triassic basin, notably at the Cornwall Iron Mines in Lebanon County, some 20 miles to the west.

Thin diabase dikes and sills, varying from 1/2 ft. to several feet in thickness, cut the Hammer Creek formation, and the lower limestone pebble conglomerate unit. Several of these thin dikes and sills were mapped at the site, most occurring in the eastern portion of the permitted landfill. Sills were also encountered in wells drilled in the central portion of the site (e.g. C6D). A thicker, and larger tongue-shaped diabase sill occurs in the southwestern portion of the permitted landfill area (see Exhibit I). This sill has been cut through by the landfill excavations exposing the underlying sandstone. Remnants of this sill occur as knobs to the southwest of the permitted fill area.

As expected, the thinner diabase intrusions are fine grained, some almost aphanitic, while the more massive intrusions are medium to coarse grained.

In the western portion of the site, a slice of Martinsburg formation phyllite and quartzite occurs. This unit was found at outcrop #700 (See Exhibit I) and penetrated by well C7D. This unit was described by Spencer (1908) as a slate, and was estimated by him to be 80 ft. thick at the Western most Wheatfield Mine, known as the Ruth Mine, located 2000 ft. west of the site. Recent inspection of the Ruth Mine revealed an approximate 20 foot thick ledge of this unit still exposed above the limestone. Minor amounts of this slate were noted by Spencer at Wheatfield Slope #1 Mine, north of the site on the north side of the unnamed tributary to Cacoosing Creek. The unit is absent in the eastern portion of the site, and was not noted in the literature on the mine workings in this area. The Paleozoic limestone unit discussed previously occurs beneath this slice of Martinsburg in the northwest portion of the site.

The diabase intrusion resulted in thermal metamorphism of the surrounding rocks and metasomatic replacement of pockets of limestone pebble conglomerate with primarily magnetite and pyrite, as well as a bunch of other minerals including a variety of metallic minerals in lesser quantities. Andradite Garnet was noted as a replacement mineral at one outcrop. The copper mineral malachite was found in waste rock in the overburden piles at Mine Slope No. 1 on the north side of Wheatfield Road. The thermal metamorphism has left green chlorite in the matrix of much of the sandstone in the northern and eastern portions of the site. The limestone pebble conglomerates in the Hammer Creek formation, the lower limestone pebble conglomerate unit and the Paleozoic limestone have numerous dark green coatings which are serpentine. This mineralization is discussed in greater detail in Section 4.3 of this narrative concerning mining history, and many of the minerals are identified in the Historical Literature included in Appendix D.

This mineralization has ground water quality implications. Mining of the magnetite and associated pyrite would have exposed pyrite to oxidation. This could result in elevated sulfate in aerobic environments, if any such environments are left in the immediate area of the landfill after the organic load exerted by the refuse decomposition. Trace metals associated with the predominant iron mineralization, such as copper, lead, zinc, and others, could, under the right conditions, become mobile and show up in ground water. This will be discussed in Section 4.4 of this narrative.

4.2.2 Structure

Bedrock structure at the site area is closer to complex than simple. Across the southern portion of the site the Hammer Creek formations appears simply homoclinal with a uniform west dip. In the north-central portion of the site the Hammer Creek formation sandstones lie unconformably over the lower Triassic limestone pebble conglomerate unit which has a south dip in this area. The lower limestone pebble conglomerate unit outcrops in the valley of the unnamed tributary to Cacoosing Creek on the north side of the site and in the north-trending drainageway on the east side of the site. On the east side of the site, the upper Hammer Creek sandstones and the lower limestone pebble conglomerate unit have approximately the same north strike and west dip, and these two units may be conformable in this area. A ridge-forming fault slice of Martinsburg formation phyllite and quartzite occurs on the western side of the site. Triassic beds lie unconformably on this fault slice, which dips to the south, and forms the northern border of the Triassic basin.

Encircling the site is an irregular diabase mass which is in some areas concordant and other areas discordant. Available data indicates that this mass is saucer-shaped, rimming the site and passing beneath it in the form of a saucer. On the north side of the site the diabase occurs beneath the limestone pebble conglomerate unit. Drilling records, to be discussed in Section 4.2.6 of this narrative, indicate that the lower limestone pebble conglomerate unit is absent beneath the southern portion of the site, so that the thick diabase mass occurs directly beneath the Hammer Creek formation sandstones in this area. Historical records (Appendix D) indicate that the thick diabase mass is concordant with the lower limestone pebble conglomerate unit on the northern and eastern sides of the site. Numerous diabase sills and dikes, varying from less than one (1) foot in thickness to tens of feet in thickness emanate from the main diabase mass, cutting the lower limestone pebble conglomerate unit and the upper Hammer Creek formation sandstones.

Across the southern portion of the site, the Hammer Creek formation is homoclinal with a general north strike and a moderate west dip. Strike ranges from north-northeast to north to north-northwest. Dip ranges from 15 to 36 degrees west. The general trend of Triassic beds in the region is ENE-WSW, so the north strike in the site area is unusual. The only Hammer Creek beds mapped during recent field work at the site which didn't have a NNE-NNW strike or dip greater than 10 degrees were in the north-central and northwest portions of the site (see OC #690, and OC #3, Exhibit I), near the contact with the Martinsburg formation and the unconformity with the underlying limestone pebble conglomerate unit. The Pennsylvania Topographic and Geologic Survey (MacLachlan et. al., 1975) mapped beds with other than a NNE-NNW strike in the southeast portion of the site, beneath the active fill area, adjacent to a diabase sill. The intrusion apparently affected the attitude of the adjacent beds in this area.

Folding of Triassic beds does occur, possibly due to deep-seated fault movement or differential compaction of the Triassic sediments, and the site appears to fall in the nose of one of these folds, which would explain the north strike. Near north-striking beds were mapped by MacLachlan et. al. (1975) to the east of the site. The pattern of mapped units to the east of the site indicates a setting in the nose of a fold, however the irregular, large diabase mass obscures a clear fold pattern.

The north strike may also be explained by movement related to the main diabase intrusion, or to movement along the Little Muddy fault to the west of the site, or movement along the Northern Triassic Border Fault to the northwest of the site. The Pennsylvania Topographic and Geologic Survey (MacLachlan et. al. 1975) has not mapped a northern border fault to the north of the site, and Triassic beds are unconformable with underlying Paleozoic beds in this area. However, based on conversations with members of the Pennsylvania Topographic and Geologic Survey, the unconformity within the triassic sequence, between the lower limestone pebble conglomerate unit and the upper Hammer Creek sandstones, suggested step faulting or episodic faulting along the border during Triassic times. Note that any mention of faulting in this narrative is academic. Any faults in the site area are ancient features which have not been active for hundreds of millions of years.

A small remnant of Hammer Creek formation was mapped by MacLachlan et. al. (1975) to the northeast of the site, northeast of the outcrop area of the lower limestone pebble conglomerate unit, along Wheatfield Road. This remnant may be non-carbonate beds within the lower limestone pebble conglomerate unit.

The historical literature in Appendix D indicates that the lower limestone pebble conglomerate unit (or Millbach formation limestones to the west and northwest) has a near east-west strike and moderate south dip on the north side of Wheatfield Road (at Wheatfield Mine Slope #1). This belt of limestone pebble conglomerate hooks around the east side of the site, with the strike changing to northwest-southeast with a southwest dip at the northeast corner of the site, and finally to a north-south strike on the eastern side of the side, with a moderate west dip. Spencer (1908) described this structure as follows:

> In the more southerly Wheatfield workings the strikes of the strata run nearly north and south, as shown by the direction in which the pit workings extend and by the beds of limestone exposed in the old excavations; but farther north the strata turn more and more toward the northwest and finally run nearly east and west at slope #1.

In the north-central portion of the site, this east-west striking, south dipping lower limestone pebble conglomerate unit dips unconformably beneath the north striking, west dipping Hammer Creek sandstone beds. On the east side of the site, the upper Hammer Creek beds and the lower limestone pebble conglomerate unit have the same approximate north strike and west dip, and the two units may be conformable in this area.

Historical descriptions of the Wheatfield mines in Appendix D indicate that the thick diabase which occurs beneath the limestone pebble conglomerate unit follows its south dip on the north side of the site and west dip on the east side of the site. On the east side of the site, the presence of the underlying diabase mass was confirmed by drilling (well C4D). On the south side of the site, drilling records also confirm that the diabase mass dips to the north beneath the site. As stated previously, the diabase mass is indicated to be saucer-shaped, rimming the site in outcrop and dipping beneath it on all sides. MacLachlan et. al. (1975) indicate that the main diabase mass is on the order of 700 feet thick in this area.

Drilling logs indicate that the dip of the lower limestone pebble conglomerate unit flattens-out beneath the north-central portion of the site. The approximate top of this limestone pebble conglomerate unit occurs between elevation 480 and 530 MSL over most of the northern portion of the site.

Structure at the site is depicted in the cross-sections in Exhibit V, and in the cross-sections accompanying Spencer's report (1908) in Appendix D. Spencer's cross sections are relatively accurate, except that they show a fine grained Paleozoic limestone instead of the lower limestone pebble conglomerate unit. Paleozoic limestone (Millbach formation) occurs to the northwest of the site, beneath the Martinsburg fault slice, but on the north and east sides of the site, the carbonate unit is the lower Triassic limestone pebble conglomerate unit.

A northeast-southwest trending, cross-cutting fault zone was noted at outcrop #107 (see Exhibit I) in the northeast portion of the site. In an early report on the Wheatfield Mines, Willis (1886 - excerpt in Appendix D) presents a cross section which shows that the limestone pebble conglomerate beds in the northeast portion of the site were emplaced by a series of strike faults. Strike faulting would explain the thick limestone pebble conglomerate beds in the northeast portion of the site, if these were fault slices of the lower limestone pebble conglomerate unit emplaced within the Hammer Creek sandstones. The simpler explanation is of course that these are limestone pebble conglomerate interbeds within the Hammer Creek formation. Discussing the Wheatfield mines, D'Invilliers (1883) states that "The gangue rock appears to be limestone wherever met with as horses and wedges that divide or cut into the ore or foot-wall trap." This comment indicates faulting. Other than these faults in the northeast portion of the site, no other faults were mapped within the site.

4.2.3 Jointing

Approximately 100 joint readings were taken at outcrops across the site during recent field work in October and November, 1986. These joint readings are presented with the geologic field notes in Appendix A, and representative measurements are plotted on Exhibit I, Site Geology. A joint rose of the strikes of all moderate to steeply dipping joints is presented in Figure 4.2.3.1. All joint readings were in the Hammer Creek formation or Diabase. No readings were collected in the lower limestone pebble conglomerate unit due to its poor exposure.

During mapping, prominent joints with steep dips and with strikes approximately parallel to bedding strike were noted at several outcrops. These are usually referred to as "strike joints." Steeply dipping joints with strikes approximately normal to bedding strike were also common, and these are usually referred to as "dip joints." Strike joints have a near north-south strike, while dip joints have a near east-west strike.

Spacing of all sets was highly variable across the site. Many outcrop areas were poorly jointed with joint spacings of several feet, while other areas

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showed well developed joints spaced inches apart. The best developed jointing generally occurred in outcrops in natural drainageways which are fracture controlled.

Thin diabase dikes and sills were generally as well jointed if not better jointed than the surrounding rock. Exposed thick diabase units were generally poorly jointed.

The joint rose shows typical scatter, but reveals five principal trends (greater than 5 readings).

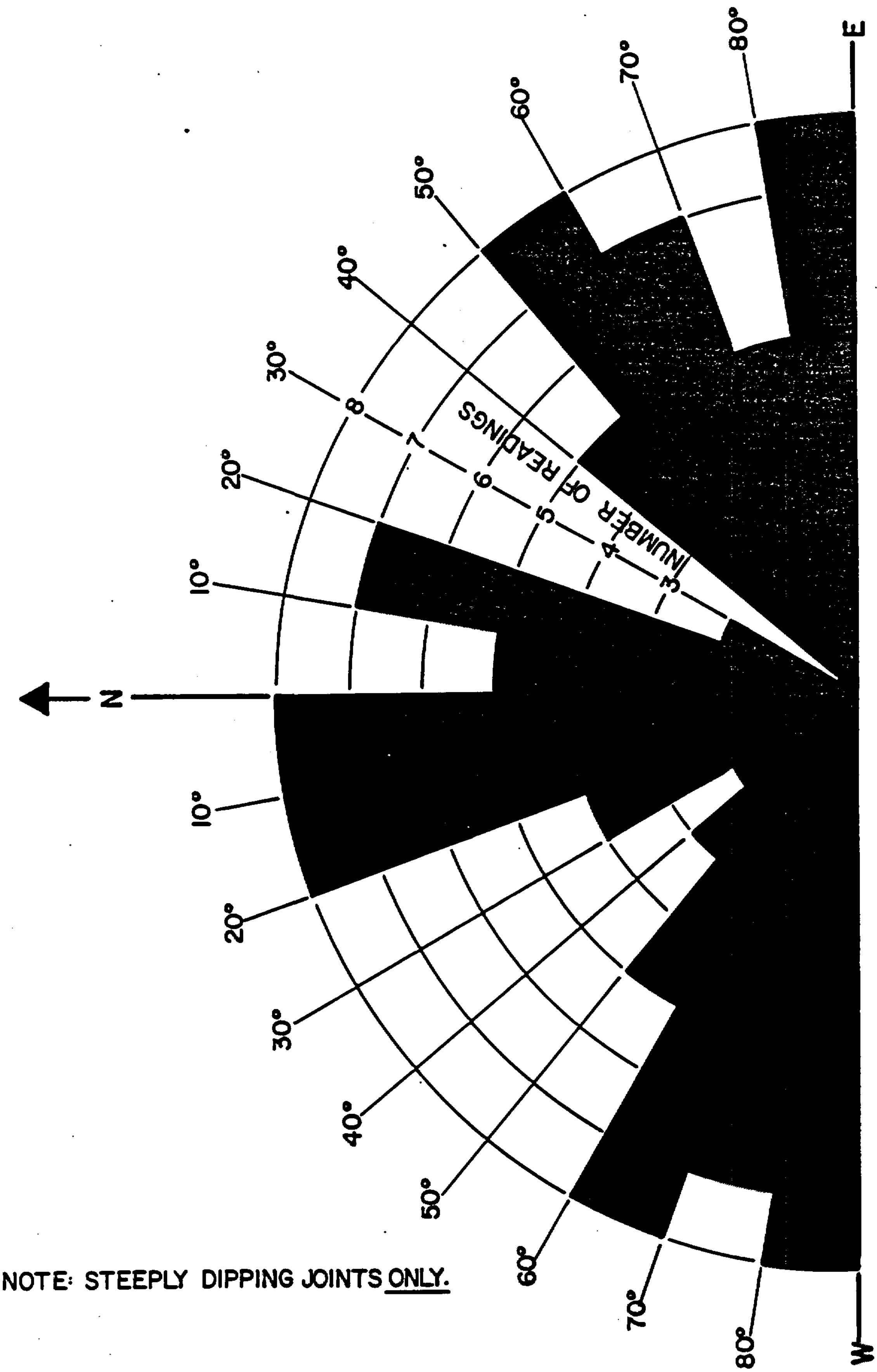
a. N10E to N20E - Strike Joints

b. N0W to N20W - Strike Joints

c. N50E to N70E

d. N80E to N90E - Dip Joints

e. N60W to N90W - Dip Joints merged with a more NW striking set.



NOTE: STEEPLY DIPPING JOINTS ONLY.

FIG. 4.2.3.1

BERKS LANDFILL CORPORATION
JOINT ROSE

4.2.4 Fracture Traces and Lineaments

Fracture Traces are linear alignments of topographic features or phototonal features less than one (1) mile in length which are usually the manifestation of zones of concentrated or prominent bedrock fracturing or jointing. Lineaments are the "big brothers" of fracture traces and are greater than one (1) mile in length. Fracture Traces and Lineaments mapped through aerial photographic and topographic map interpretation in the site area are shown on Exhibits II and IV.

SCS aerial photographs of the site taken in 1946 were used to map fracture traces. As the landfill began in the early 1950's, these 1946 photographs depict prelandfill conditions. Landfill activity has obscured many of the fracture traces at the site on more recent aerial photographs. An enlarged copy of a portion of one of the 1946 aerial photographs is included as Figure 2.2.1 in Section 2.2 of this narrative.

A rose diagram of mapped fracture traces is presented in Figure 4.2.4.1. This rose diagram shows trends similar to those on the joint rose discussed earlier, which indicates that mapped fracture traces are related to measured jointing. This fracture trace rose reveals the following trends:

a. NNE (N1E to N20E)

b. NNW (N0W to N30W)

c. ENE (N60E to N80E)

d. NW to WNW (N50W to N80W)

Three lineaments were mapped in the site area as shown on Exhibit III. Two (2) of these cross at an oblique angle in the stream valley to the north of the site, one trending ENE-WSW and the other trending WNW-ESE. The third lineament trends N-S and follows the drainageway on the western side of the site.

Streams and drainageways at the site show an angularity which is clearly joint related. Other topographic features at the site, such as sharp bends or notches in slopes, are also clearly joint related. Many of these features were too short to be mapped as fracture traces, while many were part of a larger fracture trace of lineament.

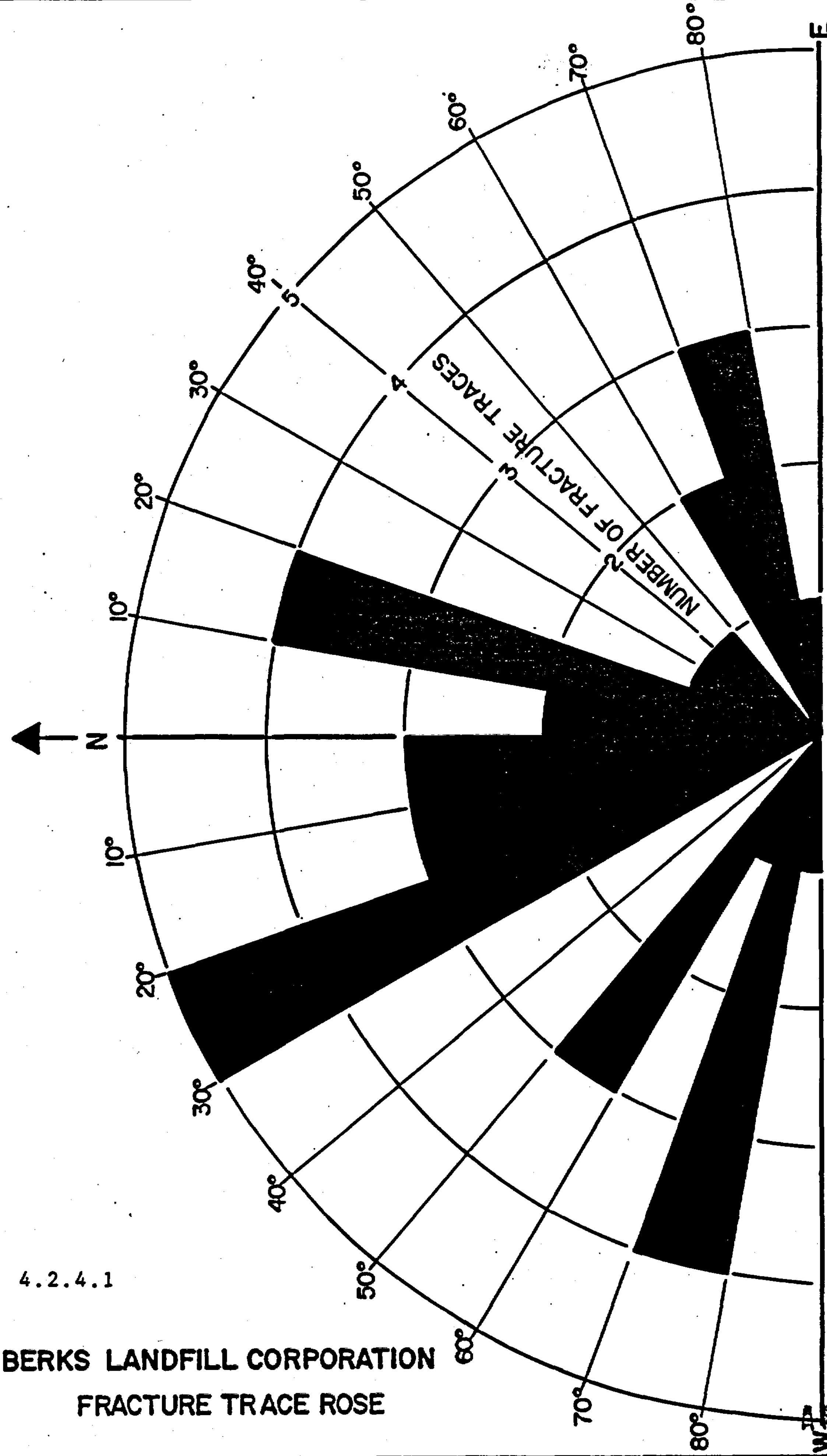


FIG. 4.2.4.1

BERKS LANDFILL CORPORATION

FRACTURE TRACE ROSE

4.2.5 Weathering

Degree and depth of weathering is variable across the site and variable between lithologies. At some points the Hammer Creek sandstones are hard and only slightly weathered, while at other points weathering has reduced the sandstone to a highly weathered, friable sandstone or sandy residuum. The argillites and hornfels in the baked zone in the eastern portion of the property are generally resistant to weathering. Historical accounts of the Wheatfield Iron mines (Appendix D) indicated a high degree of weathering of the ore to a depth of 30 to 40 feet. During recent drilling, the greatest depth of weathering was found at well C1, where the diabase, in a fracture zone setting, was found to be highly weathered to a depth of 35 feet. On a hilltop 450 feet northeast of well C1, hard, relatively unweathered diabase is exposed in an excavation less than 10 feet deep. Excavations for the landfill have removed much of the soil and highly weathered bedrock residuum.

Differential weathering is most evident in the limestone pebble conglomerate interbeds in the Hammer Creek formation and in the lower limestone pebble conglomerate unit. When fresh, these units are hard and gray. Weathering preferentially attacks the matrix of this rock, making it softer than the limestone pebbles, and in many areas completely disaggregates the rock into a loose residuum of limestone pebbles in a gray or cream colored silty decomposed matrix. The limestone pebble conglomerate was also noted to develop a saprolite at several points where both the matrix and the pebbles are completely decomposed to a brown soil with the relic pattern of the original rock.

In the bedded units at the site, the result of this variation in depth of weathering is to create a sandwiching of softer, more easily weathered beds between harder, more resistant beds. This has an impact on directions of ground water flow as will be discussed in Section 4.4.1 of this narrative. This also affected the nature of early landfilling at the site. A long term employee of the landfill reported that the excavations at the inactive landfill were carried out in an east-west direction, or across the strike of the Hammer Creek formation beds. This employee indicated that hard ridges of bedrock were encountered between softer beds, resulting in a highly variable depth of excavation.

The thick limestone pebble conglomerate beds of the lower unit are prone to some solution void development in outcrop areas. Two small closed depressions or sinkholes (5-10 feet across, 2-3 feet deep) were noted over this unit in the valley, just south of Wells C7S and C7D. Numerous small closed depressions or sinkholes occur on the Ritter property to the east of the site. These are either related to deep mine voids or solution voids in this area. The small size and conical shape of these closed depressions indicates that they are small collapes stemming from piping (subsurface erosion) of overlying soil into bedrock voids, and not due to collapes of large bedrock voids. None of the recent drilling disclosed solution voids in any of the wells which penetrated the lower limestone pebble conglomerate unit. Interpretation of 1946 SCS aerial photographs also showed a possible closed depression in the northeast portion of the inactive landfill. Mine related pits and depressions will be discussed in Section 4.3 of this narrative.

4.2.6 Test Borings and Wells

Four sets of test borings or wells were drilled at the landfill site between 1974 and 1986. The first set of seven wells was drilled in 1974 in support of the original Phase I application. These wells were shallow, ranging in depth from 7.7 to 36 feet. They were designated B1 through B7. Some of these wells were redrilled during 1974 and given an "A" suffix. Boring B6 was drilled to a depth of 6 feet, and redrilled as B6A to a depth of 14 feet. Geologic logs of some of these wells were located and these are included in Appendix B. Also included in Appendix B in a June 17, 1974, letter from Richard Conlin to PaDER summarizing well depths, depths to rock, and water level data. Only one of these original wells has survived, 36 foot deep B1 on the south side of the inactive landfill. Under the current monitoring scheme this well is designated MP6. Note that permanent monitoring wells at the site are alternately given the prefixes of "MP" for monitoring point and "MW" for monitoring well.

A second set of generally deeper monitoring wells were drilled in 1975, subsequent to issuance of the PaDER permit. These were drilled as the permanent monitoring wells for the landfill. Unfortunately this second set of wells was given a "B" prefix like the first set, which causes some confusion. As many of the 1975 wells were apparently drilled near the locations of the original 1974 wells, they were given the same designations. A 7/30/75 PaDER memo written by Richard Kraybill notes the redrilling of Wells B4, B6A, and B7 which were destroyed by the landfill. Wells which appear to have been drilled or redrilled in 1975 include B3, B4, B5, B6A, B7, B9, B10, and B11. No detailed geologic logs of this set of wells were found, and apparently only driller's logs were prepared. Driller's logs for B3, B5, B6A, B7 and B10 were located, but no logs could be found for B4, B9, or B11.

The driller's logs of the 1975 set of wells does help shed some light on the site's geology. Well B7 was drilled in the wood dump area in the southeast corner of the property. This well penetrated sandstone of the upper Hammer Creek formation from 15 to 60 feet, and granite (diabase) from 60 to 171 feet. Similarly, Well B6A, located in the southern portion of the permitted fill area, penetrated sandstone from 20 to 40 feet, and coarse grained granite (diabase) from 40 to 100 feet. Wells B7 and B6A confirm that the thick diabase mass dips beneath the southern portion of the site. Well B6A was destroyed by the landfill, however an attempt was made to preserve B7 by extending its casing. Under the current monitoring designations, B7 is known as MP3.

Well B3, located in the northwest portion of the permitted fill area, encountered sandstone from 13 to 50 feet, and granite or "olivine" (diabase) from 50 to 67 feet. Well B5 penetrated similar rocks, including sandstone from 3 to 38 feet, and granite (diabase) from 38 to 51 feet. The diabase encountered in these wells is interpreted to be smaller intrusions emanating from the main diabase mass at greater depth. Both Wells B3 and B5 have been destroyed by the landfill.

Boring B10, located in the northern portion of the site, encountered "very loose dirt" from 0 to 18 feet, and sandstone from 18 to 31 feet. This well is designated MP10 under the current monitoring scheme. Well B11 is located to the west of B10; Well B9 is located in the northern area of equipment storage of Lombardo Equipment Company; and Well B4 is located to the southeast of the trailer at the entrance to the landfill from Wheatfield Road. B9 and B11 are currently designated MP9 and MP11, respectively. Both B9 and B4 were drilled in the area of the old mine workings in the northeast portion of the property. B9 was drilled into one of the old mine overburden piles. Mr. Robert Demeno, Sr., reports that Wells B10 and B11 (MP10 and MP11) were redrilled in 1984.

In January 1986, a third set of monitoring wells were drilled at the site. Ten (10) wells were drilled at six (6) locations, including four (4) deep-shallow well pairs, and two (2) single wells. These wells were designated MP14 shallow, MP14 deep, MP15 shallow, MP15 deep, MP16, MP17, MP18 shallow, MP18 deep, MP19 shallow, and MP19 deep. No detailed geologic logs of these wells were prepared and no samples of drill cuttings were preserved. Only driller's logs of these wells were prepared. There was some confusion over the designation of well pairs MP14 and MP15, and the driller labeled his logs of MP15 (southeast side of inactive landfill) as MP14, and his logs of MP14 (north side of inactive landfill) as MP15.

The driller's logs of the January 1986, wells are useful in piecing together site geology, but use of catch-all words by the driller in describing the rocks encountered adds some confusion. Well MP17, in the southwestern portion of the permitted fill area, penetrated granite (diabase) from 8 to 47 feet. The rock types described at the other wells by the driller were mostly sandstone and "traprock." It is likely that the driller could pick-out a sandstone, particularly if it were coarse grained. "Traprock," however, is a catch-all word to many drillers. When questioned about the use of the word "traprock," the drillers (C.S. Garber and Sons) indicated that they applied it to any hard gray rock that they thought was not sandstone or limestone. Unfortunately they applied the word to a variety of rock types at the site including gray sandstone and limestone pebble conglomerate.

"Traprock" was logged by the driller from 18 to 200 feet at Well MP18 deep. Cuttings piled around the casing of this well were collected in the fall of 1986 and described (Appendix B). These cuttings were approximately 90% limestone pebble conglomerate fragments and 5-10% sandstone fragments. This was to be expected, as Well MP18 penetrated the lower limestone pebble conglomerate unit. Well MP15 (mislabeled MP14 by the driller) encountered sandstone from 0 to 73 feet, and "traprock" from 73 to 200 feet. Cuttings piled around the base of MP15 were collected in the fall of 1986 and described. These cuttings were approximately 90% sandstone, including much gray sandstone, and only 10% carbonate fragments from a limestone pebble conglomerate unit. Obviously the "traprock" logged by the driller at MP18 was very different than the "traprock" logged at MP15. Limestone was logged by the driller from 52 to 65 feet at MP14 (mislabeled MP15), and this is probably limestone of the lower limestone pebble conglomerate unit. The extensive "traprock" logged at MP14 probably included other limestone pebble conglomerate beds not logged as limestone. No cuttings were found at wells other than MP15 and MP18, so the driller's logs for these other wells should be used with caution.

In December 1986, a fourth set of eleven (11) wells were drilled at the site. Wells were drilled at seven (7) locations including four (4) deep-shallow well pairs and three (3) single wells. To avoid confusion with previous wells, these wells were given a "C" prefix. Deep and shallow wells in a pair were given "D" and "S" suffixes, respectively. Samples of drill cuttings were collected at 5 foot intervals during drilling. These samples were washed and used to prepare detailed geologic logs.

This final set of wells confirms the basic site geology. Well C1, in the southeast corner of the property, penetrated diabase from 15 to 50 feet.

Well C3D, situated on the north side of the wood dump area, on the southeast corner of the permitted fill area, encountered mostly sandstone of the upper Hammer Creek formation from 7 to 200 feet. Minor limestone pebble conglomerate interbeds were encountered at 110-115 feet and 185-195 feet. Diabase was encountered from 200 to 225 feet, and this is interpreted to be the upper portion of the thick underlying diabase mass. Well C4D, located in the northeast portion of the permitted area, encountered thick limestone pebble conglomerate beds at 0-30 feet, 40-60 feet, 90-100 feet, and 155-195 feet. Magnetite ore zones (replaced limestone pebble conglomerate) were encountered at 100-105 feet, and 135-145 feet. Interbedded with the limestone pebble conglomerate were sandstone, argillite and hornfels. This sequence of thick limestone pebble conglomerate beds interbedded with sandstone and argillaceous rocks is the lower limestone pebble conglomerate unit. Diabase was encountered in Well C4D from 215 to 275 feet, and this is interpreted to be the upper portion of the underlying thick diabase mass. Well C5 was drilled in the northeast portion of the permitted fill area, to the northwest of well pair C4, in an attempt to intercept deep mine workings of Mine Slope No. 3. This well did not encounter any mine workings, but drilled through limestone pebble conglomerate beds of the lower limestone pebble conglomerate unit from 30 to 75 feet and from 80 to 100+ feet. Interbedded with the limestone pebble conglomerate were siltstone and sandstone.

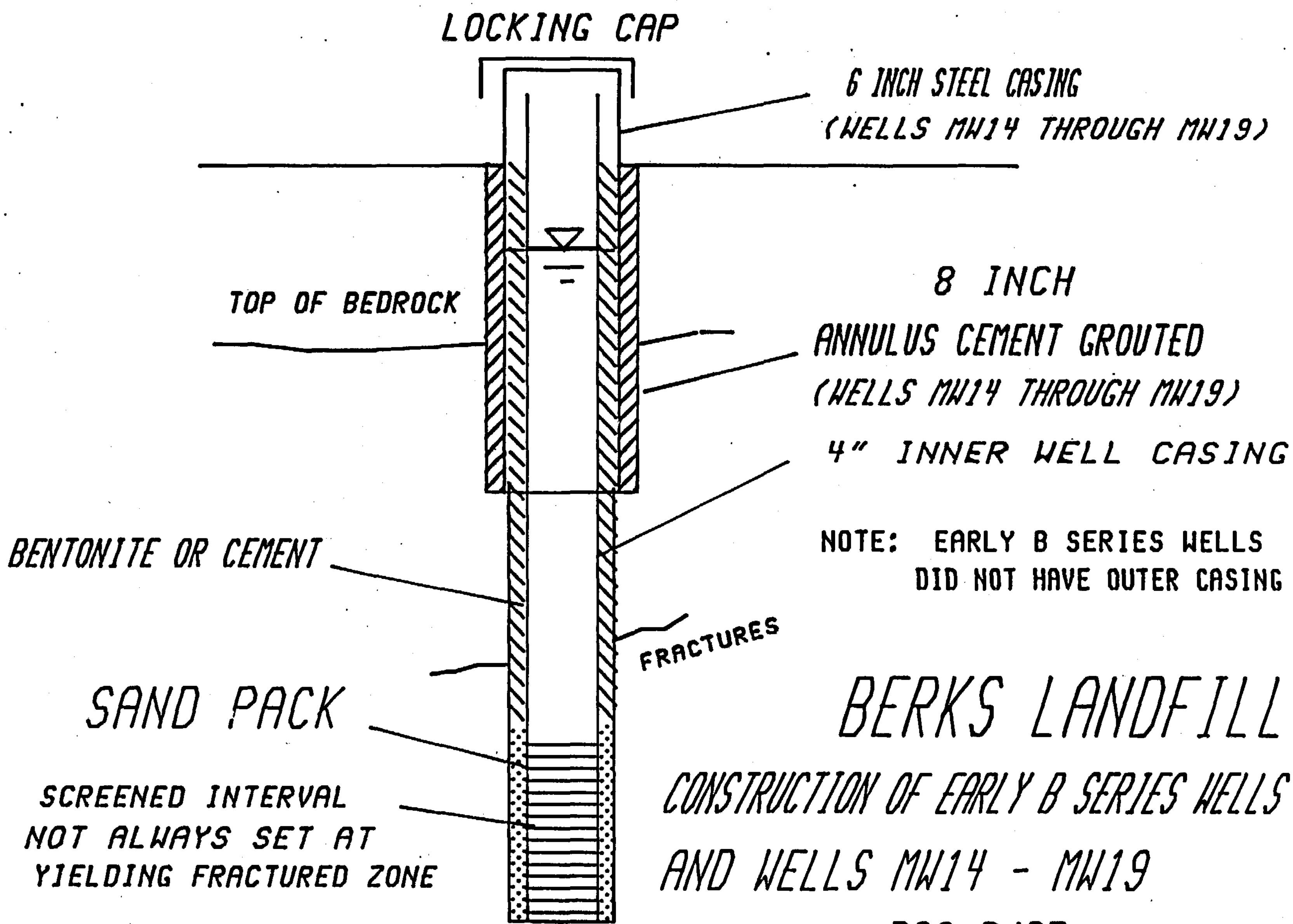
Well C6D, in the central drainageway, drilled through limestone pebble conglomerate beds at 35-75 feet, 195-200 feet, and 220-245 feet. While this well did not encounter as much limestone pebble conglomerate as Wells C4D, C5, and MP18, limestone pebble conglomerate beds comprised greater than 25% of the rock encountered below 35 feet, and this is still interpreted to be the lower limestone pebble conglomerate unit. Interbedded with the limestone pebble conglomerate were sandstone and siltstone. A diabase sill was penetrated from 265 to 285 feet with siltstone beneath. This is interpreted to be a smaller intrusion emanating from the main diabase mass. Bedrock at C6D to a depth of 35 feet is sandstone and is interpreted to belong to the upper Hammer Creek formation.

Well C2, in the borrow area in the southwest corner of the property, drilled through sandstone and siltstone of the upper Hammer Creek formation from 0 to 50 feet. Well C7D, situated in the northwest corner of the property, drilled through limestone pebble conglomerate beds of the lower unit from 15 to 60 feet, and from 70 to 75 feet. At 85 feet to the bottom of this well at 300 feet, phyllite and quartzite of the Martinsburg fault slice were encountered.

Together, the various wells drilled at the site from 1974 to 1986 clearly define the site's basic geology. Wells drilled in the southern portion of the property (e.g., C3D, B7, or B6A) encounter mostly sandstone of the upper Hammer Creek formation, while wells drilled in the northern portion of the property (e.g., C4D, C5, or MP18) encounter thick beds of limestone pebble conglomerate interbedded with sandstone and argillaceous rocks of the lower limestone pebble conglomerate unit, lying unconformably beneath the Hammer Creek formation. Several of the wells, including B7, B6A, C3D, and C4D, penetrated the underlying thick diabase mass, confirming that it passes beneath the site. Well C7D, on the west side of the site, encountered the Martinsburg fault slice, confirming that it dips to the south beneath the western portion of the property.

Bed intervals penetrated by the wells as described above must not be confused with true bed thicknesses, which will be less than the drilled interval depending on dip. This difference is negligible for dips less than 10 degrees. For a dip of 25 degrees, which is the average dip of the upper Hammer Creek beds, the true thickness is approximately 10% less than the drilled interval.

The first three sets of wells drilled at the site were constructed with short screened intervals, which were often placed without regard to the location of fractured or yielding zones in the wells. This manner of construction, while marginally acceptable for monitoring purposes, is inappropriate for pump tests. In order that fractured or yielding zones would have full access to the wells in the most recent set, these wells were constructed as single cased (grouted casings) wells with open rock bores below casing. Construction of older wells and recent C series wells is depicted graphically in Figures 4.2.6.1 and 4.2.6.2.

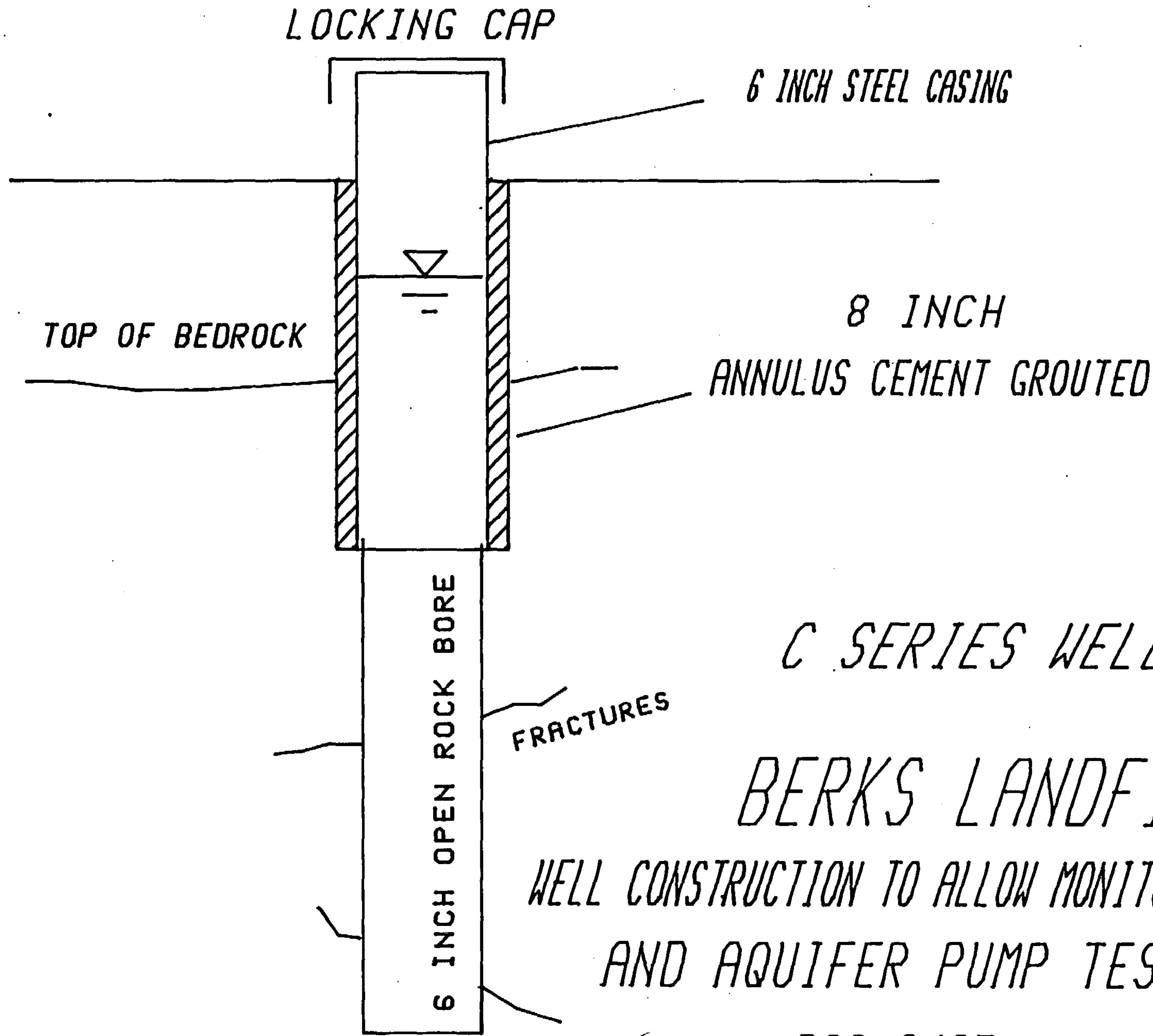


BERKS LANDFILL

CONSTRUCTION OF EARLY B SERIES WELLS AND WELLS MW14 - MW19

PGC 3/87

FIG. 4.2.6.1



C SERIES WELLS

BERKS LANDFILL

WELL CONSTRUCTION TO ALLOW MONITORING
AND AQUIFER PUMP TESTS

PGC 3/87

FIG. 2.6.2

4.3 Extent of Surface and Deep Mining

From the mid-nineteenth to the early twentieth century, iron ore was mined in open surface pits and deep mines in the site area in a group of mines known collectively as the Wheatfield Mines. The ore was magnetite, a black iron oxide, and associated with the magnetite was principally pyrite (Fool's Gold), a brass colored iron sulfide. The ore was a classic Cornwall type deposit, and was a metasomatic replacement of the limestone pebble conglomerate in the lower Triassic unit. Limestone pebble conglomerate interbeds in the upper Hammer Creek formation were also replaced with magnetite and pyrite in some areas. The Ruth mine (the westernmost Wheatfield mine), and possibly Mine Slope No. 1 (the northernmost Wheatfield mine) are in the more massive, fine grained Paleozoic Millbach formation limestone, and not Triassic limestone pebble conglomerate (see Exhibit III). Hot, iron-rich fluids emanating from the adjacent large diabase mass and cross-cutting smaller intrusions at the time of their emplacement, dissolved away pockets of limestone pebble conglomerate and limestone and left magnetite and pyrite in its place.

The Wheatfield mines are described in the three (3) pieces of historical literature in Appendix D. From oldest to most recent these are D'Invilliers (1883), Willis (1896), and Spencer (1908). Spencer gives the following summary of the mine workings:

> Most of the old workings of the group are situated near the east side of the area of sedimentary rocks which sets back from the south into the diabase dike and south of the east-west public road (Wheatfield Road) which follows the upper valley of Cacoosing Creek. About a dozen open pits have been operated at various times, and in addition many slopes and several vertical shafts. Across the creek, on the north side of the wagon road, there is an opening, formerly known as slope No. 1, and in 1905 some surface ore was taken out by means of a slope located a short distance east of these old workings. The Ruth mine is situated about one-half mile west of slope No. 1, about 200 yards east of the direct road from Fritztown to Adamstown.

The "slopes" and "vertical shafts" referenced by Spencer are two types of deep mines. A slope is an inclined tunnel from the surface to the ore body, from which other workings or gangways are driven into the ore body. Ore is removed from the deep mine by cars on railroad rails laid on the slope. A vertical shaft, is just what it implies, a vertical shaft or tunnel excavated to the ore body, from which other workings are driven into the ore body. Ore is hoisted up the shaft.

The Wheatfield ore deposits are not massive, but rather spotty, hence the old surface and deep mines at the site were also spotty, and not extensive. Spencer (1908) stated: "The ores occur as irregular masses, having a general layer-like form, interbedded with limestone strata, but the ore bodies are numerous rather than large, and lack of persistency is a marked characteristic." In discussing the nature of the deposit D'Invilliers stated: "The ore occurs in lenticular-shaped bunches from 3' to 20' thick, the top ore being black in color, and softer than ore found in the bottom levels."

The main group of Wheatfield mines occurred in a hook-shaped pattern on the north, northeast and east side of the landfill property. D'Invilliers (1883) presented a mine map of the workings situated on the north and northeast corner of the landfill as they appeared in July, 1879. The northernmost of these was the Slope No. 1 deep mine and open pit on the north side of the unnamed tributary to Cacoosing Creek. The location of this pit and deep mine is shown on Exhibit III.

The portion of the mine map covering the group of mines at the northeast corner of the property has been enlarged and superimposed on a recent large scale topographic map and is presented in Figure 4.3.1. Most of these mines are within the property retained by Mr. Sebastian Lombardo. On this map, old open pit mines are coarsely hatchured, while deep mine workings are finely hatchured. These mines are in the areas now occupied by Lombardo Equipment Company buildings, and the areas of equipment storage to the south (the "bone yard") and to the north of the buildings. A portion of the open pit at Deep mine slope No. 3 extends under the permitted landfill, and Deep Mine Slope passes approximately under the northeast corner of the permitted landfill. The mouth of mine slope No. 2 is on the east side of the landfill property, on the adjacent Ritter property. The remnants of this mine slope mouth were found, and it is a trench in the hillside along the Ritter property line with a spring-like ground water discharge.

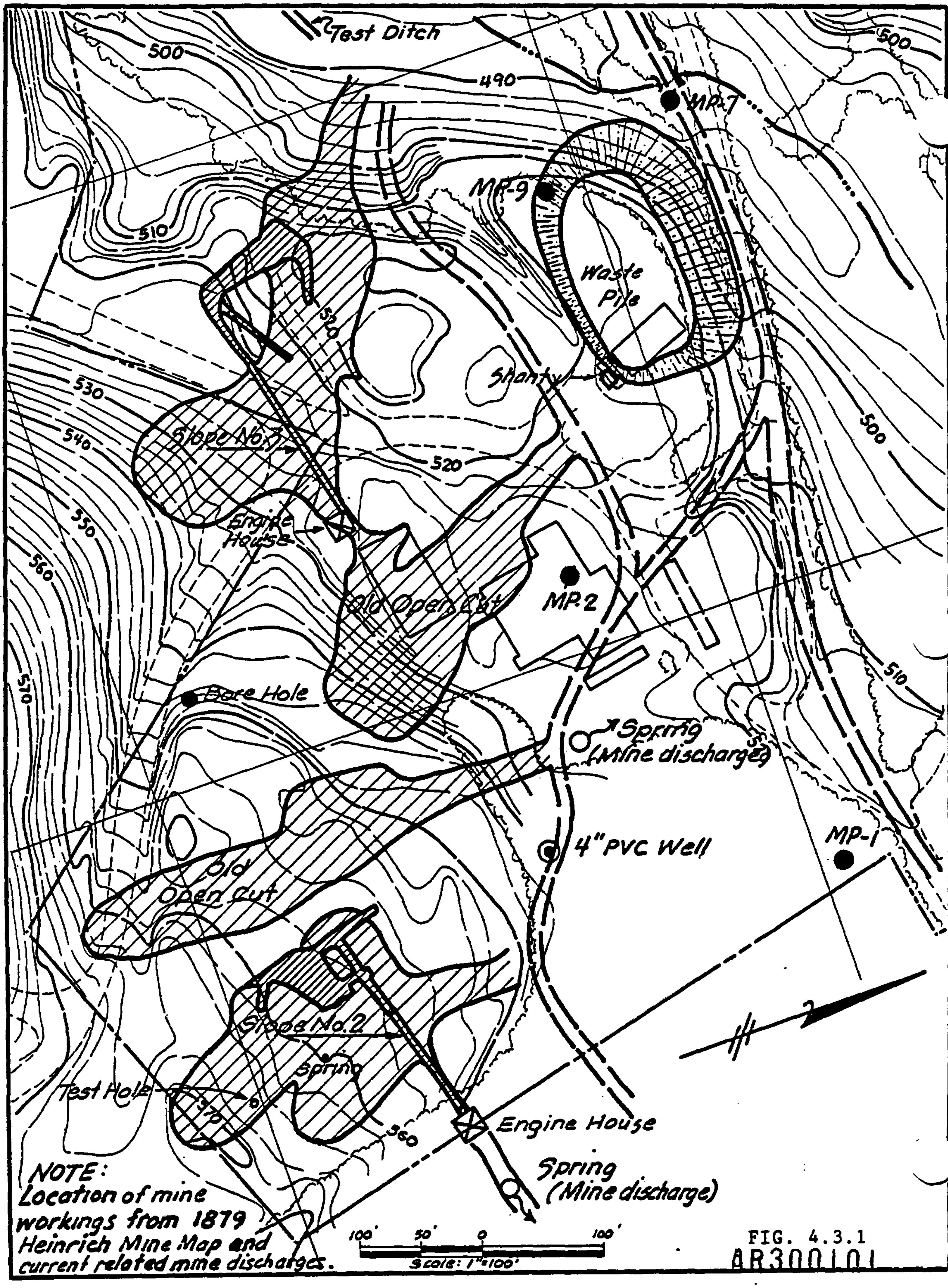


FIG. 4.3.1

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The D'Invilliers' map shows a mine waste pile along the south side of Wheatfield Road, immediately east of the point where the unnamed tributary to Cacoosing Creek crosses under the road. This waste was the soil and rock overburden from the open pits, and the non-ore rock (gangue) excavated in the open pits and deep mines. This pile still exists, and forms a steep bank along Wheatfield Road. The northernmost building of Lombardo Equipment Company is on the east side of this pile, and monitoring Well MP9 is drilled into the west side of this pile.

Aerial photographs of the site area taken over the period from 1946 to the present by the Soil Conservation Service (SCS), the U.S. Geological Survey (USGS) and by private contractors were examined and interpreted as part of the study of the site. The 1946 SCS photos were taken approximately 30-40 years after mining activity is reported to have stopped, and approximately 7 years before landfill activity is reported to have begun at the site. A copy of one of the 1946 aerial photographs, enlarged to approximately 1:10000, is included in Section 2.2 of this narrative. Included as an overlay is a sketch map of the key man-made and geologic features shown on the photo. The larger mine pits and mine waste piles which could be discerned at this scale are shown on the sketch map. There are several mine waste piles, including one on the northeast side of the property, on the north side of Wheatfield Road, on which the Cass residence is situated. The remnants of the larger mine pits shown on the D'Invilliers' map are evident on the aerial photograph. Smaller depressions, presumed to be mine pits, occur in the north-trending valley along the eastern side of the site, on the Ritter property. Some of these depressions extend to the property line, and in the east-central portion of the site, the photo shows a small cluster of depressions just within the property line.

D'Invilliers described the general progression of mining as follows: "Surface workings (open pits) were first carried on in the soft ore to the depth of 30 to 40 feet, after which a system of underground mining was pursued to gain the harder ore." Depth of deep mining can be estimated from D'Invilliers' discussion of the mine slopes:

> The most eastern workings are at slope No. 2, driven down on outcrop 140-150 feet, on a slope 45 degrees, nearly due west. Gangways have, as usual, been driven north and south.
>
> One the north side of public road, at workings called Slope No. 1 on map, ore has also been mined . . . The slope goes down on ore dipping 40 degrees to the S.E. . . . These workings are also abandoned, but were carried down nearly 100' on slope, with gangways east and west. The ore body is from 2 to 12 feet thick.
>
> About 200 feet S.W. of this another parallel trap dyke cuts through the workings at Slope No. 3, here down 270 feet on a 35 degree dip.

The distances stated by D'Invilliers above are measured along the mine slope. Converting these to depths using the mine slope angle, Slope No. 1 was carried to a depth of 64 feet, Slope No. 2 to a depth of 106 feet, and Slope No. 3 to a depth of 155 feet.

Field inspection of the Ritter property, on the east side of the permit modification area, revealed numerous mine related depressions. The larger depressions are greater than 30 feet across, and these are probably surface mine pits. Trench-like depressions occur which are probably either exploratory trenches or collapses over deep mine slopes. Numerous small circular closed depressions occur which are generally 5-10 feet across and 2-3 feet deep. As discussed in Section 4.2.5 of this narrative, these are interpreted to be sink hole collapses associated with the piping of soil into underlying mine voids or solution voids in the lower limestone pebble conglomerate unit. A sketch map of the mine related depressions on the Ritter property is included on Exhibit I.

One trench-like depression on the Ritter property was found to have a set of railroad rails projecting at an angle of 52 degrees from the horizontal, dipping towards the landfill property. The location of these rails is shown on Exhibit I. These rails are situated approximately 90 feet east of the property line, and the trench-like depression containing the rails trends due west toward the landfill property. This is interpreted to be the mouth of an old mine slope, with the mine car rails still in place. Assuming this slope or other mine slopes on the Ritter property were carried to the distances reported for Slopes No. 1, 2, and 3, the deep mining could extend under the eastern side of the permited landfill area. As with the rest of the Wheatfield mines, these mine workings are expected to be spotty, and not extensive.

Initial landfilling at Berks landfill in the 1950's began in the mine pits and associated deep mines in the northeast corner of the property and on the Lombardo property, as was discussed in Section 2.2. Based on interviews with long-term employees of the landfill, mine shafts or evidence of mine shafts or slopes were encountered in three (3) areas within or near the current Berks Landfill property as shown on Exhibit I. A mine shaft was reported on the north side of the permitted landfill, just south of the access road. This shaft was reported to have been filled with boulders before it was covered with a soil liner and then refuse. A mine shaft was encountered on the south side of the southern area of equipment storage of Lombardo Equipment Company known as the "bone yard," during excavation in this area. The exact location of this shaft is uncertain, and it may have been encountered further to the south within the current landfill property. When fully opened, this "shaft" was reported to have been greater than 10 feet across. After it was encountered, it was broken open with a large tracked backhoe, and filled with soil and rock. Mine timbers were also reported to have been encountered to the west of this second shaft. Other mine shafts or slopes were reported to have been filled on the portion of the original landfill property that was retained by Mr. Ben Lombardo.

4.4 Ground Water

4.4.1 Hydrogeology

Shallow ground water exists at the site under unconfined or water table conditions. Deeper ground water within the lower beds of the Hammer Creek formation or the lower beds of the lower limestone pebble conglomerate unit is generally semi-confined.

A water table contour map for the site was prepared based on water level measurements collected at the site on 10/20/86 (prior to installation of C-series wells). This water table contour map is based on water levels measured at twelve (12) wells, five (5) springs (including mine-related discharge points), and the elevations of perennial streams and areas of persistent ground water seepage (excluding leachate toe seeps). At deep-shallow well pairs, the water level from the shallow well was used, as the deeper well was likely to reflect a deeper hydraulic potential that was either higher or lower than the true water table.

The water table was again contoured based on water level data collected on 2/2/87. This later water table contour is based on water levels in 19 wells (including mine-related discharge points) and the elevation of perennial streams and areas of persistent ground water seepage (excluding leachate toe seeps). As before, only the water level in the shallow well of a deep-shallow pair was assumed to represent the water table. The 2/2/87 water table contour map is essentially the same as the earlier 10/20/86 contour map, although as much as a 10 feet increase in the position of the water table was noted in some higher portions of the site due to recharge which occurred in the wet weather between 10/20/86 and 2/2/87. The 10/20/86 and 2/2/87 water table contours are presented on Exhibit VI.

There are no surprises in the water table contour map, it mimmicks topography as is the usual case. Across the eastern landfill, the gradient is to the north toward the unnamed tributary to Cacoosing Creek and to the northwest, towards the central drainageway. The gradient is to the north towards the unnamed tributary of Cacoosing Creek in the central portion of the inactive landfill; to northeast into the central drainageway on the east side of the inactive landfill; and to the northwest toward the western drainageway on the west side of the inactive landfill. In the borrow area in the western portion of the property, the gradient is to the northeast towards the western drainageway.

Recent pump tests of the C series wells indicate a degree of confinement between the shallow zone to depths less than 100 feet, and the deeper zone of the aquifer from 100 to 300 feet. When the deep wells at well pairs C4S-C4D and C7S-C7D were pumped, the shallow wells situated less than 10 feet away showed no drawdown, even though 15 feet or drawdown was generated at C7D and 60 feet of drawdown at C4D. A pump test at well pair C6S-C6D did show interference between the deep and shallow well, indicating less confinement of the deep zone in some areas. When the water level in C6D was drawndown 70 feet, C6D responded with approximately 1 foot of drawdown. Well pair C6S-C6D is situated at a fracture trace intersection, in a valley bottom, and fracturing may be pervasive enough between beds in this between beds in this environment to limit confinement.

Recharge zones are characterized by decreasing head with depth, while discharge zones are characterized by increasing head with depth. In recharge zones, the water level in the deep well of a deep-shallow well pair is lower than the water level of the shallow well in the pair; while in a discharge zone, the water level in the deep well is higher than the water level of the shallow well in the pair. In a recharge zone, ground water beneath the water table is moving vertically downward to greater depths in the aquifer, as well as moving laterally. In a discharge zone, ground water is upwelling from depth within the aquifer, as well as moving laterally. Typically, hilltops are recharge areas while valley bottoms are discharge zones, however site geology can alter this usual pattern. Because hydraulic potential or head can vary with depth in an aquifer, the "true" water table is defined only by shallow wells.

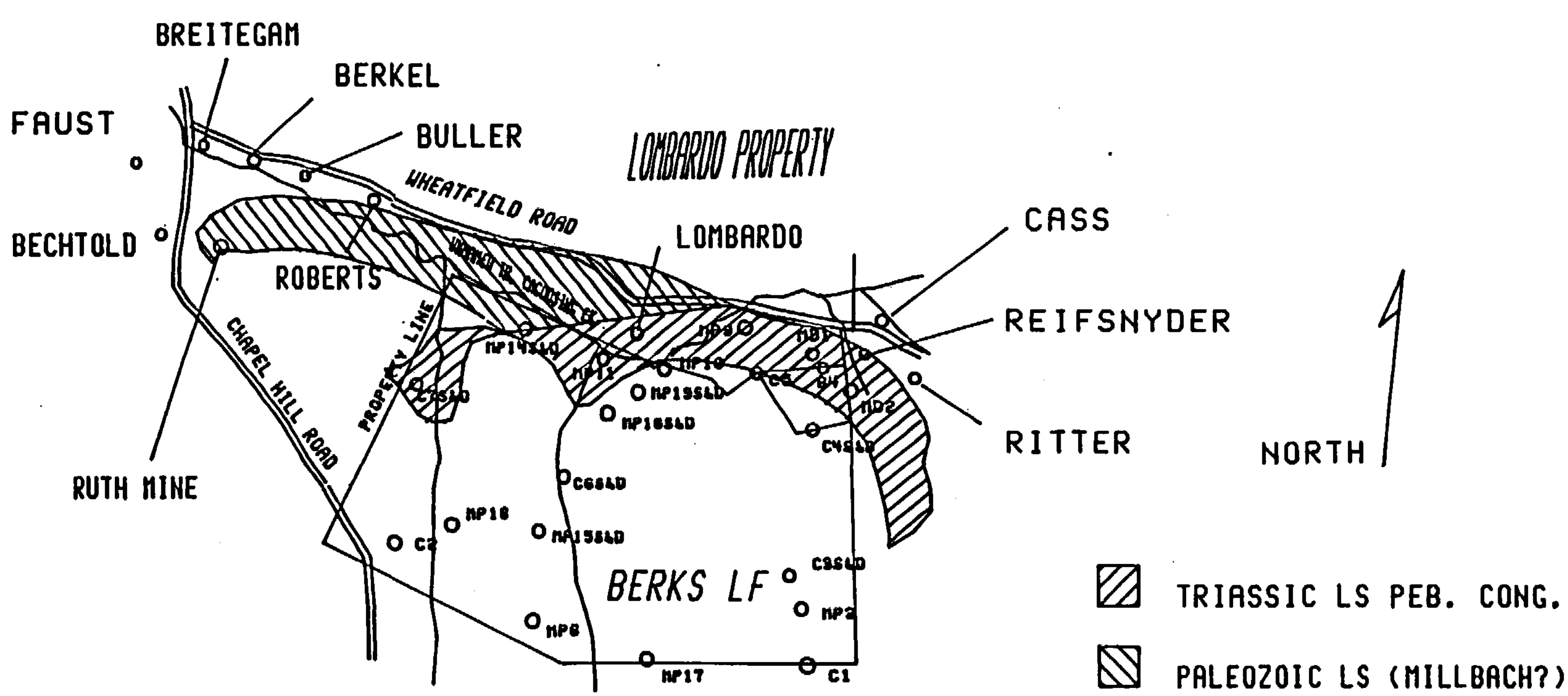
The relative water levels of seven (7) well pairs at the site are summarized below based on water level measurements in October 1986, and January, 1987:

Well Pair		Relationship of Deep Well Water Level to Shallow Well Water Level	Position In Flow System
MP14	(10/86)	8' lower	Recharge
MP15	(10/86)	14' lower	Recharge
MP18	(10/86)	2' lower	Recharge
C3	(1/87)	11' lower	Recharge
C4	(1/87)	7' higher	Discharge
C6	(1/87)	4' higher	Discharge
C7	(1/87)	25' lower	Recharge

The recharge zone setting of well pairs MP15 and C3 was expected as these are located on upper hill slopes. The discharge zone setting of C4 and C6 was also expected as these are located either on lower hill slopes or in valley bottoms. The recharge zone setting of well pairs MP14, MP18, and C7 was unexpected, however, as these three well pairs are all situated on lower hill slopes or valley bottoms, near the unnamed tributary to Cacoosing Creek on the north side of the landfill. Clearly the carbonate rocks (lower limestone pebble conglomerate unit or Millbach formation) in the west-trending valley containing the unnamed tributary to Cacoosing Creek on the north side of the site are exerting a strong underdraining effect which is inducing recharge zone conditions in this area. Inspection of Exhibit V shows that the water levels at Wells MP10 and MP11 are slightly below the level of the stream, which may be another result of the underdraining effect of the carbonate rocks in the valley bottom.

The lower limestone pebble conglomerate unit and the Paleozoic limestone to the west effectively join in the valley bottom where the Martinsburg is thin or absent, forming one carbonate aquifer. The outcrop area of these units are shown on Exhibit III and in Figure 4.4.1.

The remnants of the Wheatfield deep mines in the northeast corner of the site are also exerting an underdraining effect. Even though many of these



OUTCROP AREA OF CARBONATE AQUIFER

NOTE: BOTH UNITS DIP TO THE SOUTH EXCEPT ON THE EAST SIDE OF THE SITE WHERE THE LS PEB. CONG. DIPS WEST

FIG 4.1

AR300111

workings have collapsed or have been infilled, they would be filled with relatively loose material, and still function as high permeability conduits. The best indirect evidence of this is the spring-like mine discharge on the Ritter property at the mouth of deep mine Slope No. 2.

Most permeability in the underlying rocks at the site is secondary or fracture permeability. Weathering has created some interstitial porosity, particularly in those sandstones which have highly weathered to almost a sand, and in the limestone pebble conglomerate beds which have disaggregated to a gravel due to weathering.

Dipping, bedded sequences of rock such as the upper Hammer Creek formation typically exhibit a preferential permeability or component of ground water flow parallel to strike. This is in part due to the sandwiching of softer, less fractured beds, between more brittle, better fractured beds, and in part due to the predominance of bedding plane partings. Differential weathering is also a significant factor at this site which would encourage strike-parallel flow in the upper Hammer Creek formation beds. The limestone pebble conglomerate interbeds in the upper Hammer Creek formation are more solution-prone than the surrounding sandstone beds, which would result in a relatively higher permeability in the limestone pebble conglomerate interbeds. This was confirmed by the occurrence of a yielding zone at the level of a limestone pebble conglomerate interbed in Well C3D. Beds of highly weathered sandstone which is almost decomposed to a sand, between less weathered sandstone beds, would also encourage strike-parallel flow within the more weathered beds. Wood (1980) makes the following comments about strike parallel ground water flow:

> The greatest permeability in the Gettysburg and Hammer Creek Formations, and thus the greatest movement of water in response to pumping is parallel to the strike of bedding. Pumping-test data show that the maximum drawdown occurs along strike from the pumped well. Observation wells only a few hundred feet from the pumped well in a direction perpendicular to the strike commonly show little or no drawdown.

While strike-parallel ground water flow in the upper Hammer Creek formation is expected to predominate, local down-dip flow is also likely. However, with an average 25 degree dip in these upper beds, down-dip flow would quickly reach the effective depth of the aquifer. For instance, at a 25 degree dip, down-dip flow would reach a depth of 300 feet, which is the approximate effective depth of the aquifer, within a lateral distance of 600 feet. Therefore, down-dip flow is only locally important at the site, and would have its greatest influence in areas of low dip (less than 20 degrees).

The strike-parallel, anisotropic permeability which characterizes the Hammer Creek and similar bedded units is expected to be less evident in the lower limestone pebble conglomerate unit. This is due to the more massive bedding, susceptibility to solution enlargement of joints and bedding plane partings, and the more gentle dip of the lower limestone pebble conglomerate unit beneath much of the northern portion of the site.

The fractured zones represented by the fracture traces and lineaments on Exhibits II and IV would also be preferred avenues of ground water flow. Two of the larger leachate seeps at the western landfill area correlate to fracture traces or fracture trace intersections. These are the discharge to the north of MW6 and the discharge at the northeast corner of the western fill, west of Lagoon #4. The C series wells at the site were located on fracture traces or at fracture trace intersections to intercept these preferred avenues of flow. Previous monitoring wells were apparently randomly located.

4.4.2 Aquifer Characteristics and Pump Test Results

Yielding characteristics of the Triassic Hammer Creek Sandstone aquifer and the related Triassic Gettysburg aquifer, and the yielding characteristics of Triassic Diabase are described by Wood (1980). Longwill and Wood (1985) describe transmissivities for the related Triassic Brunswick aquifer. The Brunswick and Gettysburg aquifers contain must less sandstone than the Hammer Creek, but are generally comparable. Longwill and Wood cite a range in transmissivity for the Brunswick of 100 to 5000 GPD/FT, with a median in the range of 600-1100 GPD/FT, depending on the method used to determine transmissivity.

Wood (1980) reports median specific capacities for wells in the Hammer Creek formation of 1.2 GPM/FT for non-domestic wells (large diameter and deep industrial and public water supply wells, and 0.45 GPM/FT for domestic wells.

Early descriptions of the yielding characteristics of the Triassic sandstones and shales of Southeastern Pennsylvania were given by Hall (1934). A histogram of well yields for Triassic sandstones and shales presented in Figure 4.4.2.1 was developed from data provided by Hall (p. 64). This data shows that

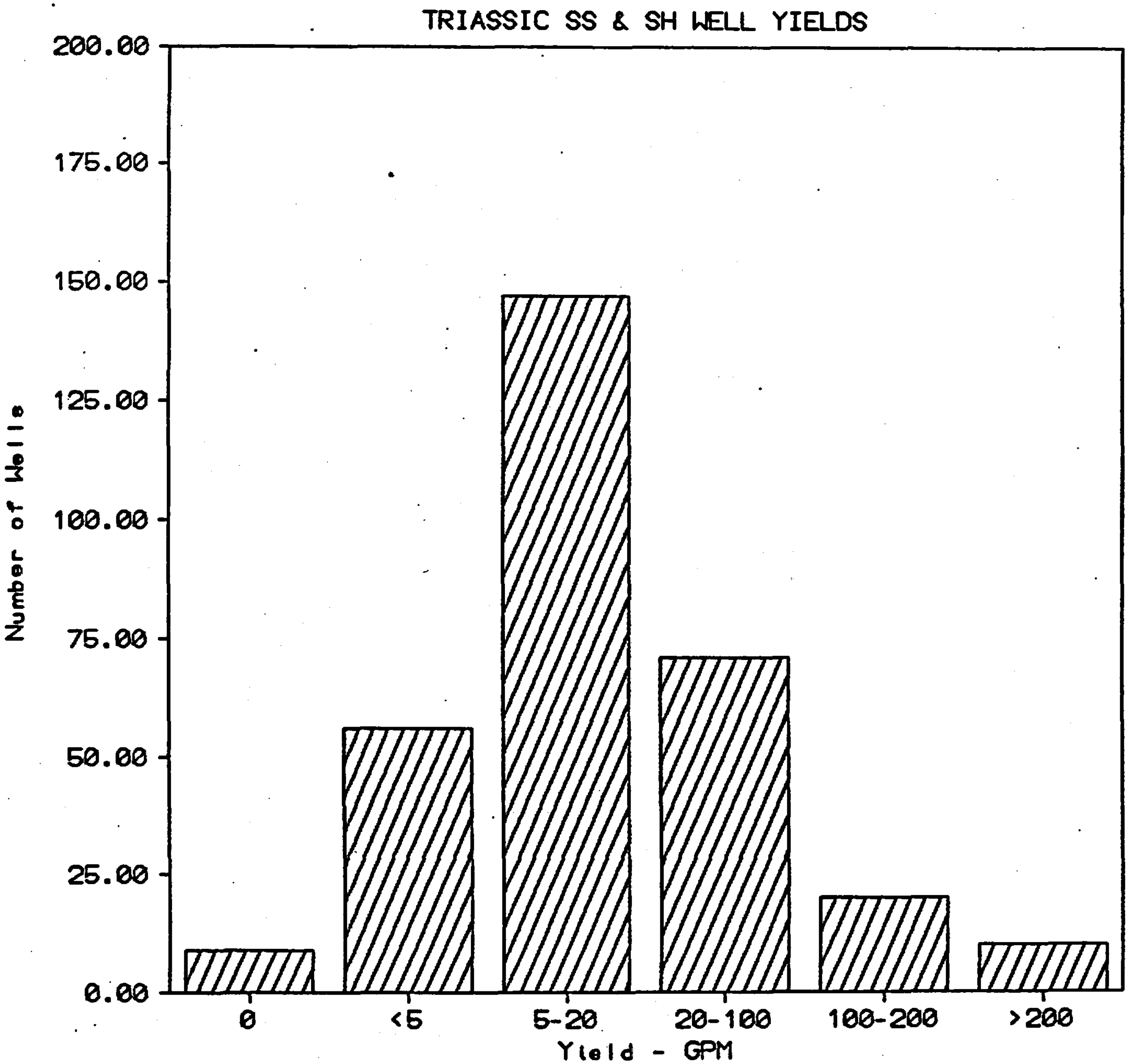

TRIASSIC SS & SH WELL YIELDS
200.00
175.00
150.00
125.00
100.00
75.00
50.00
25.00
0.00
Number of Wells
0
<5
5-20
20-100
100-200
>200
Yield - GPM

FIG. 4.4.2.1

the average expected yield is in the range of 5 to 20 gpm with nearly half of the 313 wells inventoried exhibiting yields in this range.

Concerning the Triassic diabase, Hall makes the following comments (p.66):

> The dikes doubtless act as barriers to the water in the porous Triassic Sandstones . . .
>
> Diabase is very impervious but the upper part is usually deeply weathered, and from the weathered material most wells draw their supplies.

Wood (1980) makes the following similar comments about the diabase:

> (p.19) The diabase weathers to a maximum depth of about 30 feet, and almost all groundwater storage occurs in this zone. Water moves through joints and other fractures. The size of the openings decreased rapidly with depth, and fractures capable of transmitting water are rarely found below 150 ft.
>
> (p.29) The diabase is the poorest aquifer. At least 10 percent of the wells in diabase fail to yield enough water for even a barely adequate domestic supply. Wells yielding more than 30 gpm are rate. Because it is such a poor aquifer, diabase dikes and sills tend to act as farriers to the movement of water through the Gettysburg and Hammer Creek formations.
>
> (pp.1-2) Median yields of nondomestic wells are 110, 85, and 6 gallons per minute in the Hammer Creek Formation, Gettysburg Formation, and diabase, respectively. Median specific capacities of nondomestic wells are 1.2, 1.0 and 0.07 gallons per minute per foot of drawdown for the same units.

Based on these reports, thick diabase units in the Triassic basin would have Transmissivities an order of magnitude lower than the Hammer Creek formation, and would function as aquitards.

Little information is published on the yielding and aquifer characteristics of the Triassic limestone pebble conglomerates, because these beds are irregular and of limited extent along the northern Triassic Border. Wood (1980) comments on Triassic limestone pebble conglomerates in the Gettysburg and Hammer Creek formations.

> The limestone conglomerate is one of the most variable aquifers, but data on this unit are scarce. Nearly half the wells yield large to very large supplies of water, but some are barely adequate for domestic use. This variability is controlled by the size of the openings in the rock, some of which have been developed by solution, and whether a well intersects them.
>
> In general, well yields in the limestone conglomerate are low in York and Cumberland Counties, and high in other areas. The median yield of six wells in Adams County is 225 gpm. Specific-capacity data indicate that even the poorest of these six wells could yield more than 100 gp,, although their median depth is only 116 feet. Yields of five wells in York and Cumberland Counties ranged from 7 to 75 gpm and median was 25 gpm. These five wells have a median depth of 300 feet.

Considering the thick bedded to massive characteristic of this unit at the site, its limey cement, and the occurrence of small sinkholes where this unit outcrops in the lower portion of the western drainageway, the characteristics of this unit are expected to be similar to the nearby Cambro-Ordovician carbonate aquifers, which are generally higher in transmissivity than the Triassic sandstones and shales due to solution enlargement of joints and bedding plane partings. The underdraining effect exerted by the lower Triassic limestone pebble conglomerate unit (see discussion in Section 4.4.1) in the valley bottom is good indirect evidence of its higher transmissivity. However, the lack of continuous beds within this unit, with numerous evidenced pinch-outs and interlayers of non-carbonate beds, would tend to limit the overall effective transmissivity of the unit.

The driller reported estimated yields of 0.5 to 30 gpm for the eleven C series wells. These wells were all located on fracture traces, so the range of yields is expected to be higher than for randomly located wells. The ten (10) wells drilled in early 1986 (MW14 - MW19; 10 wells at 6 sites) had reported yields of 0 to 20 gpm and these were randomly sited wells. Of these 21 wells, 3 of the 4 with reported yields above 10 gpm were drilled into the lower Triassic limestone pebble conglomerate unit, which is again good evidence that this is a generally more permeable unit due to solution enlargement of joints or bedding plane partings. These were C5, MW14D (mistakenly labeled MW15D by the driller), and MW19D.

The eleven (11) C series wells were constructed with open rock bores, as is standard well construction practice in the area, to allow aquifer pump tests in addition to ground water quality monitoring. Previous monitoring wells were constructed with well screens generally placed without regard to the location of fractured or yielding zones, and as a result these earlier wells could not be used for pump tests. The only information on the yielding characteristics of these older wells is the driller's reported yield prior to construction of the screened inner casing.

In January and early February 1987, the eleven C series wells were subjected to short duration pump tests up to 1 hour in length to determine approximate transmissivity in the area of each well. Pumping rate ranged from 6 to 9 gpm, depending on head, but was approximately constant at each well. Four of the eleven wells, C1, C2, C5, C7D, produced sufficient yield to be pumped for longer than 30 minutes. Transmissivity at these four (4) wells was calculated by the standard graphical straight line method, and these plots are presented in Appendix C. No corrections were made for well loss, dewatering or partial penetration of the aquifer. Three of these four tests showed boundary conditions. Wells C2 and C5 showed barrier boundaries, indicating that the high transmissivity zones in the area of the wells are of limited areal extent. Well C7D shows a recharge type boundary, which could represent either a true recharge boundary due to the nearby stream, but more likely delayed gravity drainage or leakage into the deep, semiconfined yielding zones of the well.

The seven (7) wells which produced low yield were all drawndown to the pump (pump set at 50-70 feet) within 20 minutes. These wells all had 10-20 minute specific capacities of from 0.12 to 0.27 GPM/FT, and the aquifer in the area of these wells is of low transmissivity. Most of the water produced during the pump tests of these wells was actually derived from casing storage and not from the aquifer. The approximate transmissivity at these 7 wells was calculated by the numerical method of Walton (1970, p.315).

The calculated transmissivities of the 11 C series wells is presented in Table 4.4.1. As is typical of fractured rock aquifers, the range of transmissivities covers three orders of magnitude (10-100, 100-1000, and 1,000-10,000 GPD/FT). The average transmissivity is approximately 1100 GPD/FT. Figure 4.4.2.2 presents this data in the form of a histogram.

BERKS LANDFILL

TABLE 4.4.1

Well	Transmissivity From Time - Drawdown Data (Straight Line Method) GPD/FT	Transmissivity From Specific Capacity Data (Walton, 1970, p. 315) GPD/FT
C1	245	
C2	9293	
C3S		84
C3D		91
C4S		139
C4D		58
C5	1936	
C6S		58
C6D		55
C7S		64
C7D	228	

Avg. = 1114 GPD/FT

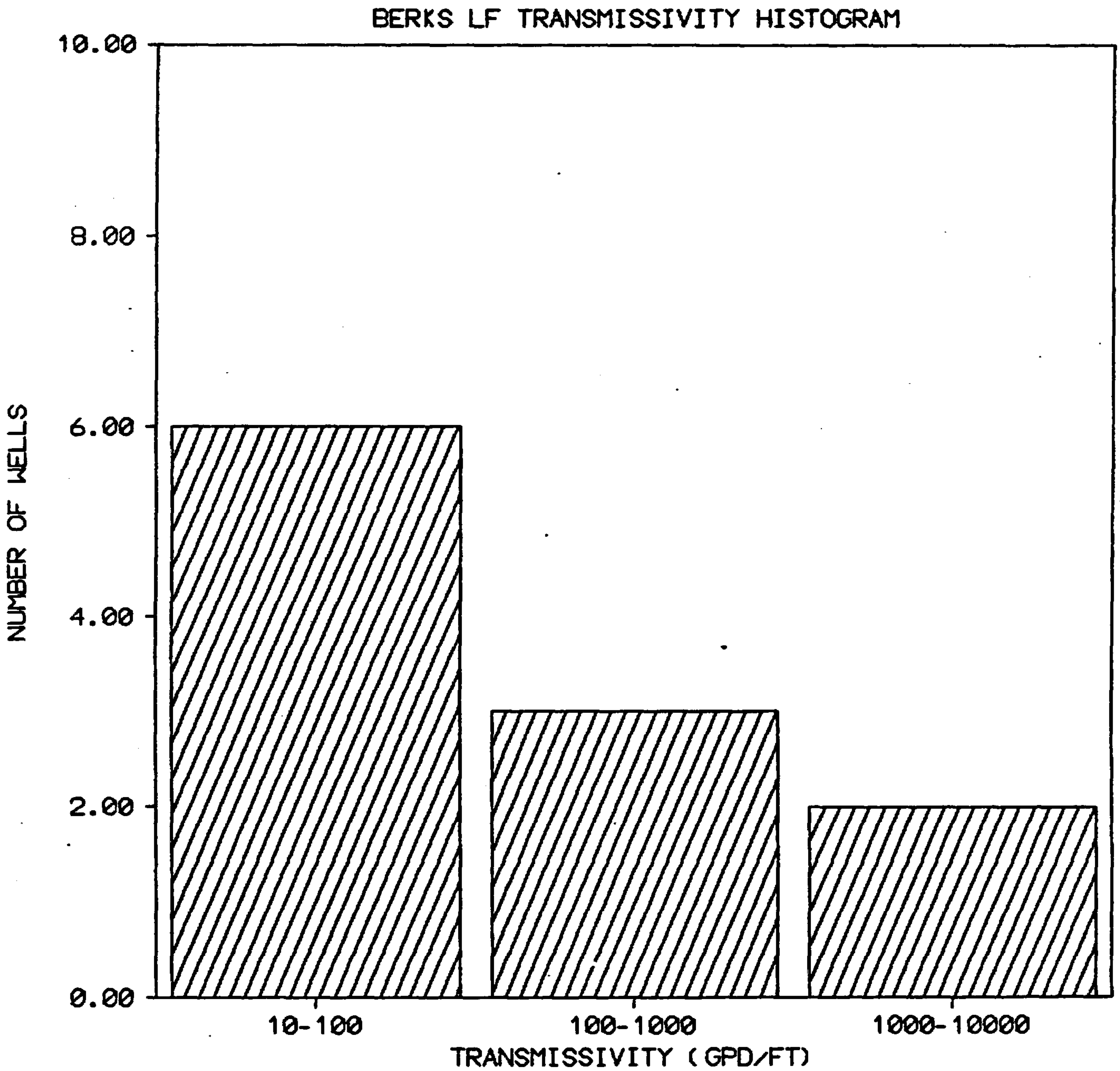

BERKS LF TRANSMISSIVITY HISTOGRAM
10.00
8.00
6.00
4.00
2.00
0.00
NUMBER OF WELLS
10-100
100-1000
1000-10000
TRANSMISSIVITY (GPD/FT)

FIG. 4.4.2.2

There is no clear correlation between transmissivity and aquifer in this limited set of data. Interestingly, the Diabase well, C1, shows a fair transmissivity. Inspection of the well log for this well indicates that it obtained its yield in a highly weathered zone at 30 feet. This is consistent with Hall's comments (1934), and the generally held view that the diabase has its greatest effective permeability in the weathered zone. The highest transmissivity, 9200 GPD/FT was obtained in a 50 foot deep well in the Hammer Creek sandstones. The barrier boundary shown during the pump test of this well indicates that this high transmissivity zone is not extensive. The second highest transmissivity, 1900 GPD/FT, was found in Well C5 which taps the lower limestone pebble conglomerate unit. However Wells C4S, C4D, C6S, C6D, and C7S also tap the lower pebble conglomerate unit, and these all had transmissivities lower than 150 GPD/FT.

The old deep mine workings and collapsed zones associated with these old workings would represent high permeability zones. However, in light of the fact that these mines were of limited extent, their impact on ground water movement would be localized.

The average or approximate velocity of ground water at the site can be estimated by using the basic ground water velocity equation:

$V = KI/SY$ where V = Velocity

K = Permeability

I = Hydraulic Gradient

SY = Effective Porosity or Specific Yield

An average transmissivity of 1100 GPD/FT equates to a permeability of 0.5 ft/day for an aquifer with an effective depth of 300 feet. Using a gradient of 10% which is typical along the northern side of the fill areas, and a specific yield of 0.5 or 5%, the average ground water flow velocity would be 1 foot per day. Using a specific yield of .01 of 1%, the velocity would be 5 feet per day. These represent average flow velocities. Flow in solution conduits in the carbonate aquifer can be faster than these calculated velocities.

4.4.3 Nature and Pattern of Contamination

A study of the spatial pattern of the contaminants at Berks landfill was the heart of the ground water quality portion of this investigation. Ground water contamination from an ongoing source of contamination spreads in a front, affecting an area, and leaving a trail. The contaminated area downgradient of a contamination source is referred to as a plume. The areal or horizontal extent of the contamination plumes at Berks landfill is discussed in Section 4.4.3.1, and the vertical distribution discussed in Section 4.4.3.2.

4.4.3.1 Areal Patterns

Four isocon plots of key water quality parameters or pollutants are presented in this section as Figures 4.4.3.1 through 4.4.3.4. These are for the three indicators Electrical Conductivity, Chloride, and Sulfate, and for the volatile contaminants which are of greatest concern at Berks, the Chloroethenes. The plots are based on analyses of shallow monitoring points only, so they represent quality in the water table aquifer. The concentrations presented were

ISOCON TCE + 1,2 DCE + CE

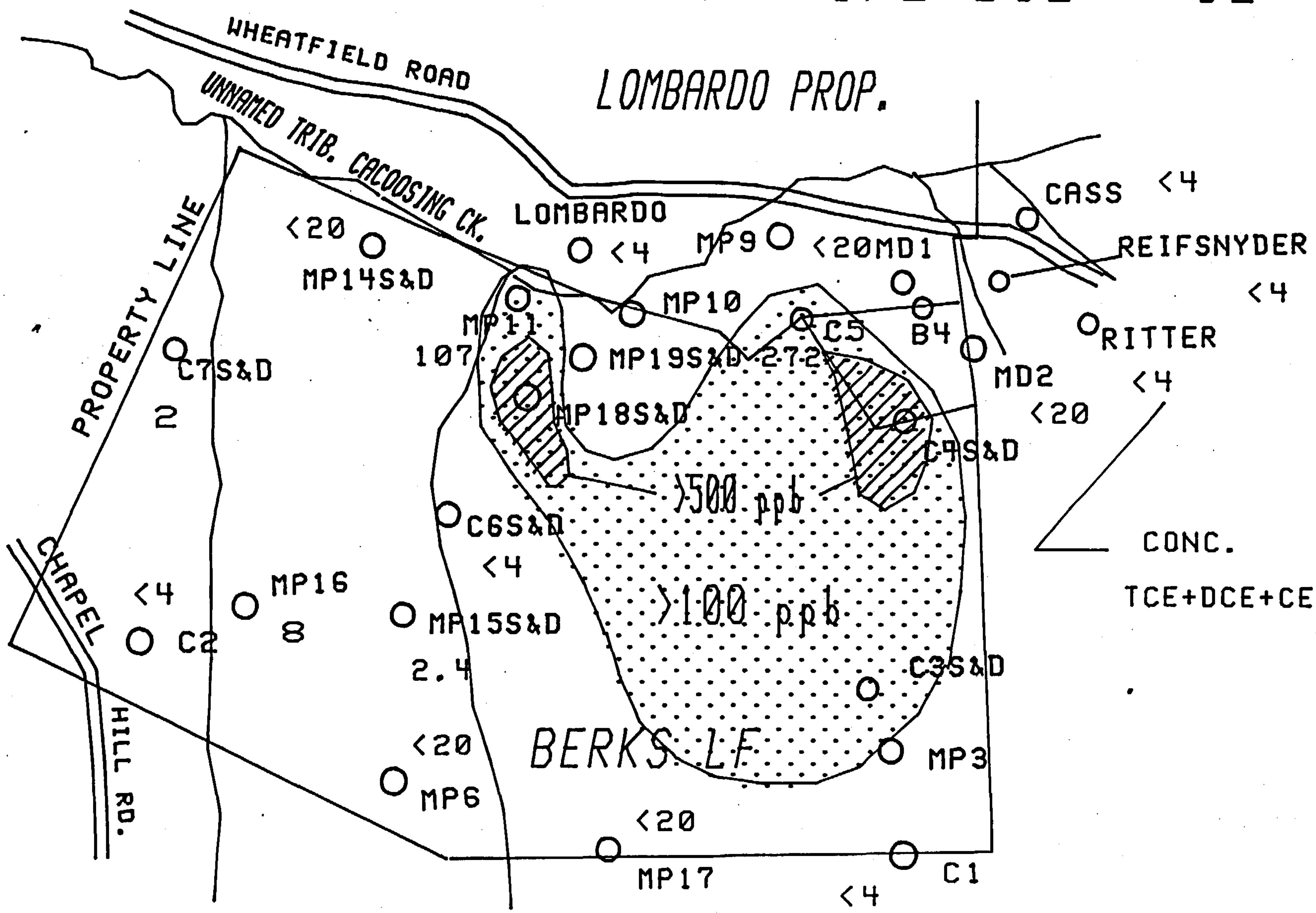


FIG. 4.4.3.4

AR300127

ISOCON - SULFATE

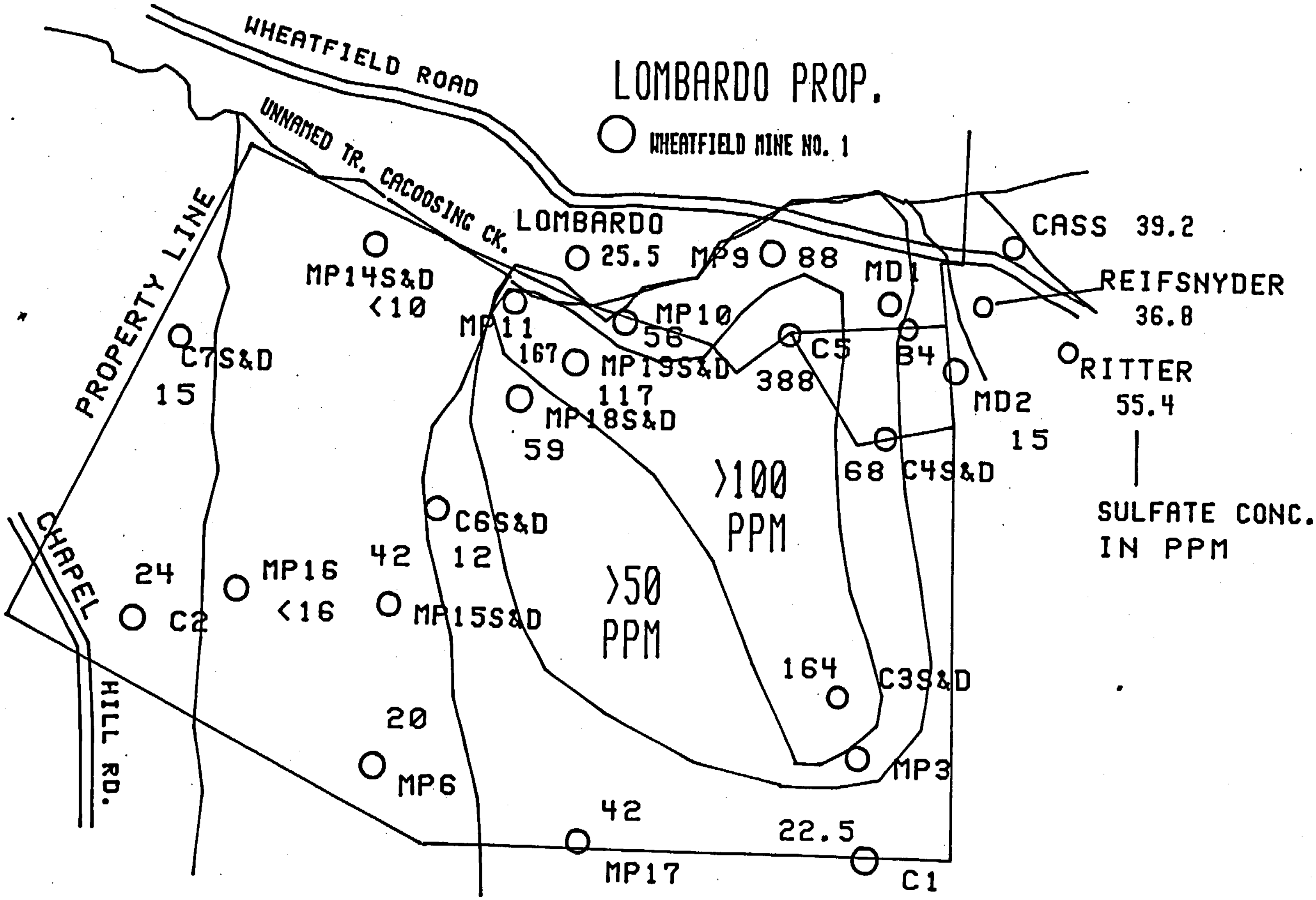


FIG. 4.4.3.3

ISOCON CHLORIDE

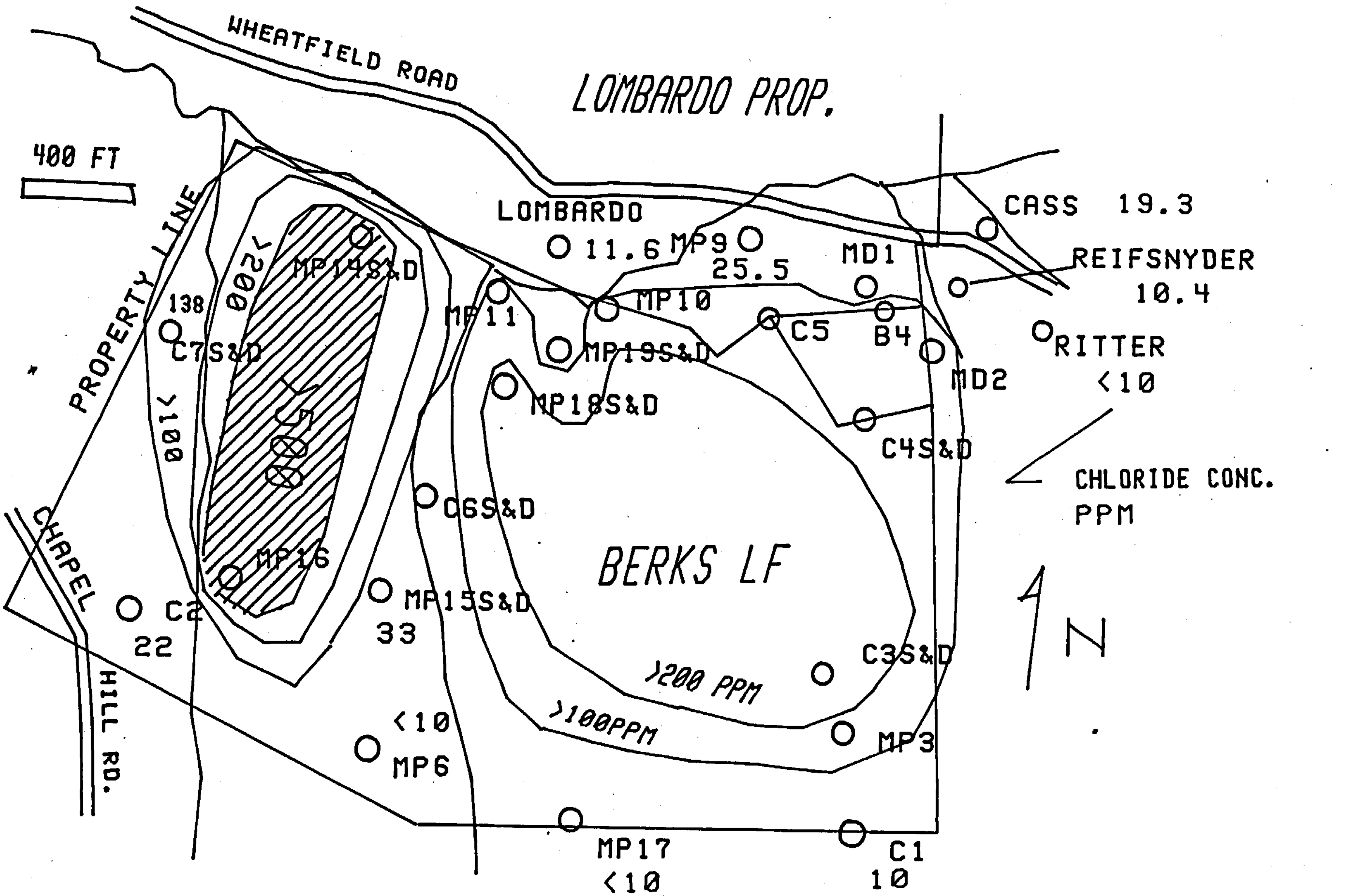


FIG. 4.4.3.2

ISOCON - CONDUCTIVITY

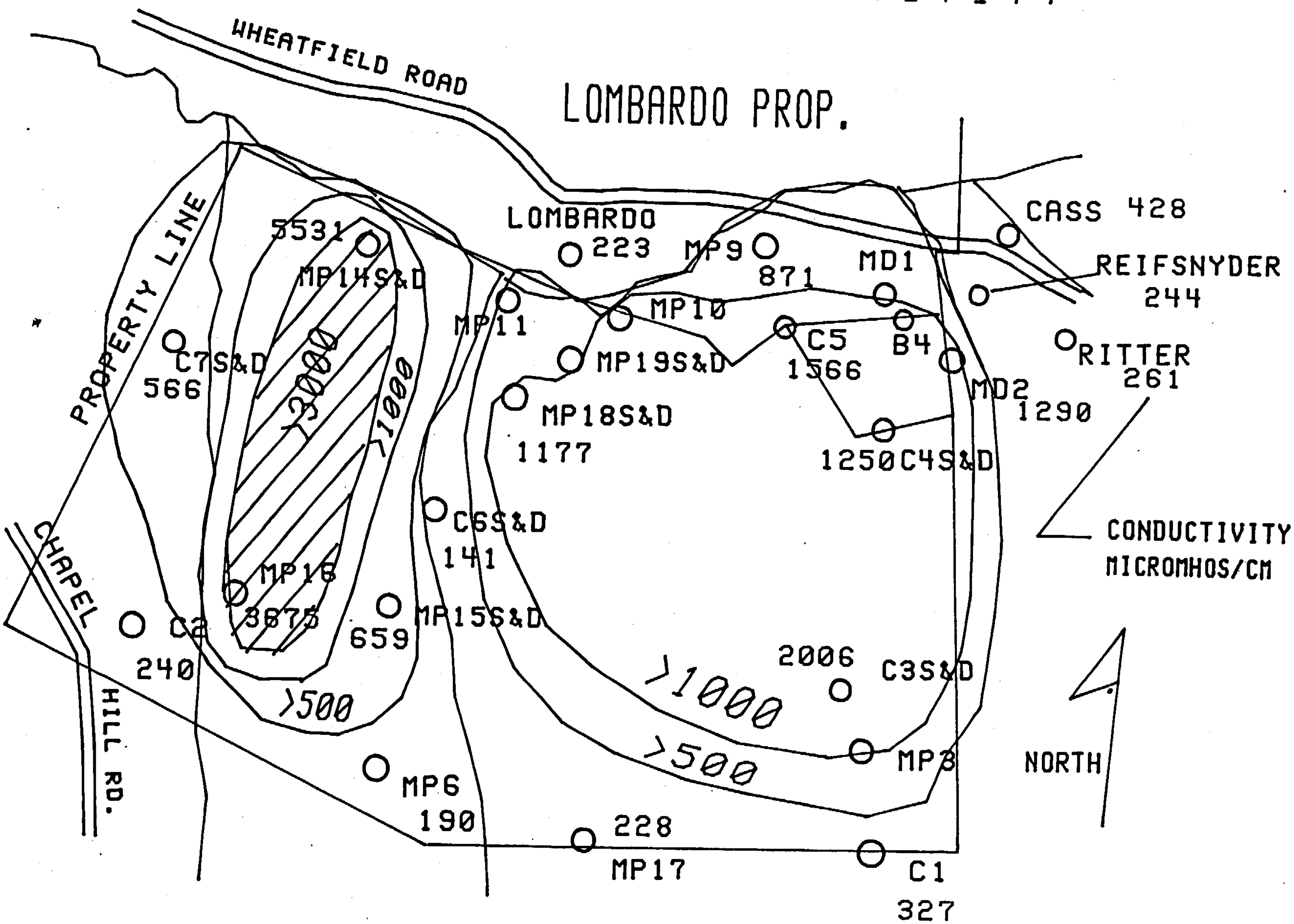


FIG. 4.4.3.1

for samples collected at the site over the course of this study from December 1986 to the beginning of February, 1987. The laboratory reports for these analyses are presented in Appendix E, along with a description of field sampling and QA/QC procedures.

The first plot of Electrical Conductivity (E.C. or Conductivity) shows two (2) plumes of high dissolved solids, one stemming from each of the two major fill areas. Some of the elevated dissolved solids are probably a result of sulfate related to the Wheatfield mineralization. Strike-parallel control of the plums over the southern and central portions of the site is evident. Conductivity at C6S is quite low, even though this well is between the two large fill areas. This is in part a result of the effectiveness of the interceptor drain on the west side of the eastern fill area, and in part a result of the strike-parallel control on ground water flow which encourages a northward migration of contaminants with the Hammer Creek beds. On the east side of the eastern fill area, the plume does not cross the north-trending drainageway near the Mine Slope No. 2 discharge, and the conductivities at the off-site residences are all less than 500 micromhos/cm. On the western side of the western fill area the plume does cross the north-trending drainageway, and the conductivity at C7S is greater than 500 micromhos/cm. The higher permeability and underdraining effect of the lower limestone pebble conglomerate unit which outcrops in this area is interpreted to be responsible for this migration of contaminants beneath the western north-trending drainageway. Background conductivities at C1, MW17, MW6, and C2 are in the range of 190-327 micromhos/cm. On the north side of the site, the plumes terminate at the unnamed tributary of Cacoosing Creek. Discharge to this stream has limited the extent of contamination.

Anomalously high conductivity occurs in the central portion of the plume at the western landfill, where conductivity at MP14S is over 5500 micromhos/cm and conductivity at MP16 is over 3600 micromhos/cm. An anomalously high conductivity at MP16 was anticipated as this well produces virtually raw leachate, however the level obtained is higher than that obtained in the average raw leachate collected by the interceptor and underdrain system. The conductivity at MP14S is approximately twice that of the raw leachate.

The isocon map for Chloride (Figure 4.4.3.2) shows the same basic pattern as the Conductivity isocon map. As chloride is a conservative contaminant and a fairly reliable leachate indicator parameter, this isocon map should define the leachate plumes. The chloride concentration of 138 mg/l at C7S confirms that the plume has crossed the western north-trending drainageway as a result of the underdraining effect of the lower limestone pebble conglomerate unit. Background Chloride concentrations at C1, MW17, MW6, and C2 are in the range of <10 to 22 mg/l. A chloride concentration of <10 mg/l at C6S again shows the effectiveness of the interceptor drain along the western side of the eastern fill area and the strike-parallel pattern of the plumes. High Chloride extends through MW18S, MW19S, MW11, MW10, C5, B4, MD#3 (mine discharge by trailer), and MD#2 (Mine Slope #2 discharge). The extension of the high chloride plume through these points indicates that the interceptor drain on the north and east sides of the site is not totally effective. This is interpreted to be the result of the underdraining effect of the lower limestone pebble conglomerate unit and deep mines in this area. The high chloride in this area could also stem from waste which was placed to the north of the perimeter drains, outside of the permitted area. Known fill areas occur between C5 and MW10, and to the north of C5, and these are to the north of the interceptor drain system. There is a slight indentation in the chloride plume in the area of MW19S where chloride is less than at MP10, MP11, and MP18S. This is interpreted to result from anisotropy in the bedrock aquifer, and possibly from strike-parallel control. The chloride concentration at the Ritter, Reifsnyder, Cass, and Lombardo residences are all at background levels of <22 mg/l.

The anomalously high conductivity at MW14S and MW16 is a result of elevated chloride, as the chloride concentrations were 1200 and 662 mg/l at these two wells. These chloride concentrations are generally higher than those found in most of the law leachate at the site. The reason(s) for the anomalous high chloride in the plume from the western fill area is not clear. Leachate was sprayed back onto the western fill for several years. The elevated chloride could stem from a build-up of dissolved solids and chloride due to this past recycling of leachate back onto the fill. Another possibility is that a waste high in a chloride salt was accepted at the western fill area.

The sulfate isocon map is rather bland, but shows an irregular area of elevated sulfate within the eastern fill area. Although the pattern of high sulfate correlates to the eastern landfill, this could be naturally occurring high sulfate associated with oxidation of the Wheatfield sulfide minerals. The highest sulfate concentration of 388 mg/l occurred at C5.

As Trichloroethene, 1,2, Dichloroethene, and Vinyl Chloride (Chloroethene) are related through a chain of microbial transformations, they were treated as one family of contaminants, and an isocon map prepared for the combined concentration of the three. The most interesting aspect of the Chloroethene isocon map is the lack of any contamination above 20 ppb in the western fill area. The area of high chloroethenes is restricted to the eastern fill area. The plume of high chloroethenes in the eastern fill area resembles somewhat the chloride plume for this area, although the plume of high chloroethenes is less extensive. There are two lobes in the chloroethene plume, one extending through MP18S and MP11 and one extending through C4S and C5. None of the chloroethenes were found at the Ritter, Riefsynder, Cass or Lombardo wells. Previous EPA and PaDER sampling showed these compounds in the Lombardo well at low levels, and there is no clear explanation for their absence in this recent sampling. The transient nature of the contamination in the Lombardo well could result from seasonal variations.

The chloroethenes have bypassed the interceptor drain system on the north side of the eastern landfill, again as a result of the underdraining effect of the lower limestone pebble conglomerate aquifer on the north side of the side. Density sinking of the heavier-than-water chloroethenes also explains the underflow of the interceptor drain system. The extent of migration of the chloroethenes is limited by discharge to the unnamed tributary to Cacoosing Creek on the north side of the site. However, as demonstrated by the degraded ground water at Well C7S on the western side of the site, the contamination may not be entirely stopped by stream discharge due to the high permeability of the lower limestone pebble conglomerate unit. This unit could be so permeable in the valley bottom as to allow some underflow of the stream.

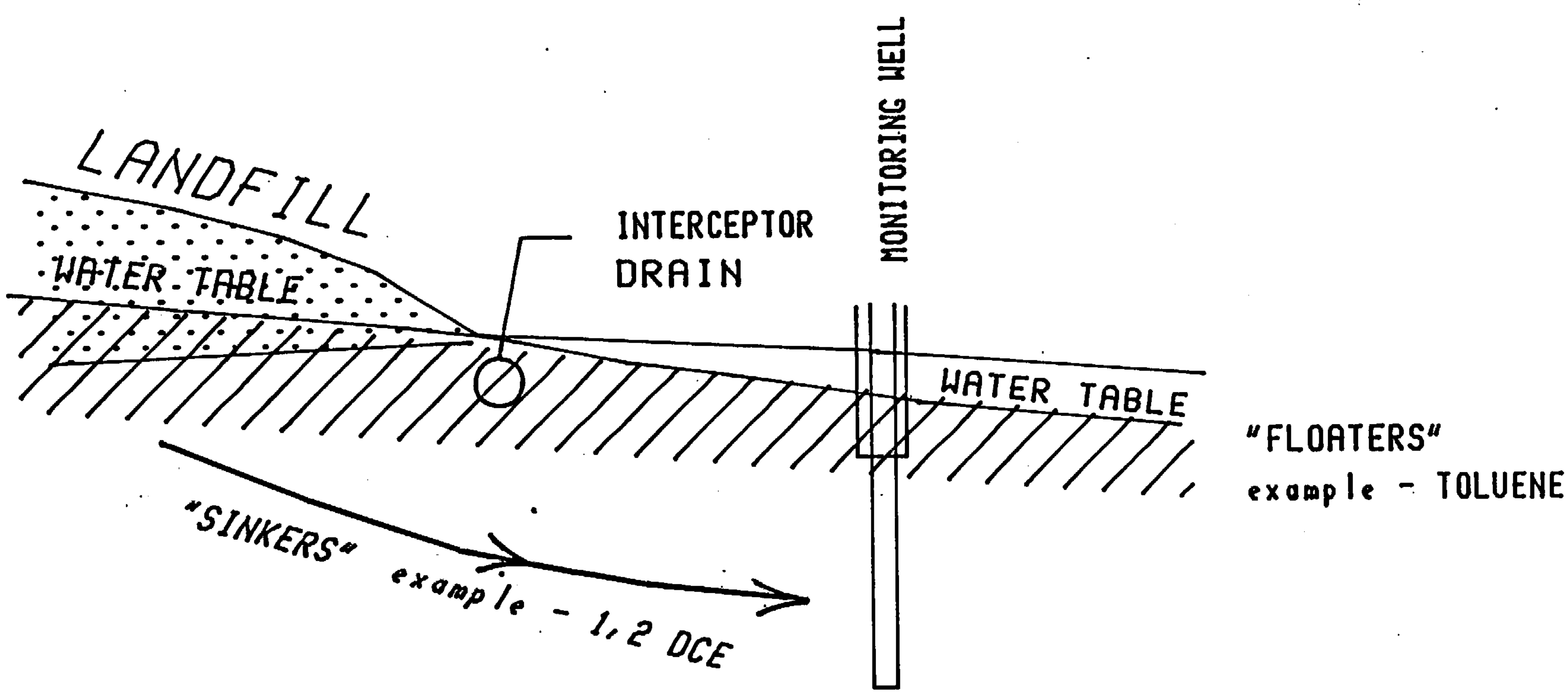
4.4.3.2 Vertical Distribution

The vertical distribution of contaminants within the flow system at the site is controlled by two factors: (1) recharge-discharge relationship, and (2) density separation. In general, ground water is less contaminated at depth than in the shallower zones of the aquifer, although significant concentrations of contaminants were found in several deep wells. Deep wells exhibiting significant levels of the key inorganic indicator parameter chloride are C3D, MP14D, MP18D, and MP19D. Three of these four are in the carbonate aquifer in the northern portion of the site. Deep wells exhibiting significant levels of the Chloroethenes are MP18D and C3D.

Five (5) of the eight (8) well pairs at the site show a recharge head relationship, while two (2) show a discharge head relationship. One of the wells in well pair MP19 is in use as a pumping water supply well, and true static water levels could not be obtained from this well pair to allow a determination of recharge-discharge head relationship. Of the five (5) well pairs showing recharge head relationships, three (3), MP18, MP14, and C3, showed significant inorganic and/or organic contamination in the deeper wells of the pairs. Of the two (2) well pairs showing discharge head relationships, C4 and C6, neither showed significant inorganic or organic contamination at depth, although C4D showed a trace level of TCE. This data confirms that contaminants have a greater tendency to work their way to depth in the aquifer in the recharge zones at the site where downward flow occurs in the flow system. Recharge zones include the higher portions of the site and the outcrop area of the carbonate aquifer in the northern portion of the site.

Well pair C4 also demonstrates that water quality is better in the underlying diabase mass. The yielding zones in C4D were obtained within the diabase. Both the inorganic and organic quality of the water from C4D are drastically better than the water from adjacent C4S, which obtained its yielding zones in the overlying carbonate aquifer.

Several samples of the leachate were collected during the sampling of the monitoring wells in December 1986 and January 1987. These samples showed the same relative proportions of volatile contaminants as the earlier leachate samples discussed in Section 3.0 of this report. The leachate has relatively high concentrations of the chloroethene "sinkers." Significant levels of the aromatics and ketones were only found in one well, MP16, which, as the analyses summarized in Section 3.0 indicate, is yielding virtually raw leachate and not leachate contaminated ground water. This explains the anomaly at Well MP16. As discussed in Section 3.0, the "floaters" such as the ketones and aromatics are staying in the upper portion of the saturated zone and are readily collected by the downgradient leachate interceptor drains. The "sinkers" such as the chloroethenes are sinking in the flow system, underflowing the shallow collector drains, and showing up at relatively high concentrations in some downgradient monitoring wells. This density induced vertical separation of the contaminants is depicted graphically in Figure 4.4.3.5.



DENSITY SEPARATION OF VOLATILE CONTAMINANTS

FIG 4.3.5

4.4.4 Impacts on Private Wells

Based on the water table contour map, the isocon maps presented in Section 4.4.3, and the occurrence of the carbonate unit in the valley bottom on the north side of the landfill, private wells in or near the valley bottom on the north side of the site would be most at risk from contamination from the landfill. However, private wells are located across perennial streams from the landfill. Discharge of contaminants to these streams acts as a barrier, and ground water contaminants do not usually cross under perennial streams. However, the occurrence of the carbonate aquifer in the valley bottom could induce some contaminants to cross beneath the stream in areas where the unit has a high permeability due to solution enlargement of joints or bedding plane partings. Fortunately driller's records and reports of homeowners indicate that most of the wells in or near the valley bottom tap the diabase, which is the lowest permeability aquifer in the area. The migration of contaminants from the highly permeable carbonate aquifer in the valley bottom into the low permeability diabase is unlikely.

Figures 4.4.4.1 through 4.4.4.4 show the location of private wells in or near the valley bottom which were investigated as part of this study. These include from east to west the Ritter, Reifsnyder, Cass, James Lombardo, Roberts, Buller, Berkel (Breitegam rental property), Breitegam, Bechtold, and Faust wells.

A well not considered to be a private off-site well is the well at Lombardo Equipment Company at the northeast corner of the permitted landfill. However, it is enlightening to include the Lombardo Equipment well in the discussion at this point. Drilling records indicate that this well is 380 feet deep, and that it penetrated limestone (limestone pebble conglomerate) from 4 to 212 feet, and diabase (ironstone) from 212 to 380 feet. All of the reported yielding zones in the well were from the top of the diabase downward including yielding zones at 212, 253, and 272 feet. Although this well was not included in sampling conducted during this study, past analyses have shown this well to yield good quality water, even though it is at the northern margin of the landfill. This is attributed to the fact that the well obtains its yield in the diabase. Monitoring Well C4D is similar to the Lombardo Equipment well, in that it obtained its yield from a deep zone in the diabase. Well C4D is relatively uncontaminated even though adjacent shallower Well C4S, with yielding zones in the limestone pebble conglomerate unit, is contaminated. Clearly the main diabase mass is of a low enough bulk permeability that it does not attract contaminants from the landfill.

Drilling records also show that the 160 foot deep well at the Cass residence was completed in the diabase. The driller logged "ironstone," a common name for diabase, from 34 to 160 feet. The upper 19 feet of material penetrated by the Cass well was logged as fill, and this is overburden from the old Wheatfield mines. The driller's log of the Reifsnyder well is less clear. "Traprock" is logged which could be diabase or some other hard gray rock. The Riefsnyder well is near the contact between the diabase and limestone pebble conglomerate. As the diabase dips beneath the limestone pebble conglomerate, the Riefsnyder well probably obtains its yield in the diabase.

There are two wells on the Buller property, the deepest of which is used for the water supply. This well was reported by Mr. Buller to be 420 feet deep and to have penetrated "ironstone" or diabase from 14 to 420 feet. The Berkel residence is a rental property which belongs to the Breitegam's. Mrs.

Breitegam reported that the 86 foot deep well at the Berkel residence also was completed in the diabase (ironstone).

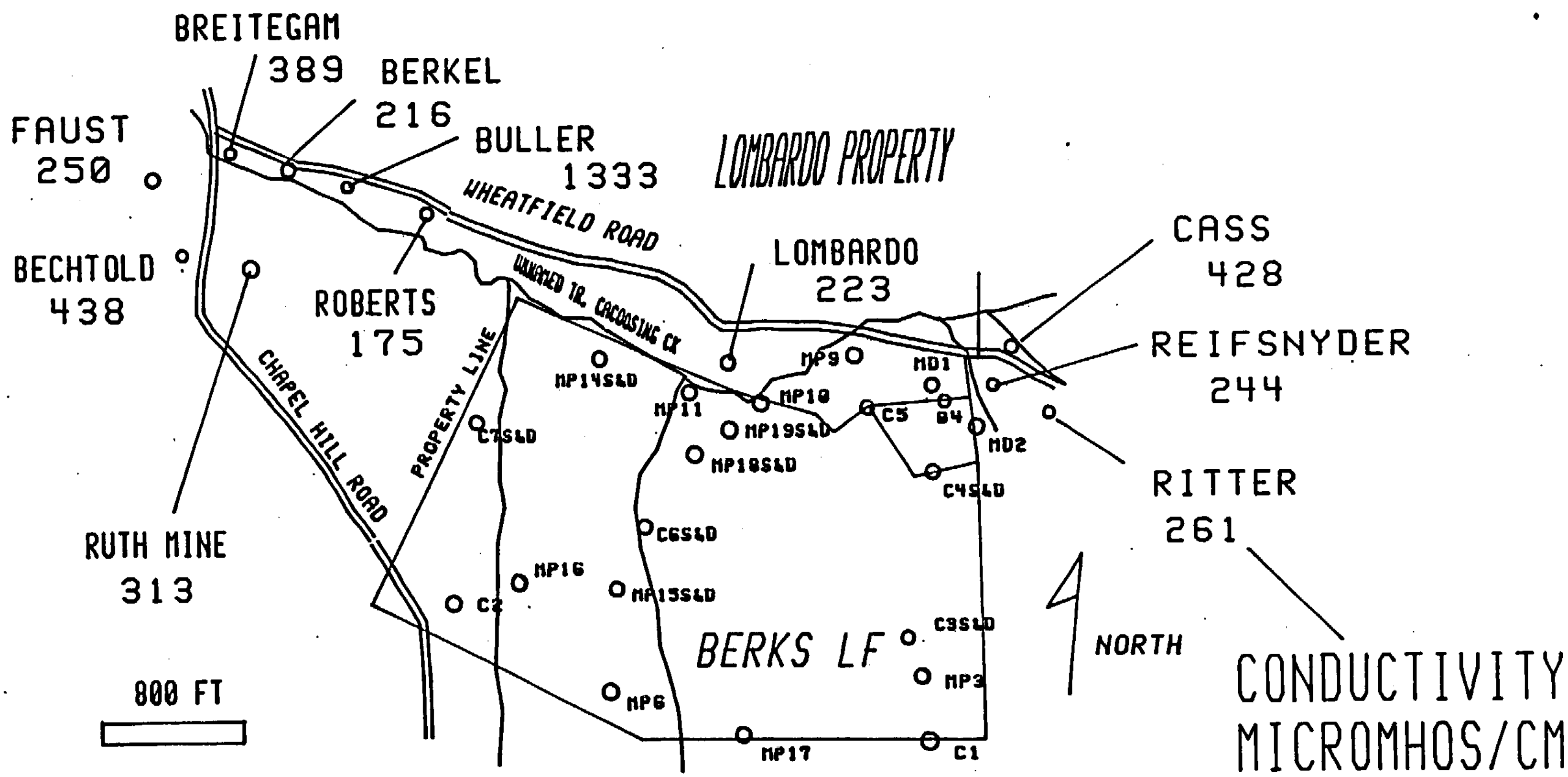
Mrs. Breitegam did not know the rock type penetrated by the well at their own residence, only that the well was 85 feet deep. Mrs. Faust reported that their well is 55 feet deep, but has no records of the rock type penetrated. Both Mrs. Bechtold and Ms. Carol Ritter could only report the approximate location of their wells. They knew nothing of their wells' depths or the rock types penetrated. Geologic mapping indicates that the Faust, Breitegam, Ritter and Bechtold wells are situated within the diabase.

Neither Mr. nor Mrs. Roberts knew anything of their well's construction, and were uncertain of its location, except that they believe it to be on the north side of the property against Wheatfield Road. Like the Riefsnyder well, the Roberts' well is near the contact of the diabase and the carbonate unit. As the diabase dips beneath the carbonate unit to the south, it is likely that the Roberts' well, like the Riefsnyder well, is drilled into the diabase.

The James Lombardo well is within the limestone pebble conglomerate aquifer in the valley bottom.

This well is reported to be a shallow hand dug well, less than 20 feet deep.

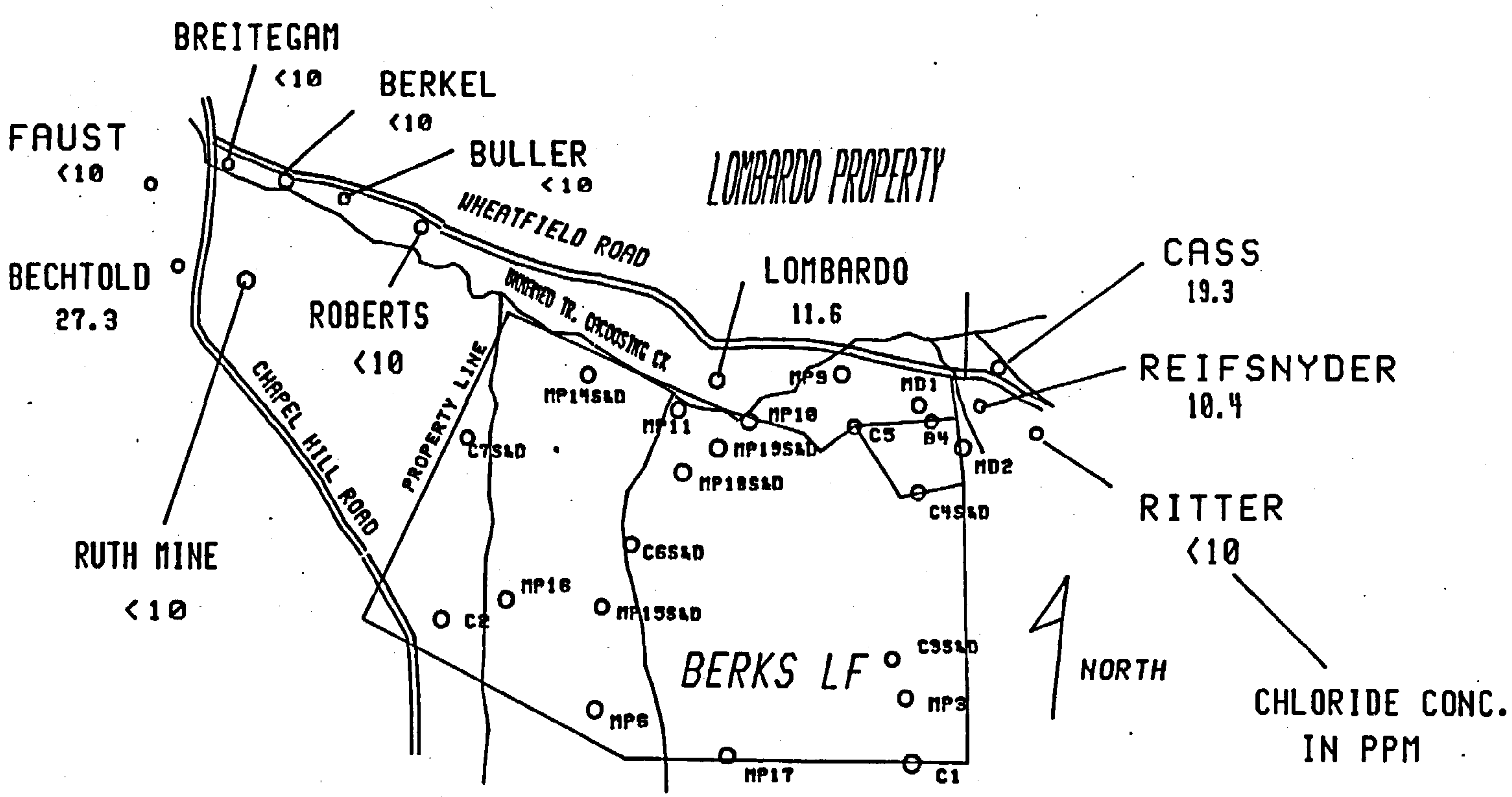
Samples of the 10 private wells listed above were collected in January and February 1987 and analyzed for volatiles, chloride, and sulfate. Also sampled was the discharge from the Ruth Mine. The results of these samples are plotted on Figures 4.4.4.1 through 4.4.4.4. Chloride is less than 20 mg/l with the exception of the Bechtold well where a chloride concentration of 27.3 mg/l was found. Sulfate was less than 60 mg/l except at the Breitegam and Buller wells. At the Breitegam well, sulfate was 78 mg/l, while at the Buller well sulfate was 665 mg/l. Both the Breitegam and Buller wells were reported to be flowing wells, indicative of a ground water discharge zone. The high sulfate found in the Buller well is attributed to its location in a discharge zone, and to the fact that this well had a quite deep yielding zone at 390 feet. The sulfate in the Buller well is higher than that found at any on-site well, and the elevated sulfate in both the Breitegam and Buller wells is interpreted to be naturally occurring. Conductivity is less than 500 micromhos/cm, except at the Buller well where conductivity is over 1000 micromhos/cm due to the naturally high sulfate.



CONDUCTIVITY - PRIVATE WELLS
BERKS LF

FIG. 4.1

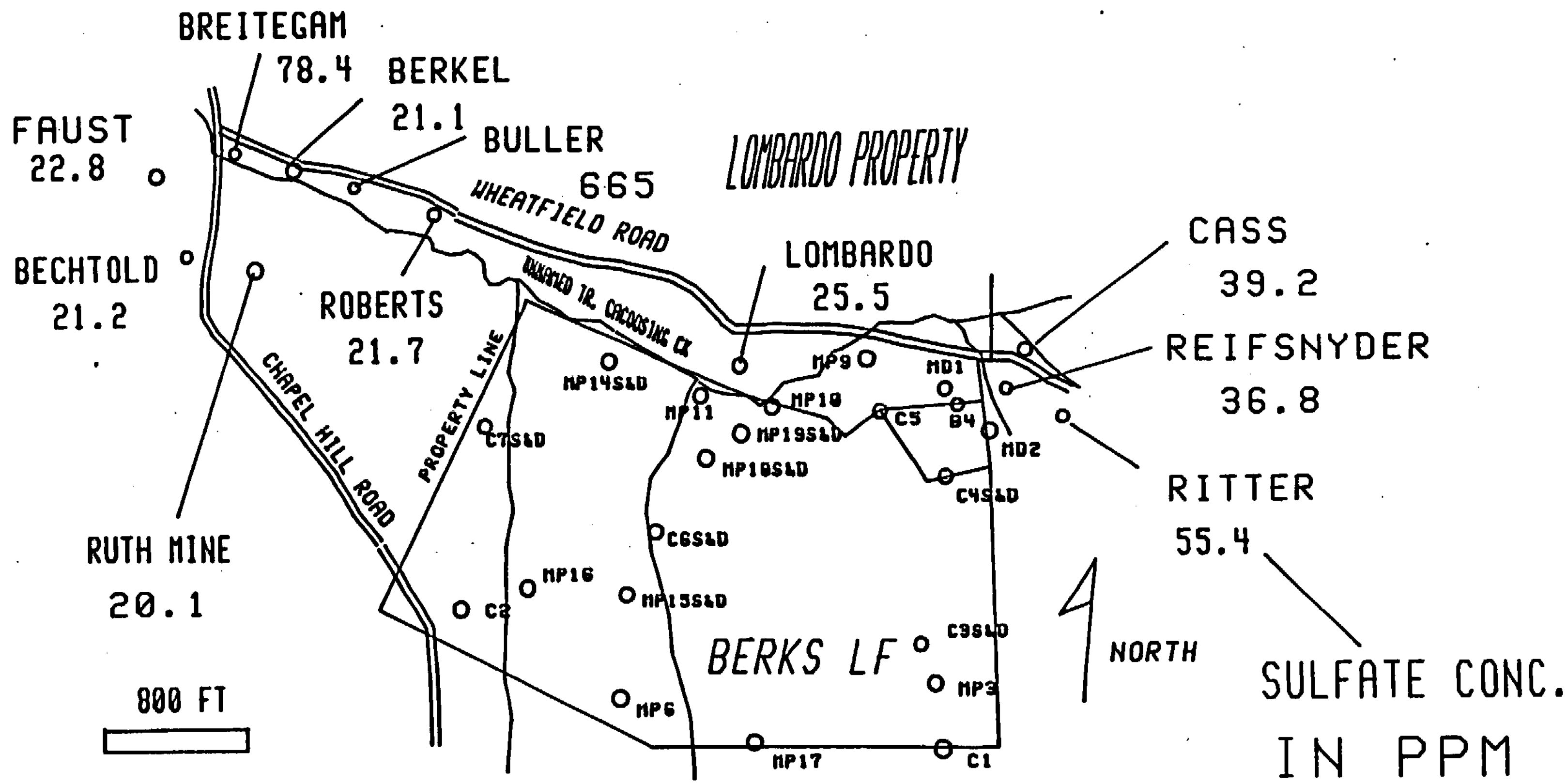
AR300147



CHLORIDE CONCENTRATION - PRIVATE WELLS
BERKS LF

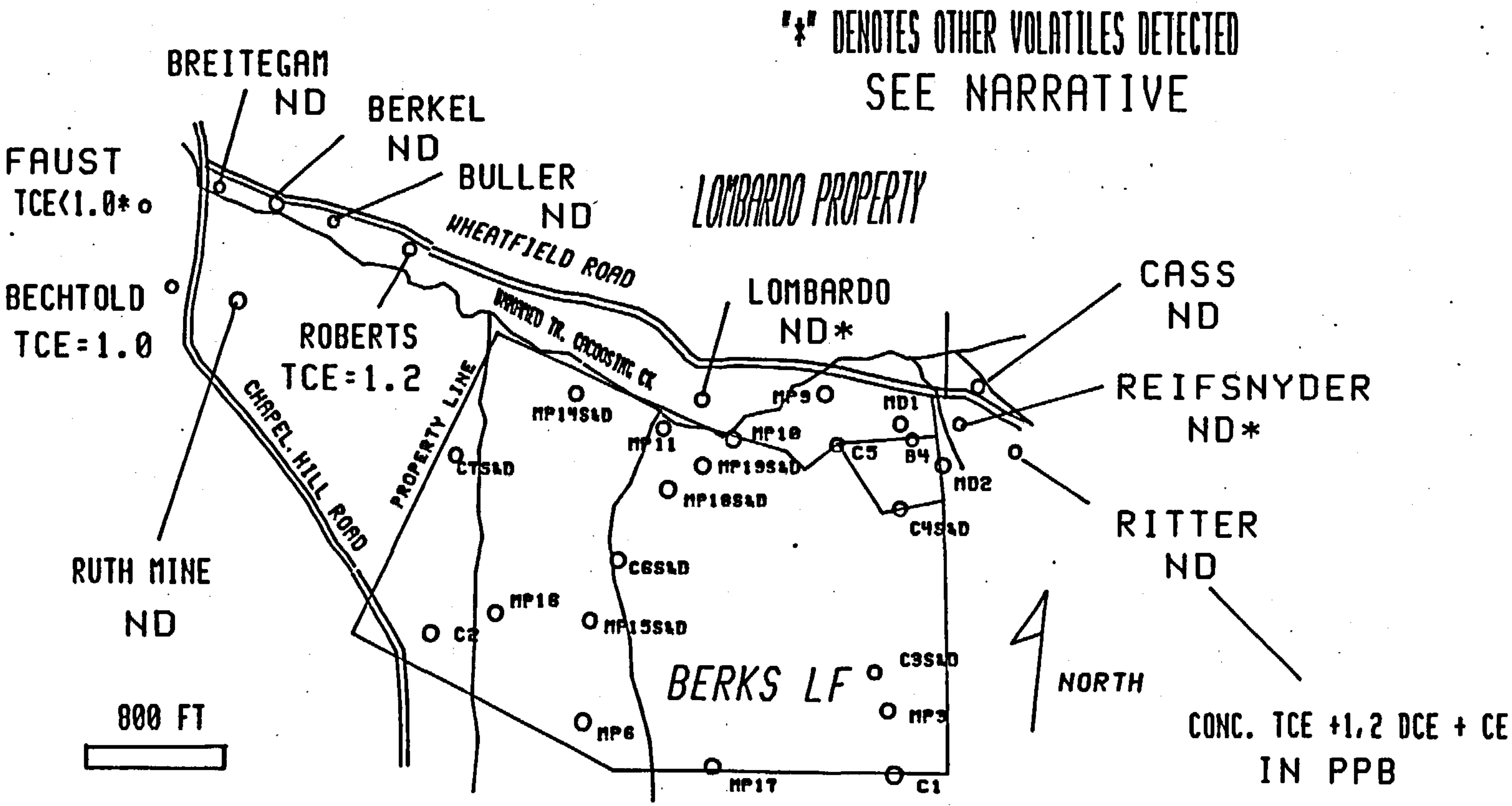
FIG. 4.4.4.2

AR300148



SULFATE CONC. - PRIVATE WELLS
BERKS LF

FIG. 4.3



PRIVATE WELLS - CHLOROETHENES = TCE + 1,2 DCE + CE

BERKS LF

FIG. 4.4.4.4

Trace levels of TCE were detected in three wells, the Roberts well, the Bechtold well, and the Faust well. The concentrations at these three were 1.2 ppb, 1.0 ppb, and <1.0 ppb (reported as ND), respectively. These levels are extremely low, near the detection level of the laboratory, and within the EPA and NAS recommended drinking water limits of 2.6 and 4.5 ppb, respectively. This is the first report of even trace levels of TCE in any well other than the Lombardo well. In light of the trace level concentrations, and the lack of previous detection in these wells, the only recommended action is continued monitoring. If continued monitoring shows this TCE to be persistent and to increase in concentration beyond recommended limits, replacement water supplies are recommended.

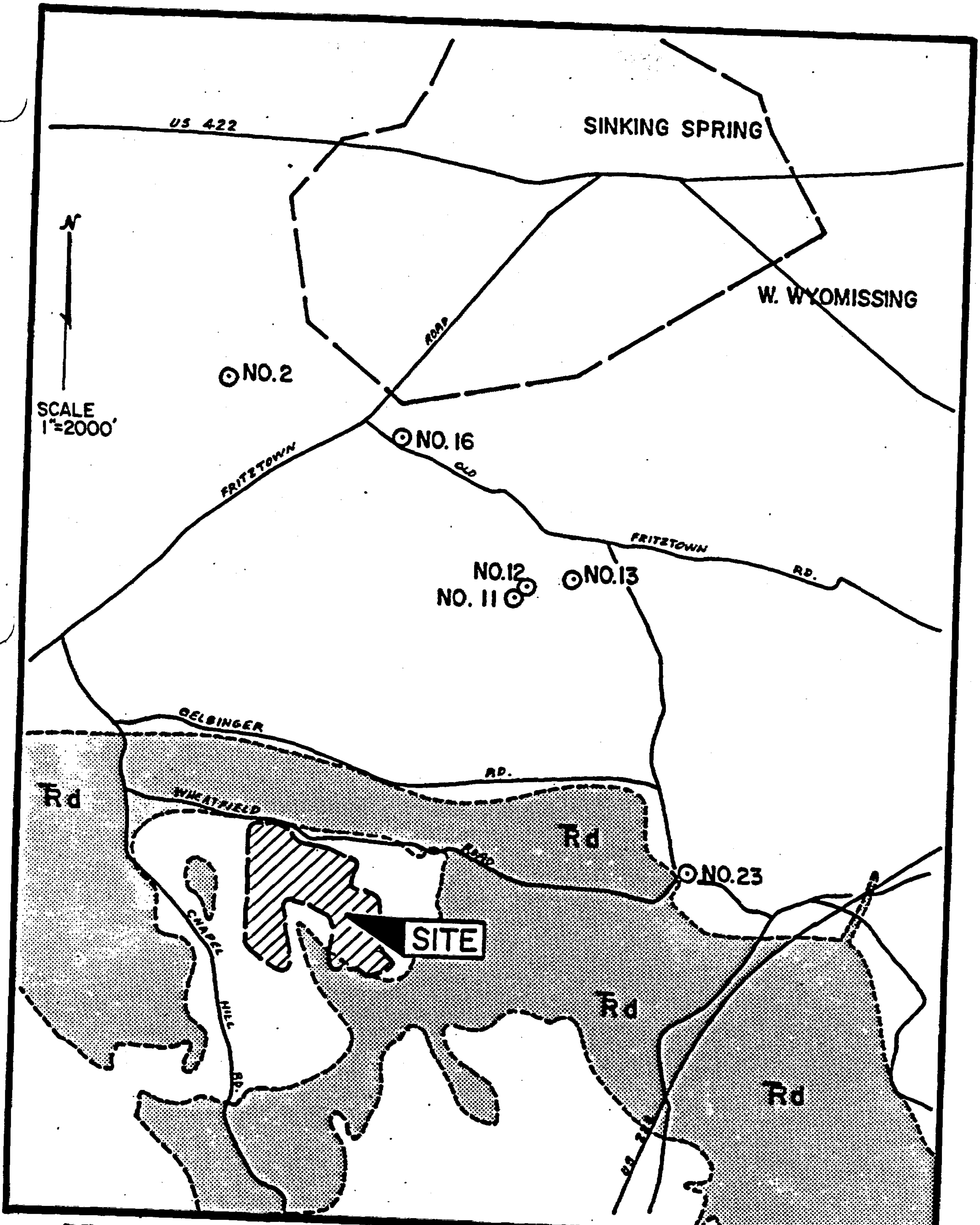
Interestingly, none of the chloroethenes were detected in the James Lombardo well, where they had previously been detected by EPA and PaDER. Mr. James Lombardo reported that several weeks before the samples were collected, he had found two dead rabbits in his well, and had removed the rabbits and disinfected the well with 3 gallons of chlorine bleach. This combination of chlorine bleach and organics should have produced trihalomethanes. Predictably the primary trihalomethane, Chloroform, was found in the Lombardo well at a concentration of 33 ppb, along with bromodichlorometane at 1.2 ppb. Although the chloroethenes appear to be transient at this well, replacement of this water supply is recommended, as it is poorly constructed, and further, because it taps the carbonate aquifer.

Chloroform was also found at near trace levels of 1.4 ppb in the Faust well, and Methylene Chloride at 11 ppb in the Reifsnyder well. Both Chloroform and Methylene Chloride are common lab contaminants and it is likely that these reported concentrations represent lab error. For example, 5.5 ppb of Methylene Chloride was detected in the January 1987 Trip Blank. Chloroform is commonly formed in septic tanks through the interaction of chlorine bleach with simple organics. Methylene Chloride is also a common household contaminant, found in paint strippers. As with TCE, resampling is recommended. Remedial action is only recommended if these volatiles are persistent and show an increasing trend to levels of health significance.

4.4.5 Impacts on Public Wells

Citizens Utilities Water Company has several wells in the general area including four (4) within 1 mile of the site. The map in Figure 4.4.5 shows the location of Citizens Utilities wells #2 (reported not in service due to gasoline contamination), #16, #11, #12, #13, and #23. The locations of these wells and usage are based on an interview with the staff engineer of Citizens Utilities Water Co. Wells #11, #12, #13, and #16 are in service and are reported to be pumped at a combined rate of approximately 800,000 gpd. Well #23 is a new well which has recently been permitted and which will probably go on line within the next year, and is the only one of these wells within the Triassic Hammer Creek aquifer.

As shown in Figure 4.4.5, the diabase mass that encircles the site hydrologically isolates Berks Landfill from these public water supply wells. The thick diabase intrusion lies between the site and these wells and functions as an aquitard. The chances that pumping of these public wells could induce ground water flow across this 700 foot thick intrusion are remote to nonexistent.



RELATIONSHIP OF TRIASSIC DIABASE TO CITIZENS UTILITIES WATER COMPANY WELLS

AR300154

the PaDER permit file of Citizens Utilities Well #23 was reviewed to determine the results of the pump test performed for the PaDER and DRBC permit. Several wells were monitored during the long term pump test of Well #23 including a well within the diabase, between Well #23 and Berks Landfill. This intervening well showed no drawdown during the pump test, indicating a lack of interference due to the diabase mass. The only drawdown found during the test was in a well located close to Rte. 222, along strike to the east of Well #23 and within the same aquifer. Strike-parallel interference in this terrain is expected.

4.4.6 Remedial Options

There are several options available for remedial action at Berks Landfill to reduce or eliminate the off-site migration of ground water contaminants into the carbonate valley-bottom aquifer. These are all more-or-less standard remedies, however, the success or failure of any one of these actions is highly dependent on site-specific conditions. Remedial Action Alternatives (RAA's) applicable to the hydrogeologic conditions at Berks are discussed below. Not discussed are such actions as slurry walls which are obviously not applicable to this type of hydrogeologic setting.

4.4.6.1 No Action Alternative

Presented first, as a reference, is the option of taking no remedial action other than continued monitoring. If no action were taken, the James Lombardo well would still be at risk of at least transient contamination by the Chloroethenes. Unless new private wells were developed in the carbonate aquifer, no other private wells would be placed at significant risk. Degraded ground water would continue to discharge to the unanmed tributary of Cacoosing Creek, and the volatiles would air-strip naturally after discharge to the creek. The contaminant plumes from the landfill are old and limited by stream discharge. These plumes would probably not spread any further if no action were taken. Although the impacts of taking no remedial action would not be widespread, this alternative is not recommended as it places one water supply at risk, and as significant levels of Chloroethenes would continue to escape the property.

4.4.6.2 Removal of Select Wastes

The removal of select wastes is applicable where certain problematic wastes are concentrated in one small area. The industrial wastes accepted at Berks were reported to be concentrated in the wood dump area in the southeast corner of the site. However, this area covers more than 5 acres and the waste in this area, which is mostly demolition waste, is reported to have an average thickness of over 30 feet. As much of the liquid waste received was not drummed or as many of the drums were emptied, removal would entail virtually all of the wood dump material, which amounts to approximately 250,000 cubic yards. At an estimated handling and disposal cost of over $100 per cubic yard, the cost for this action would be over $25 million. This action would not effectively eliminate the problematic contaminants such as the chloroethenes, as these wastes, while concentrated in the wood dump, are likely to be found almost anywhere in the pre-1983 portions of the landfill. Removal of small areas of waste outside of the main landfill areas, such as those possible small fill areas on the Lombardo tract, would be practical if further investigation of those possible off-site fill areas discloses problems.

4.4.6.3 Capping, Covering, and Regrading

Placement of an "impermeable" cap over the landfill areas would reduce the production of leachate caused by infiltration, but not the production of that leachate caused by ground water coming into direct contact with wastes. Much of the landfill is in contact with the water table, and the western or inactive landfill area was reported to have been excavated well below the water table in several areas. Therefore, a cap would not eliminate leachate production. An impermeable cap would also reduce methane production to levels where the recovery of methane for energy production and sale would not be viable. As capping would only reduce leachate production by a limited amount, and as Berks is dependent on the recovery and sale of methane for some revenue towards site maintenance costs and the costs of remedial action, wholesale capping of the landfill is not recommended. Capping of small areas such as the Stabatrol fill area would be an effective way to deal with this limited industrial waste fill area if continued monitoring discloses problems with this portion of the fill. The existing monitoring data, while suggesting some leaching of the Stabatrol fill, does not disclose problems sufficient for any action in the near future.

Cover soil on the western landfill area is poor, and refuse protrudes through the cover in several areas. However, vegetation is well established on the western landfill area. Removal of this vegetation to allow placement of better final cover would cause more short term problems, such as erosion and sedimentation control, than would be off-set by the long term benefits of better cover.

The eastern fill area includes areas which have steep interim slopes, such as along the eastern side of the permitted area. There are also areas with slopes that are too gentle to minimize infiltration and leachate production, such as on top of the eastern fill area. It is recommended that a low leachate strength waste, like demolition waste, be used to complete the eastern fill to maximum allowable grades to reduce infiltration and minimize leachate production. Continued filling of demolition waste within the degraded area is not expected to affect the degree or extent of contamination.

4.4.6.4 Bioreclamation

Bioreclamation is the destruction of organic contaminants in ground water through the enhancement of microbial action. Bioreclamation can have the undesired effect of producing decomposition products which are worse than the parent material. Unintentional bioreclamation is already underway at the site and undesirable by-products are already being produced. Due to such potential complications as this, enhanced bioreclamation activities are not recommended.

4.4.6.5 Gradient Control

Gradient Control is the selective lowering of the water table upslope from a pollution source to reduce the amount of ground water moving through or near the pollution source. In this manner, the amount of contaminated ground water is reduced. Gradient control is tricky business, as too much lowering of the water table upgradient can reverse the direction of ground water flow and cause contaminated ground water to move in a normally upgradient direction.

Gradient control would apply easily to the western or inactive fill area. The water table is shallow along the southern side of this fill area, and a cut bank along the southern property line in this area has numerous seeps with combined flow of several gallons per minute. Inspection of the water table contour map in Exhibit VI indicates that the water table could be lowered as much as 10 feet in the area of MW6 with minimal risk of reversing the gradient. An upgradient interceptor/diversion drain along the southern portion of the property, excavated to a depth of 10 feet below the base of the existing cut slope in this area, is recommended. Because of the bedrock exposed in this area, excavation of the drain would require some blasting.

4.4.6.6 Downgradient Interceptor Drains

Downgradient interceptor drains are used to intercept leachate contaminated ground water downgradient of a landfill.

Downgradient interceptor drains are most effective where discharge conditions exist, and where the drains can be installed as low as the elevation of nearby perennial streams. In areas where recharge conditions exist or where drains must be installed well above the elevation of the closest stream, drains are usually not effective, and contaminated ground water underflows the drains.

The eastern or permitted landfill has a system of perimeter interceptor drains. In some areas these drains are effective, such as in the area of well pair C6S and C6D where water level data indicates that discharge conditions exist and where monitoring data indicates that leachate contaminated ground water has not bypassed the interceptor drain. The perimeter interceptor drain has not effective in the area of Wells MW18 and C5, where leachate contaminated ground water is underflowing the existing interceptor drain. The lower Triassic limestone pebble conglomerate aquifer is partially responsible for this, creating recharge conditions in the valley bottom where discharge conditions normally would exist, which encourages the underflow of the drain. The carbonate aquifer is so permeable in some areas that contaminants have underflowed the nearest perennial stream, such as in the area of Well C7S. Another factor is that some of the contaminants such as the chlorinated solvents are more dense than water and behave as "sinkers." High density contaminants tend to move vertically downward in the flow system and underflow the drains. Flow net theory indicates that, to be effective, an interceptor drain would have to be installed to an elevation as low as the elevation of the nearest perennial stream. In the areas of MW18 and C5 such a drain would have to be 30-40 feet deep to be as deep as stream level. A final complication is the old deep mine workings which are high permeability zones which would encourage underflow of a shallow interceptor drain system in the eastern side of the landfill. Considering these several factors, interceptor drains are not suited to controlling the off-site migration of contaminants. The only recommended use of interceptor drains at the site is their installation in areas of leachate toe seeps to prevent the direct discharge of leachate or leachate contaminated ground water to surface streams.

4.4.6.7 Recovery Wells

Recovery wells are applicable where contaminated ground water extends to too great a depth to allow the use of interceptor drains, and where the aquifer will allow the development of productive interferring wells. The conditions at Berks fit this bill, and a recovery well network is the appropriate remedial action necessary to prevent the off-site migration of contaminated ground water. The sizing and spacing of the recovery well network is discussed in Section 4.4.7 of this report.

Two questions are basic to the layout and design of a recovery well network: (1) How much of the ground water plume must be captured? (2) What do you do with the large volume of contaminated ground water after you recover and treat it? In considering how much of the plume should be captured at Berks, there are two possible strategies: (1) capture the plume from the eastern fill area which is high in chloroethenes, and do not capture the plume from the western fill area which mainly consists of high dissolved solids with trace to low levels of chloroethenes, or (2) capture the plumes from both the western and eastern fill areas. It was the high chloroethenes found in Wells MW18, MW11, and the Lombardo well north of the stream on the north side of the site which triggered this ground water study. The contaminants in Wells MW18 and MW11 stem from the eastern fill area. The contaminants in the Lombardo well on the north side of the stream may stem from the eastern fill area or from off-site fill areas on the Lombardo tract on the north side of Wheatfield Road. Based on the above, it is recommended that only the plume from the eastern or permitted fill area should be captured. The ground water model and calculations presented in Section 4.4.7 assume capture of only the plume from the eastern fill area, however calculations are presented for a recovery well network which would capture the plumes from both the eastern and western fill areas.

As the calculations in Section 4.4.7 will indicate, ground water recovery will involve approximately 200,000 GPD. Obviously this is too great a volume to truck away from the site. On-site treatment will be required with either reinjection or stream discharge. Reinjection at Berks would either have to occur either upgradient of the recovery wells or downgradient of the recovery wells. If reinjection occurred upgradient, it would mound the water table in the fill areas, which would increase leachate production. Reinjection downgradient would mound the water table in the valley bottom and lead to new springs and seeps which would, in effect, be stream discharges. Stream discharge of the recovered ground water is the only sound approach at Berks.

Treatment of the recovered ground water will have to include some conventional biological waste water treatment, as the ground water monitoring data summarized in Section 3.0 of this report indicates that downgradient wells produce water with BOD's typically in the range of 0-250 mg/l, although the BOD in the recovered ground water is expected to average less than 100 mg/l. Air stripping after conventional biological treatment may be required to further remove volatiles, although aeration during conventional biological treatment is expected to significantly strip volatiles. As a stream discharge permit will be necessary, it is also recommended that the more concentrated leachate collected by the existing drain system be included in the treated and discharged waste flow. Treatment of the more concentrated leachate will also involve the same treatment steps - biological treatment and possibly air stripping, to remove any volatiles not removed during aeration in the biological treatment phase. As the ground water contamination at the site has existed for several years, and as risk to off-site water supplies is low (with the exception of the Lombardo well), there is no urgency to installation of the recovery well system.

4.4.6.8 Replacement Water Supplies

Only one (1) off-site private water supply has been contaminated by the same contaminants found at the landfill to significant levels. This is the James Lombardo well on the north side of the site. It is not clear from existing data that this well has been contaminated by the main fill areas on the south side of the stream, and this well may have been contaminated by the possible small fill areas which are reported to exist on the north side of Wheatfield Road, upslope from the Lombardo well. The Lombardo well does tap the carbonate aquifer in the valley bottom, although it is only a shallow, hand dug well.

Although it is uncertain that the landfill has affected the Lombardo well, it is recommended that Berks supply a replacement water supply to James Lombardo. This should be a drilled well tapping the diabase below the carbonate valley bottom aquifer to eliminate the sanitary problems with the existing shallow dug well. The carbonate acquifer should be cased-off in the new well.

If the contamination is found to persist in the replacement well, a carbon filter should also be provided by Berks, until such time as the source of the contamination of the Lombardo well is determined not to stem from Berks. Replacement of the Lombardo water supply is a remedial action which should be completed in the short term or near future.

4.4.6.9 Long Term Monitoring

The 26 wells existing at the site includes many wells in the interior of the landfill, such as MW3, C3S and C3D. The long term monitoring emphasis should shift to a select number of wells and mine discharges located around the perimeter of the site. The recommended long term network includes MP17 and C2 as background wells, and C7S, C7D, MP14S, MP14D, MP11, MP10, and Mine Discharge MD2 as downgradient points.

4.4.7 Remedial Action

The combination of remedial actions recommended at Berks include replacement of the James Lombardo water supply, regrading of the eastern fill area to minimize leachate production, installation of an upslope ground water diversion drain, and development of a recovery well system at the eastern landfill. Most of these actions are straight-forward and require no further discussion in this report. Sizing of the recovery well system was accomplished with the aid of a computer ground water model which is discussed below.

4.4.7.1 Ground Water Model of Recovery Well Network

Recovery of the plume of contaminated ground water from the eastern landfill will require a line of recovery wells along the north side of the landfill from the area of Well MW18 through Well C5 and ending near C4. Recovery wells should be included in the deep mines in the northeast corner of the site, as these are high permeability conduits. Monitoring of the Mine Slope No.

2 discharge on the Ritter Property did not disclose any significant volatiles, however high levels of the Chloroethenes were found in Well C4S, just upslope from Slope No. 2. High levels of the Chloroethenes were also found in Well C5, near Mine Slope No. 3. Recovery from Mine Slopes No. 2 and No. 3 would require wells on the Lombardo property, and Berks' access to this area is questionable.

The recovery wells should be completed in the lower Triassic limestone pebble conglomerate unit. Inspection of the logs for the several monitoring wells drilled into this unit shows that all reported yielding zones were obtained at depths of less than 100 feet, and all but one reported yielding zone occurred at depths less than 70 feet. Conventional 6" drilled wells completed to 100 foot depths are therefore recommended. These wells should have as little casing as necessary, with open rock bores from bottom of casing to the bottom of the holes.

A 40 x 40 mesh PLASM finite difference computer ground water model was used to test the spacing and withdrawal rates to obtain complete capture. This model assumed an isotropic, uniform transmissivity of 1100 GPD/FT, the approximate average transmissivity found in the pump tests. Obviously these are big simplifying assumptions in a fractured rock aquifer with transmissivity covering three orders of magnitude, and with certain anisotropy. The model is intended as guide only. The installed recovery well network will have to be pump tested to verify complete capture, and more than the indicated number of recovery wells will almost certainly have to be drilled to allow for low yielding wells.

The approximate water table gradient along the northern side of the eastern fill area is 10%. The model was laid out with constant head boundaries of 460' and 560' on opposite sides of the square model. The 460 foot constant head boundary was intended to model the stream to the north which occurs between elevation 460 and 480. The model grid spacing was 25 feet, so each side of the model represented 1000 feet. The 100 foot head difference in constant head boundaries spaced 1000 feet apart, generated a uniform flow field with a 10% gradient. The line of recovery wells was placed parallel to and at a distance of 300 feet from the 460 foot constant head boundary to mimmick a line of recovery wells placed 300 feet from the stream. With a well spacing of 150 feet, the model was first run with a withdrawal rate of 10 gpm or 14,400 gpd from each well. This configuration reduced the gradient toward the stream, but did not achieve complete capture.

A second run was made with wells spaced 150 feet pumping 15 gpm or 21,600 gpd each. This configuration obtained complete capture, with no remaining gradient from the line of recovery wells toward the stream. The results of the two model configurations were contoured and they are presented on Figures 4.4.7.1 and 4.4.7.2.

The distance from Well MW18 to Well C4 is 1300 feet or approximately 1/4 mile. At a spacing of 150 feet, nine (9) recovery wells would be required along this 1300 foot line, producing a combined flow of approximately 195,000 gpd (21,600 gpd each). Using the basic equation of ground water flow, the flow across this 1300 foot distance was calculated as a check:

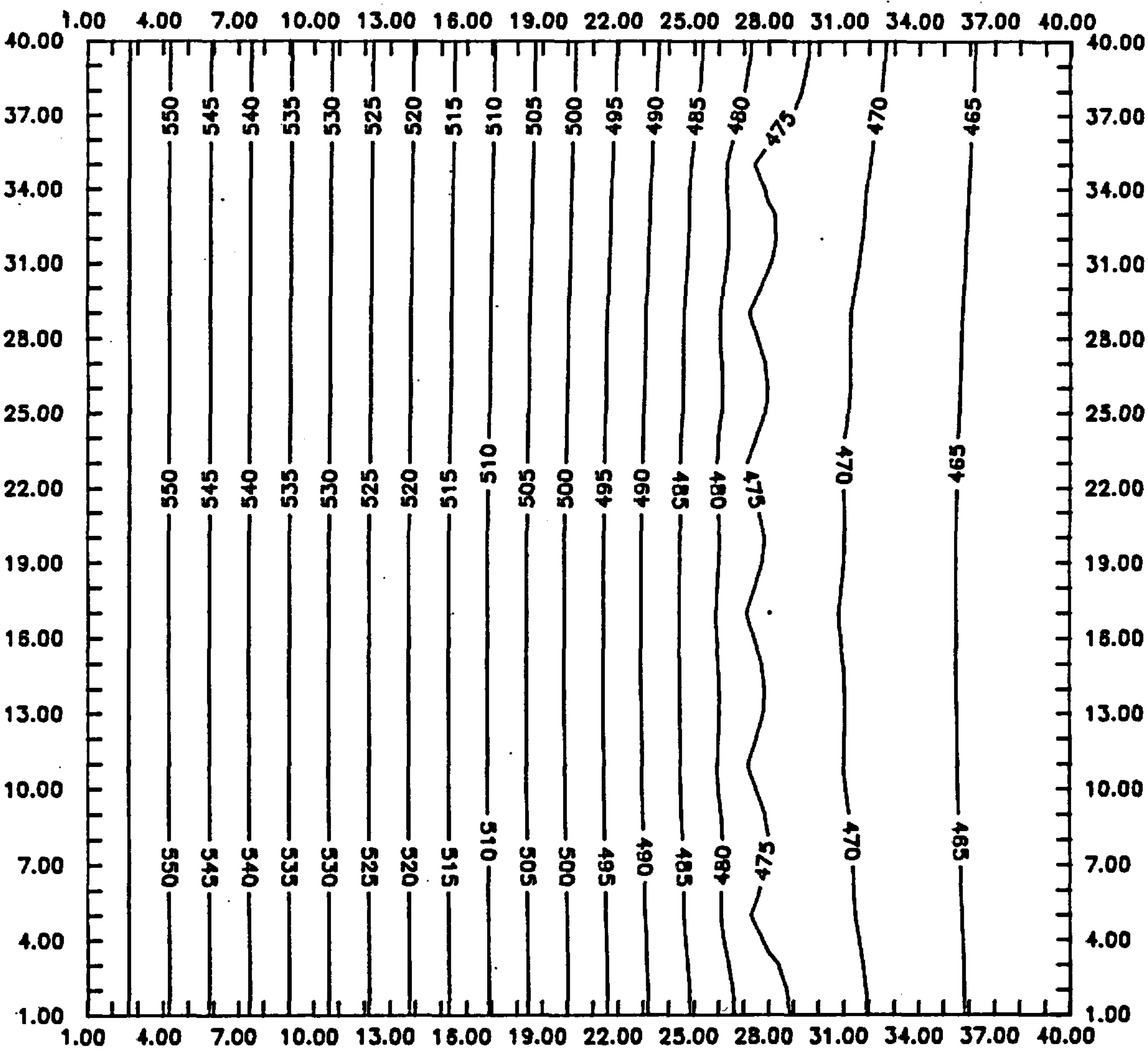
Q = TIL = 1100 GPD/FT x .10 FT/FT x 1300 FT

= 143,000 GPD

Based on this check and the model, a nine (9) well system, each well producing approximately 21,600 gpd for a total flow of 195,000 gpd would completely capture the plume from the eastern fill area. In light of previous drilling at the site, a high percentage of wells completed will yield less than 15 gpm or 21,600 gpd each. In areas along the line of recovery wells where sustained well yields will be less than 15 gpm, the well spacing will have to be decreased, increasing the overall number of recovery wells. This will be a field decision during completion of the recovery well system. However, it is likely that the final number of recovery wells will exceed nine (9) and may be as high as fifteen (15). Those recovery wells which tap the old deep mines should have no problem producing high yields. The completed recovery well system should be pump tested to verify that it will achieve complete capture before it is put into service.

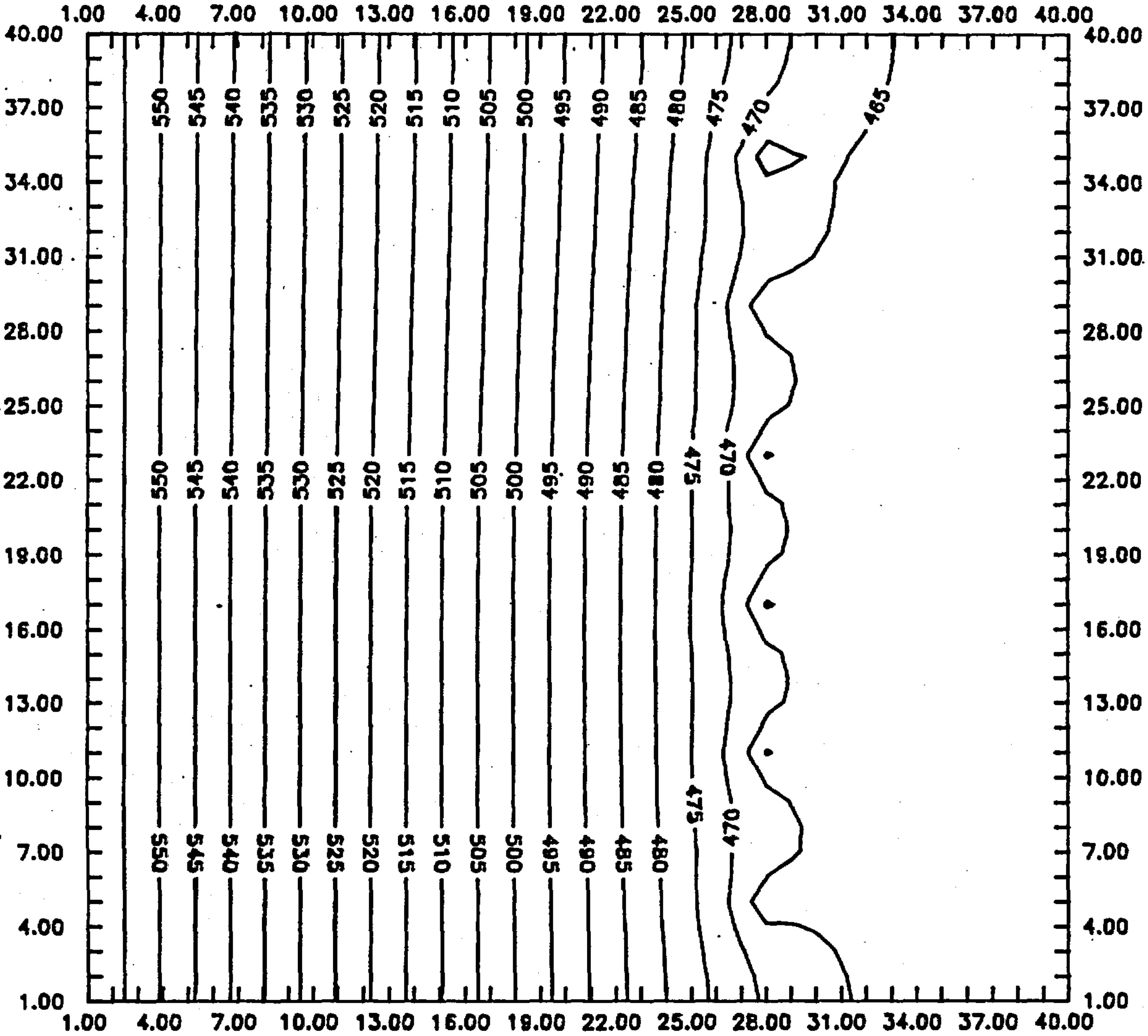
To capture the plume from the western or inactive fill area would approximately double the number of recovery wells and the flow. The distance from MW18 to C7 is approximately 1300 feet, and this would add another 9-15 wells and an additional 195,000 gpd of captured flow. As discussed previously, the low levels of chlorinated solvents in the plume from the western fill area does not warrant recovery of this plume.

RECOVERY WELL NETWORK MODEL – 10 GPM EACH



AR300177 FIG. 4.4.7.1

RECOVERY WELL NETWORK MODEL – 15 GPM EACH



AR300178

FIG. 4.4.7.2

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BERKS LANDFILL

GROUND WATER STUDY
AND
REMEDIAL INVESTIGATION

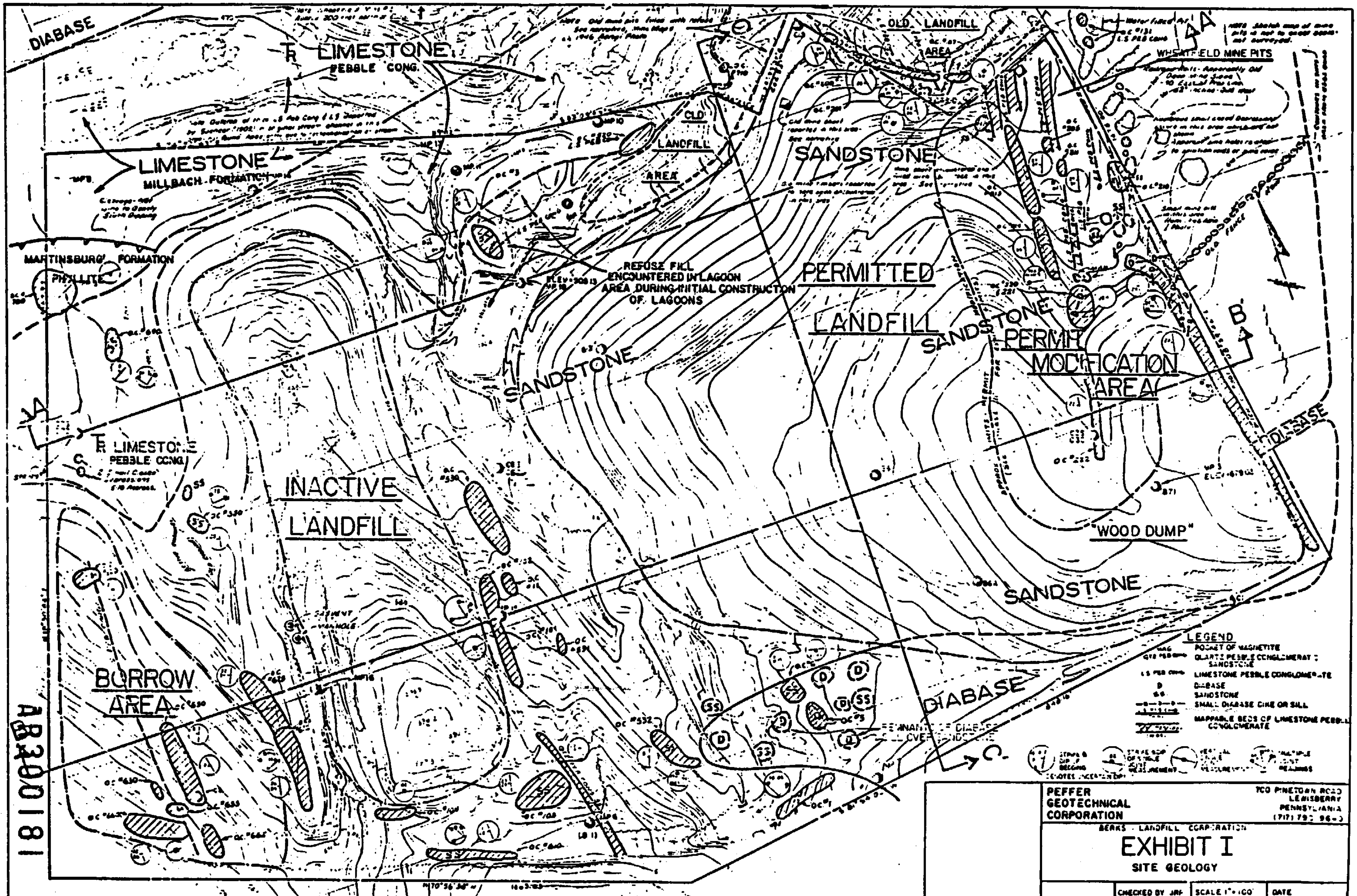
PREPARED FOR

BERKS LANDFILL CORPORATION
AND
BERKS SANITARY LANDFILL, INC.

BY

<u>Peffer Geotechnical Corporation</u>

FEBRUARY 1987



PEFFER GEOTECHNICAL CORPORATION

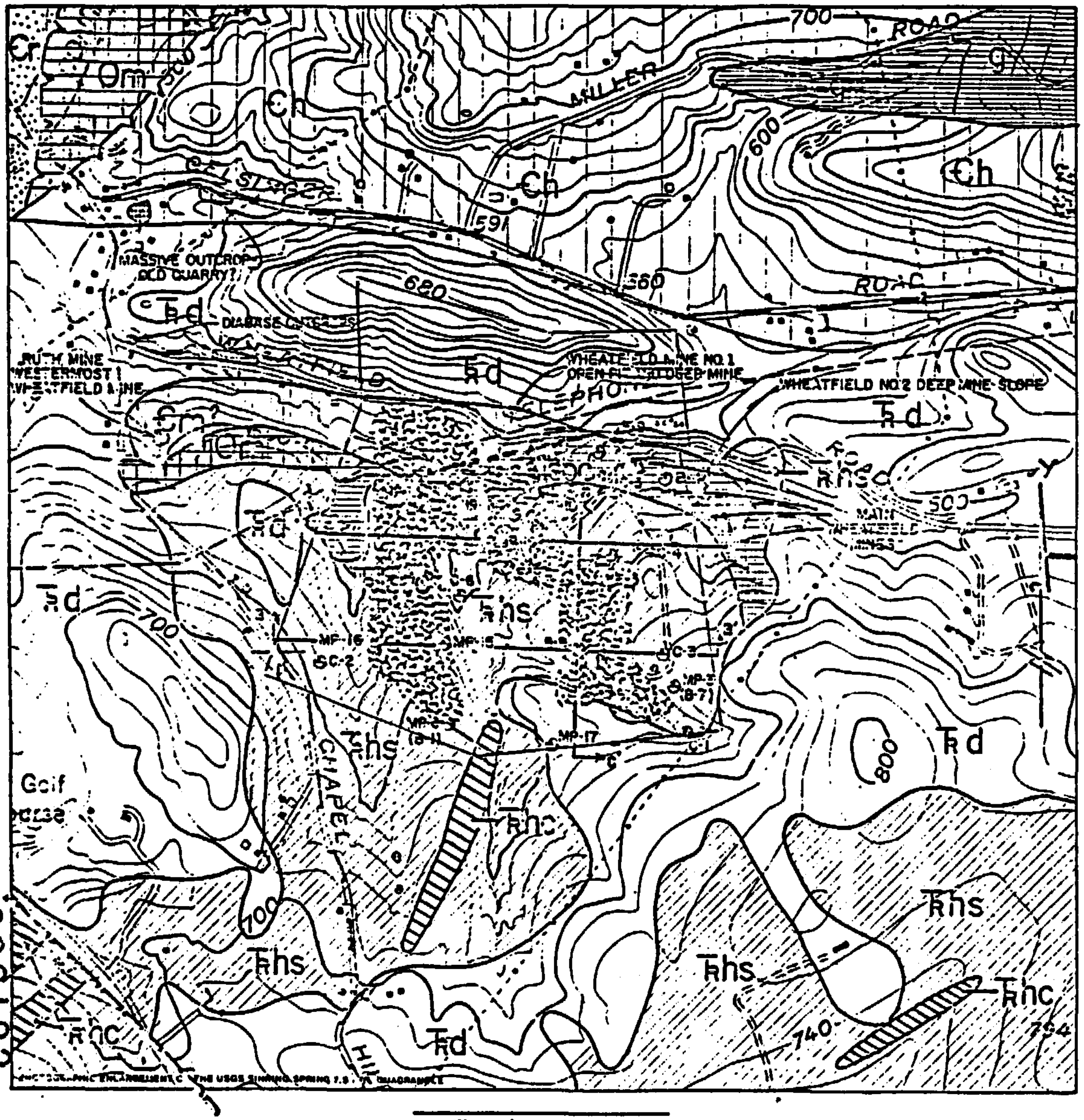
700 PINETOWN ROAD
LEWISBERRY
PENNSYLVANIA
(717) 792-96--

BERKS LANDFILL CORPORATION

EXHIBIT I

SITE GEOLOGY

CHECKED BY JRF | SCALE 1"=100' | DATE



⊖	TEST BORING/MONITORING WELL LOCATION
TRlspc	LOWER LIMESTONE PEBBLE CONGLOMERATE UNIT (TRIASSIC)
TRd	DIABASE (TRIASSIC)
TRhc	QUARTZ CONGLOMERATE-HAMMER CREEK FM (TRIASSIC)
TRhs	SANDSTONE-HAMMER CREEK FORMATION (TRIASSIC)
Om	PHYLLITE & QUARTZITE-MARTINSBURG FM (ORDOVICIAN)
Ꞓr	RICHLAND FORMATION (CAMBRIAN)
Ꞓm	LIMESTONE-MILLBACH FORMATION (CAMBRIAN)
Ꞓh	HARDYSTON FORMATION (CAMBRIAN)
g	GRANITIC GNEISS

NOTE: GEOLOGIC CONTACTS FROM PA. TOPOGRAPHIC & GEOLOGIC SURVEY ATLAS 177d. CONTACTS WITHIN SITE MODIFIED BY PEFFER GEOTECHNICAL CORPORATION BASED ON SITE-SPECIFIC MAPPING.

PEFFER GEOTECHNICAL CORPORATION
700 PINETOWN ROAD LEWISBERRY PENNSYLVANIA (717) 790 9640

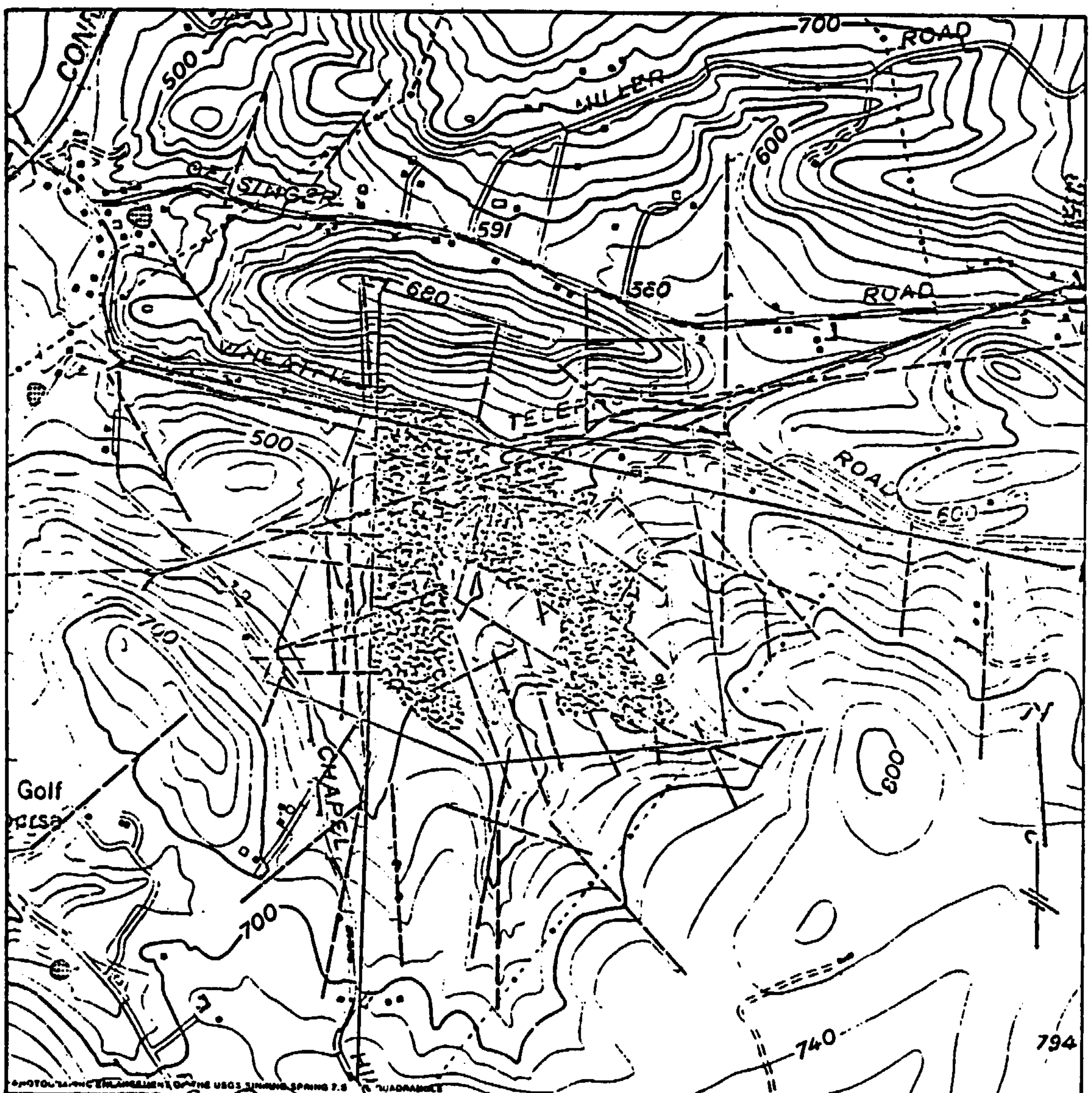
BERKS LANDFILL CORPORATION

EXHIBIT III

REGIONAL GEOLOGY

CHECKED BY JRP | SCALE 1"=400' | DATE

SHEET 1 OF 1



FRACTURE TRACE

LINEAMENT

APPROX PROPERTY LINE

PEFFER GEOTECHNICAL CORPORATION

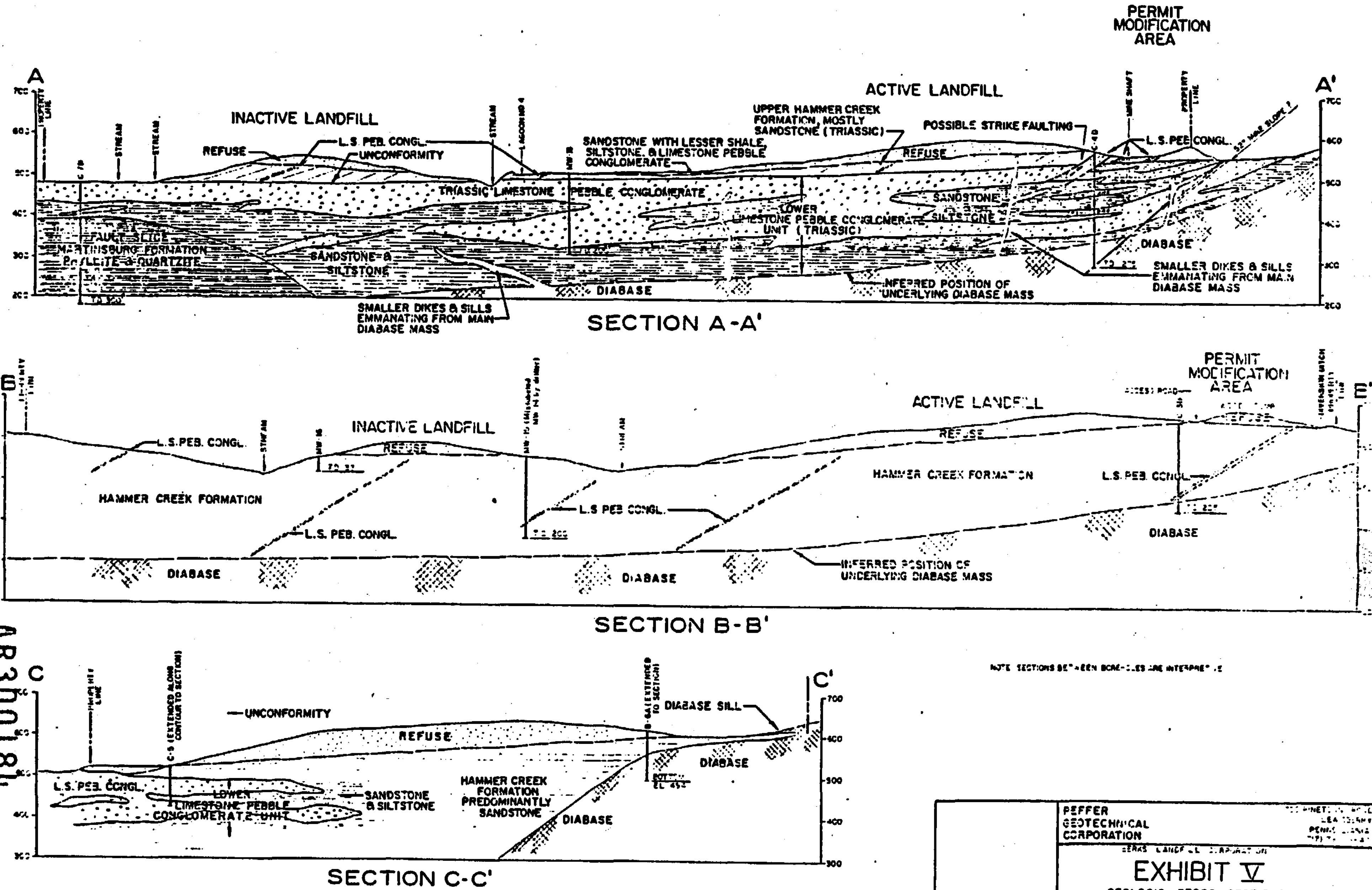
BEAR LANDFILL CORPORATION

EXHIBIT IV

FRACTURE TRACES & LINEAMENTS

CHECKED BY JRP | SCALE | DATE

AR300183



NOTE: SECTIONS BETWEEN BOREHOLES ARE INTERPRETIVE

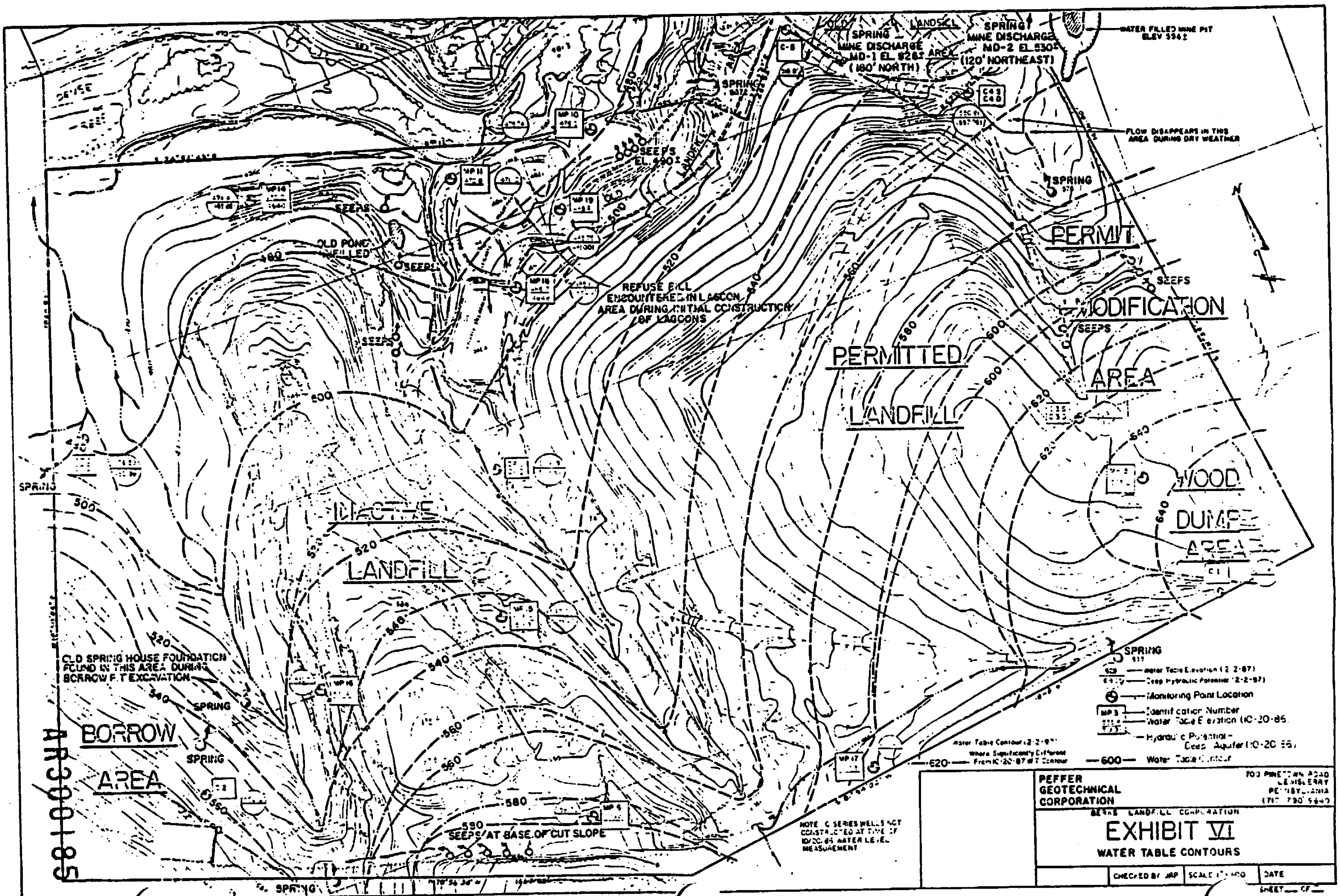
PEFFER GEOTECHNICAL CORPORATION

EXHIBIT V

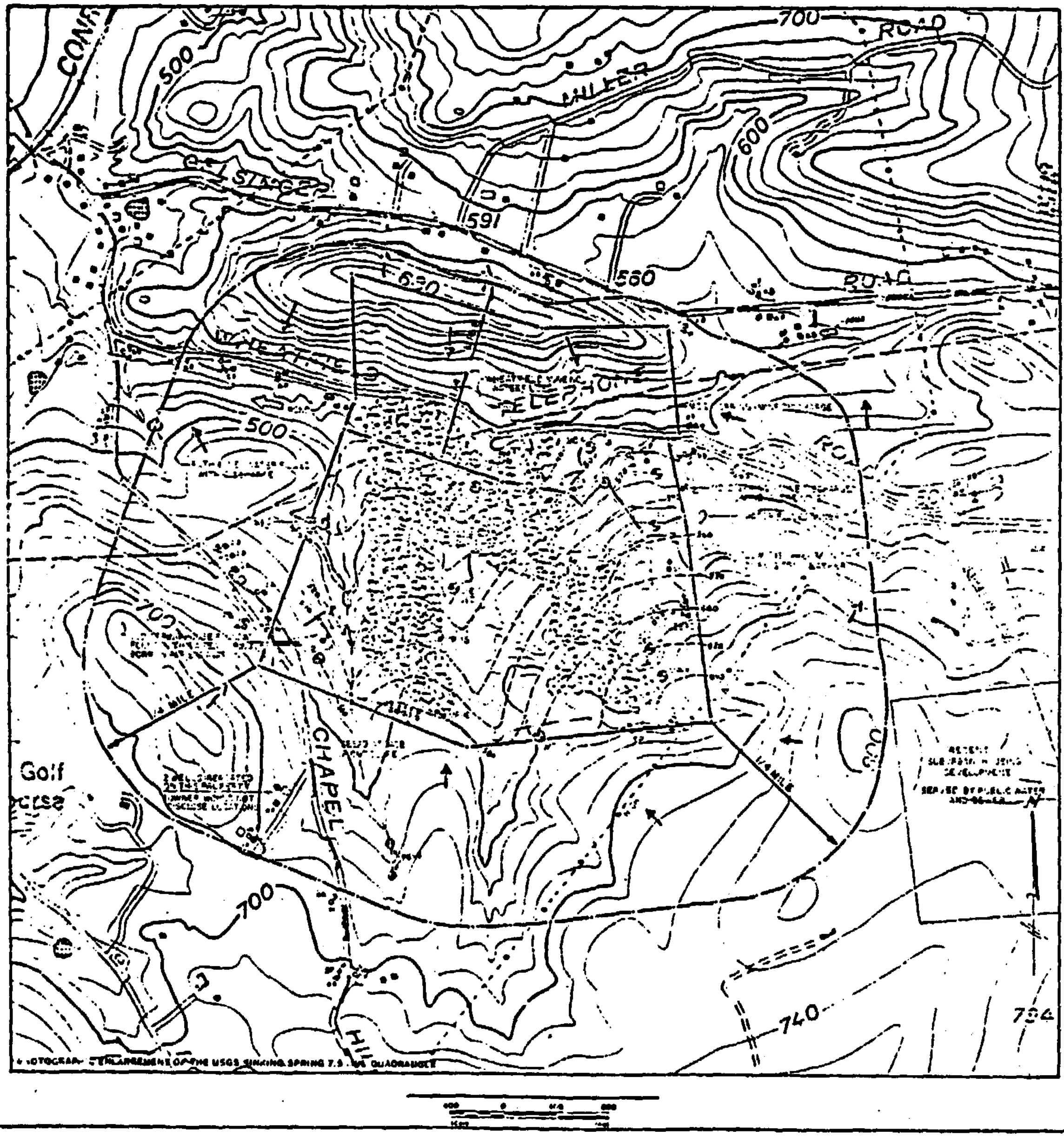
GEOLOGIC CROSS SECTIONS

CHECKED BY JRP | SCALE | DATE

AR300184


WATER FILLED MINE PIT ELEV 556±
OLD SPRING MINE DISCHARGE MD-1 EL. 826± (180' NORTH)
LANDFILL AREA
SPRING MINE DISCHARGE MD-2 EL.530± (120' NORTHEAST)
FLOW DISAPPEARS IN THIS AREA DURING DRY WEATHER
SPRING
SEEPS EL.490±
SEEPS
OLD POND INFILLED
REFUSE FILL ENCOUNTERED IN LAGOON AREA DURING INITIAL CONSTRUCTION OF LAGOONS
PERMIT MODIFICATION AREA
PERMITTED LANDFILL
WOOD DUMP AREA
INACTIVE LANDFILL
BORROW AREA
OLD SPRING HOUSE FOUNDATION FOUND IN THIS AREA DURING BORROW PIT EXCAVATION
SEEPS AT BASE OF CUT SLOPE
NOTE: C SERIES WELLS NOT CONSTRUCTED AT TIME OF 10/20/86 WATER LEVEL MEASUREMENT
Monitoring Point Location
Identification Number
Water Table Elevation (10-20-86)
Hydraulic Potential - Deep Aquifer (10-20-86)
600 Water Table Contour
620 Water Table Contour (2-2-87) Where Significantly Different From 10-20-87 W.T. Contour
N
PEFFER GEOTECHNICAL CORPORATION
BERKS LANDFILL CORPORATION
EXHIBIT VI
WATER TABLE CONTOURS
CHECKED BY JRP
DATE
SHEET OF

AR300185



LEGEND

- DIRECTION OF GROUND WATER FLOW BASED ON [illegible] CONTROL
- DIRECTION OF GROUND WATER FLOW BASED ON STRUCTURAL CONTROL
- OCCUPIED DWELLING
- PRIVATE WELL
- PRIVATE WELL, HOMEOWNER UNCERTAIN OF LOCATION OR NOT HOME ON SURVEY DATES
- SPRING
- SEEP

PEFFER GEOTECHNICAL CORPORATION		
BERKS LANDFILL CORPORATION		
EXHIBIT VII REGIONAL HYDROLOGY		
CHECKED BY JRR	SCALE 1"=400'	DATE

SHEET ___ OF ___